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Fertilizer Pricing Policy in Bangladesh

edited by Bruce Stone

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CONTENTS

FOREWORD..... xxiii

1. POLICY ISSUES FOR LONG-TERM GROWTH OF FERTILIZER USE IN BANGLADESH..... 1
   Gunvant M. Desai, Indian Institute of Management

2. FERTILIZER DEVELOPMENT AND PRICE IN INTERNATIONAL PERSPECTIVE..... 71
   Bruce Stone, International Food Policy Research Institute

3. STRUCTURE, DYNAMICS, AND RELATED POLICY ISSUES OF FERTILIZER SUBSIDY IN BANGLADESH..... 117
   Raisuddin Ahmed, International Food Policy Research Institute

4. FERTILIZER CONSUMPTION, PRICING, AND FOODGRAIN PRODUCTION IN BANGLADESH..... 181
   Mahabub Hossain, Bangladesh Institute of Development Studies

5. AGRONOMIC AND ENVIRONMENTAL CONSTRAINTS ON FERTILIZER EFFECTIVENESS..... 281
   S. M. H. Zaman, Bangladesh Rice Research Institute

6. NATIONAL FERTILIZER SUPPLY AND SUPPLY ADJUSTMENT PLANNING IN BANGLADESH..... 337
   A. Samad, Consultant, Bangladesh Ministry of Agriculture

7. SUPPLY AND DISTRIBUTION OF FERTILIZERS IN BANGLADESH..... 357
   Md. Abul Quasem, Bangladesh Institute of Development Studies

8. THREE NOTES ON FERTILIZER SUBSIDY REMOVAL IN BANGLADESH... 413
   Abu Abdullah, Bangladesh Institute of Development Studies

BIBLIOGRAPHY..... 447

TABLES

Chapter 1. POLICY ISSUES FOR LONG-TERM GROWTH OF FERTILIZER USE IN BANGLADESH, by Gunvant M. Desai

1. Growth of fertilizer use in Bangladesh vis-à-vis India and major states of East India, 1961/62 to 1983/84..... 3

2. Fertilizer consumption in Bangladesh, 1952/53 to 1983/84 6

3. Share of crops in total fertilizer consumption in Bangladesh, 1960/61 to 1973/74..... 10

4. Ratios of official prices of nitrogen to procurement prices of rice and wheat in Bangladesh and India, 1967/68 to 1983/84..... 15

5. Findings of IFDC-BARC surveys on percentage of area fertilized and average rates of application for Aus, Aman, and Boro paddy, wheat, and jute, 1979-82..... 18

6. Fertilizer use by sample farmers on Aus paddy in Bangladesh, 1980-82..... 19

7. Fertilizer use by sample farmers on Boro paddy in Bangladesh, 1979/80 - 1981/82..... 20

8. Fertilizer use by sample farmers on Aman paddy in Bangladesh, 1979-81..... 21

9. Fertilizer use by sample farmers on wheat in Bangladesh, 1979/80 - 1981/82..... 22

10. Fertilizer use by sample farmers on jute in Bangladesh, 1980-82..... 23

11. Fertilizer use by Bangladesh district as a proportion of potential, 1983/84 and changes in district-wide shares, 1969/70 - 1983/84..... 30

12. Monthly opening stocks, current supply, availability, sales and closing stocks of urea in Bangladesh, 1977/78 - 1983/84..... 45

Chapter 1--Continued

13. Monthly opening stocks, current supply, availability, sales, and closing stocks of triple superphosphate (TSP) in Bangladesh, 1977/78 - 1983/84..... 49

14. Monthly opening stocks, current supply, availability, sales, and closing stocks of muriate of potash (MP) in Bangladesh, 1977/78 - 1983/84..... 53

15. Monthly sales, ratios of monthly opening stocks to monthly sales, and ratios of monthly availability to monthly sales of urea, TSP, and MP in Bangladesh, 1977/78 - 1983/84..... 67

Chapter 2. FERTILIZER DEVELOPMENT AND PRICE IN INTERNATIONAL PERSPECTIVE, by Bruce Stone

1. Consumption of fertilizer per hectare of arable land and land under permanent crops, various Asian countries, 1961-83..... 72

2. Growth of fertilizer use in Bangladesh compared with China, India, and major states of East India, 1961/62 to 1984/85..... 74

3. Provincial fertilizer nutrient application per sown hectare in China, 1981-85..... 75

4. Growth of fertilizer nutrient application per sown hectare in Bangladesh districts, 1962-63..... 76

5. Relative intensity of chemical fertilizer application expenditures among crops in China, 1975-78..... 80

6. Fertilizer use in crop production in Central and South Asia, and in Southeast and Northeast Asia..... 81

7. Ratios of farm-gate prices of nitrogen to wheat and to paddy, various countries, 1979-83..... 84

8. Ratios of official prices of nitrogen to procurement prices of rice and wheat in Bangladesh, India and China, 1967/68 to 1983/84..... 85

9. Ratios of official prices for nitrogen and phosphate to farmers' harvest prices of paddy and wheat in Bangladesh and China, 1966-84..... 86

Chapter 2--Continued

10. Application of manufactured fertilizers in China, disaggregated, 1972-85..... 88

11. Ratios of fertilizer nutrient prices to farm-gate harvest prices of paddy in Bangladesh, by season, 1975/76 - 1982/83..... 90

12. Rice and wheat yields, irrigation and fertilizer use intensity, and population pressure in selected countries, 1982..... 91

13. Yield, production, and area growth rates for wheat and paddy, selected countries, 1966/70 - 1976/80..... 93

14. Effectively irrigated area, fertilizer nutrient application, small hydropower stations, and electrical use in rural areas in China, 1952-85..... 103

15. Numbers of agricultural service institutions in China, various years, 1949-1984..... 105

16. Chinese sown area affected by natural disasters, 1949-84 107

17. Proportion of Chinese provincial sown area affected by natural disasters, 1983..... 109

18. Soil and water conservation, prevention of waterlogging, and improvement of saline land in China, 1982-85..... 110

19. Mini-reservoirs and power-pumped wells in China, 1978-83 111

20. Effectively irrigated area in China under irrigation systems with capacity of at least 1,000 hectares, 1982-85 111

21. Area irrigated by reservoirs in China, 1982-85..... 112

22. Shares of various cash costs for crop production in China 113

Chapter 3. STRUCTURE, DYNAMICS, AND RELATED POLICY ISSUES OF FERTILIZER SUBSIDY IN BANGLADESH, by Raisuddin Ahmed

1. Fertilizer subsidy and its share of the agricultural development budget, 1977-78 to 1983-84..... 118

2. Fertilizer subsidy, 1983-84..... 121

3. Estimated subsidy requirement for fertilizers, 1984-85.. 122

Chapter 3--Continued

4. Average procurement cost of fertilizers distributed in 1983-84 124

5. Estimated full budget subsidy on fertilizers distributed, 1983-84 125

6. Cash flow impact on procurement and distribution of fertilizers, 1983-84 128

7. Production cost, ratio of production cost to f.o.b. price, and rates of capacity utilization and depreciation at four fertilizer factories, 1983-84 130

8. Full economic subsidy on fertilizers, 1983-84 133

9. International prices of fertilizers, 1965-84 136

10. Simulated yearly surplus or deficit on fertilizer account, 1977-78 to 1983-84, under a simple average and a moving average pricing mechanism 138

11. Average exchange rates, 1971-72 to 1982-83 141

12. Official subsidized retail fertilizer prices, 1973-84 ... 142

13. Growth in official subsidized fertilizer prices, 1973-84 143

14. Internal distribution cost of fertilizers, 1980-81 to 1983-84 145

15. Distribution targets and supply of fertilizers, 1985-86 and 1986-87 147

16. Procurement and distribution costs projected for 1985-86 and 1986-87 149

17. Budgetary subsidy on fertilizers, scenarios for 1985-86 and 1986-87, using 1984-85 sales prices 150

18. Estimated sale price of fertilizers in 1985-86 and 1986-87 for a zero budgetary subsidy and with a cross-subsidy of TSP from urea 151

19. Scenarios for 1985-86 and 1986-87 of economic subsidy on fertilizers, using 1984/85 sales prices 152

20. Estimated sale price of fertilizers in 1985-86 and 1986-87 for a zero economic subsidy and with a cross-subsidy of TSP from urea 153

Chapter 3--Continued

21. World fertilizer prices, 1955-81 (actual) and 1982-95 (projected)..... 155

22. Ratios of rice and urea prices in domestic and world markets, 1972-73 to 1983-84..... 161

23. Ratios of three-year moving average rice and urea prices in domestic and world markets, 1973-74 to 1983-84..... 161

24. Ratios of rice and TSP prices in domestic and world markets, 1972-73 to 1983-84..... 165

25. Ratios of moving average rice and TSP prices in domestic and world markets, 1973-74 to 1983-84..... 165

26. Weighted average of wholesale domestic prices of coarse rice, 1972-73 to 1983-84..... 171

27. World rice prices, 1972-73 to 1983-84..... 172

28. Ex-PDP or equivalent wholesale prices of fertilizers, 1972-73 to 1984-85..... 173

29. World urea prices, 1972-73 to 1983-84..... 174

30. World TSP prices, 1972-73 to 1983-84..... 175

31. World prices, muriate of potash, 1972-73 to 1983-84..... 176

32. Comparison of free market world prices and prices of fertilizers under tied aid in Bangladesh, 1983-84..... 177

Chapter 4. FERTILIZER CONSUMPTION, PRICING, AND FOODGRAIN PRODUCTION IN BANGLADESH, by Mahabub Hossain

1. Long-term trends in fertilizer consumption, 1962/63 to 1983/84..... 184

2. Trends in fertilizer consumption by seasons, 1965/66 to 1983/84..... 185

3. Growth of fertilizer consumption in different regions, 1962/63 to 1983/84..... 188

4. Diffusion of fertilizer use according to sample surveys, 1969/70 to 1981/82..... 191

Chapter 4--Continued

5. Rate of fertilizer application on treated land for different crops, 1969/70 to 1981/82..... 194

6. Intensity of fertilizer use per cropped acre, 1979/80 to 1981/82..... 195

7. Locational variation in fertilizer application to foodgrain crops, 1980-82..... 197

8. Irrigation and fertilizer use in paddy crops, 1980..... 197

9. Estimates of the share of various crops in total sown area and in fertilizer consumption, 1969/70, 1977/78, and 1983/84..... 199

10. Trends in the development of modern irrigation facilities, selected years..... 202

11. Expansion of area under HYVs, 1969/70 to 1983/84..... 203

12. Diffusion of HYVs in different regions, 1970/71, 1977/78, and 1982/83..... 205

13. Trends in the supply of agricultural credit from institutional sources, 1970/71 to 1983/84..... 208

14. Estimates of the availability of institutional credit to farmers, 1979/80-1981/82..... 209

15. Availability of institutional credit for different groups of farmers, 1981/82..... 209

16. Share of credit in financing fertilizer costs, Chandra and Banguri villages, 1977/78 and 1983/84..... 211

17. Sizes of stocks under the old and new marketing systems, July 1977-June 1980 and July 1980-June 1984..... 217

18. Trend in prices of fertilizer and paddy, 1969/70 - September 1984..... 218

19. Trends in BADC procurement and distribution costs for different types of fertilizers, 1975/76 to 1983/84..... 219

20. Fertilizer demand functions, linear form, 1976/77-1982/83 and 1978/79-1982/83..... 227

21. Fertilizer demand functions, log-linear form, 1976/77-1982/83 and 1978/79-1982/83..... 228

Chapter 4--Continued

22. Trends in fertilizer use per hectare and in foodgrain production, area, and yields, 1969/70 to 1983/84..... 231

23. Fertilizer response on experimental plots, based on findings from trials, 1972-83..... 234

24. Response of crop output to various types of fertilizer: results from experiments on farmers' plots..... 235

25. Distribution of sample locations according to output response to different types of fertilizer..... 237

26. Response of paddy yields to various nutrients in different districts, 1981/82..... 239

27. Responses of paddy yields to various nutrients in locations characterized by different soil types, 1981/82 240

28. Yield responses of paddy to zinc and sulfur applications in locations characterized by different soil types, 1981/82..... 242

29. Yield responses of paddy to zinc and sulfur applications in different regions, 1981/82..... 243

30. Estimates of fertilizer response under farmers' operating conditions from IFDC/BARC surveys, 1979/80 -1981/82..... 245

31. Estimated benefit-cost ratios for fertilizer use at prices of fertilizers and foodgrain crops prevailing in July-August 1984..... 246

32. Estimates of the elasticity of foodgrain output to changes in fertilizer use, 1981/82..... 248

33. Share of fertilizer cost in farm budget, 1982/83..... 249

34. Fertilizer use by different farm-size groups, 1979-82... 251

35. Diffusion of fertilizer consumption by farm size in Chandra and Banguri villages, 1977-84..... 253

36. Fertilizer use by crop in Chandra and Banguri villages, 1977/78 and 1983/84..... 254

37. Changes in fertilizer use by farm size on various crops in Chandra and Banguri villages, 1977/78 and 1983/84.... 255

Chapter 4--Continued

38. Changes in fertilizer use by farm size on total cropped land in Chandra and Banguri villages, 1977/78 and 1983/84 255

39. Changes in cropping patterns by farm size in Chandra and Banguri villages, 1977/78 and 1983/84..... 257

40. Proportion of urea, TSP, and MP used on major crops, by farm size, Chandra and Banguri villages, 1983/84..... 258

41. Share of different sizes of farms in land cultivated and fertilizer consumption, Chandra and Banguri villages, 1977/78 and 1983/84..... 258

42. Effects of a withdrawal of fertilizer subsidies on fertilizer consumption and foodgrain production..... 261

43. Capital investment, operation, and maintenance costs for irrigation development..... 265

44. Effect on foodgrain production of the reallocation of budgetary savings from fertilizer subsidy withdrawal to irrigation development..... 266

45. Estimated cost of production and profit per acre associated with HYV Boro and local Aus paddy cultivation at 1982/83 prices..... 268

46. Distribution of commercial fertilizer by weight, 1969/70 - 1983/84..... 274

47. Fertilizer use in different seasons and locations, 1980 275

48. Fertilizer use in different seasons and locations, 1981 and 1982..... 276

49. Output response to fertilizer application, HYV Boro, 1982/83..... 277

50. Output response to fertilizer application, HYV Aman, 1982/83..... 278

51. Output response to fertilizer application, HYV Aus, 1982/83..... 279

52. Output response to fertilizer application, HYV wheat, 1982/83..... 280

Chapter 5. AGRONOMIC AND ENVIRONMENTAL CONSTRAINTS ON FERTILIZER EFFECTIVENESS, by S. M. H. Zaman

1. Effect of fertilizer application timing on yields of broadcast Aus rice..... 283

2. Effect of timing of N application on yields of deep-water rice..... 283

3. Effect of timing and rates of N application on T. Aman yield..... 284

4. Effect of timing of N application and transplanting date on Boro rice yields..... 284

5. Effect of N application rate on wheat yields..... 285

6. Wheat yield response to NPK, Zn, and S application..... 285

7. Wheat yield variation in different floodplains at various fertilizer doses..... 286

8. Nutrients removed from soil by rice crops..... 289

9. Response of T. Aman rice yields to potash application... 291

10. Response of irrigated wheat yields to potash in 50 trials..... 292

11. Nutrients removed by rice crops, 1981/82..... 294

12. Nutrients supplied to all crops, 1981/82..... 295

13. NPK balance sheet for rice crops..... 296

14. NPK balance sheet for a wheat area of 513,200 hectares.. 296

15. Wheat yield response to NPK, S, and Zn..... 299

16. Wheat yield response to NPKS..... 300

17. Rice yield response to NPK with and without Zn, S, and manure..... 301

18. Yield response on transplanted Aus, Boro, and transplanted Aman rice crops to NPKS and Zn..... 302

19. Rice yield response to zinc..... 306

20. Mean rice yields with and without NPK or zinc..... 306

Chapter 5--Continued

21. Fertilizers and other usable materials containing zinc.. 310

22. Percent of organic matter among different soil types and series in Bangladesh..... 312

23. Effect of drought on the yield of T. Aman and Boro HYV rice (drought in October or April)..... 317

24. Effect of timing and frequency of insecticide applications on rice yield..... 324

25. Effect of preventive and curative sprays on rice yield.. 325

26. Variation in labor needed for weeding using three rice seeding methods..... 327

27. Comparative labor inputs for different operations of direct seeded upland rice..... 327

28. Costs and returns associated with weeding during rice cultivation..... 328

29. Area sown with T. Aman rice in different agroecological zones..... 332

30. Quantity of improved seeds supplied by the Bangladesh Agricultural Development Corporation, 1974-82..... 334

Chapter 6. NATIONAL FERTILIZER SUPPLY AND SUPPLY ADJUSTMENT PLANNING IN BANGLADESH, by A. Samad

1. Annual fertilizer sales, 1969/70 - 1983/84..... 339

2. BADC fertilizer procurement from domestic and foreign sources, 1974/75 - 1983/84..... 339

3. Imports of fertilizers by source, 1981/82 - 1983/84..... 341

4. Second Five-Year Plan target fertilizer sales, 1980/81 - 1984/85..... 342

5. Annual fertilizer sales targets and actual sales, 1980/81 - 1983/84..... 342

6. Requirements and availability of fertilizer, 1983/84.... 344

7. Projected and actual fertilizer sales, April-September 1984 350

Chapter 6--Continued

8. Urea procurement slippages, 1984/85..... 350

9. TSP procurement slippages, 1984/85..... 351

10. Urea exports by the Bangladesh Chemical Industries Corporation..... 356

11. Urea import prices, 1982/83 and 1983/84..... 356

Chapter 7. SUPPLY AND DISTRIBUTION OF FERTILIZERS IN BANGLADESH, by Md. Abul Quasem

1. Share of imports among fertilizers used in Bangladesh, 1978/79 - 1983/84..... 358

2. Annual procurement of urea from domestic factories and imports, 1975/76 to 1983/84..... 360

3. Capacity utilization among domestic factories, 1975/76 to 1983/84..... 360

4. Opening stocks and availability of fertilizers, 1975/76 to 1984/85..... 363

5. Farm-gate fertilizer prices, November 1983 and November 1984..... 374

6. Highest and lowest fertilizer-consuming upazillas within high-consuming districts..... 376

7. Per acre use of fertilizer by district, 1978/79 to 1983/84..... 377

8. Average monthly fertilizer sales and opening stocks as percentages of monthly sales in various low- and high-consuming districts, 1980/81 through 1983/84..... 379

9. Ratio of quarterly availability to quarterly sales of fertilizer by district, 1980/81 to 1983/84..... 380

10. Ratio of quarterly stocks to quarterly sales of fertilizer by district, 1980/81 to 1983/84..... 381

11. Stocks and sales of fertilizers in the three peak months of each year, 1980/81 to 1983/84..... 382

12. Fertilizer storage capacity as a percentage of peak monthly sales by district, 1980/81 and 1983/84..... 383

Chapter 7--Continued

13. Decline in fertilizer wholesaler and retailer participation in eight upazillas, from 1979/80 to 1982/83 385

14. Number of dealers in operation and average quantity lifted, 1979/80 to 1982/83 385

15. Stocks of fertilizer with dealers during May and June 1983 387

16. Principal occupations and business involvements of fertilizer traders, May and June 1983 387

17. Area irrigated by modern methods by district, 1978/79 to 1982/83 389

18. HYV area as a proportion of total grain acreage, rice and wheat, 1978/79 to 1982/83 390

19. Fertilizer shortages reported by the Ittefaque Press, 1975/76 to 1983/84 393

20. Prices of fertilizers by district, under price control and decontrol 394

21. Effect of opening stocks on the spread between farm-gate and ex-PDP prices--regression estimates 398

22. Farm-gate price changes in fertilizer due to increases in official (ex-PDP) prices in July 1982 399

23. Fertilizer prices in accessible and less accessible areas of Bangladesh, 1982-84 401

24. Fertilizer prices paid by operators of farms of different sizes in selected locations during a period of supply scarcity, November 1984 404

25. Monthly sales of fertilizer, 1980/81 to 1984/85 405

26. District-wide distribution of institutional credit, extension personnel, and fertilizer traders, 1983/84 408

Chapter 8. THREE NOTES ON FERTILIZER SUBSIDY REMOVAL IN BANGLADESH, by Abu Abdullah

1. Pattern of distribution of landownership, 1979..... 420

2. Changes in distribution of landholdings, 1960-82..... 420

3. Shares of land operated, and consumption of modern inputs by farm size groups, 1981/82..... 422

4. Income effect of a 20 percent rise in fertilizer prices 424

5. Proportionate burden of subsidy elimination..... 425

6. Fertilizer use and agricultural credit, 1976/77 - 1983/84 427

7. Bangladesh Krishi Bank loan distribution by size of holdings and size of loans, 1976/77 - 1980/81..... 428

8. Loan distribution by size of holdings and size of loans, various credit institutions..... 429

9. Use of fertilizer by farm size, Boro season..... 431

10. Use of fertilizer by farm size, Aus season..... 431

11. Use of fertilizer by farm size, Aman season..... 432

12. Disbursement and recovery of agricultural credit by different financial institutions, 1976/77 - 1982/83..... 433

13. Output response by crop to fertilizer nutrient application, based on farm survey data, 1979-81..... 434

14. Fertilizer use and agricultural credit by district in Dhaka Division, 1976/77 to 1982/83..... 436

15. Fertilizer use and agricultural credit by district in Chittagong Division, 1976/77 to 1982/83..... 437

16. Fertilizer use and agricultural credit by district in Khulna Division, 1976/77 to 1982/83..... 438

17. Fertilizer use and agricultural credit by district in Rajshahi Division, 1976/77 to 1982/83..... 439

18. Total distribution and value of fertilizer..... 440

ILLUSTRATIONS

Chapter 1. POLICY ISSUES FOR LONG-TERM GROWTH OF FERTILIZER USE IN BANGLADESH, by Gunvant M. Desai

1. Fertilizer nutrient consumption per hectare of total cropped area in various districts of Bihar, West Bengal, Orissa, Assam, and other Northeastern Indian states in the early 1980s..... 4

2. Fertilizer nutrient consumption per hectare of total cropped area in various districts of Bangladesh in the early 1980s..... 5

3. Percentage of area fertilized, and average rates of application on Aus paddy by sample farmers at different locations in 1980, 1981, and 1982..... 24

4. Percentage of area fertilized, and average rates of application on Aman paddy by sample farmers at different locations in 1979, 1980, and 1981..... 25

5. Percentage of area fertilized, and average rates of application on Boro paddy by sample farmers at different locations in 1979/80, 1980/81, and 1981/82..... 26

6. Percentage of area fertilized and average rates of application on wheat by sample farmers at different locations in 1979/80, 1980/81, and 1981/82..... 27

7. Percentage of area fertilized and average rates of application by sample farmers at different locations in 1980,1981, and 1982..... 28

8. Fertilizer consumption trends in various districts of Bangladesh..... 32

9. Opening stocks, current supply, total availability, and sales of urea in Bangladesh from 1977/78 to 1983/84 57

10. Opening stocks, current supply, total availability, and sales of triple superphosphate (TSP) in Bangladesh from 1977/78 to 1983/84..... 58

Chapter 1--Continued

11. Opening stocks, current supply, total availability, and sales of muriate of potash (MP) in Bangladesh from 1977/78 to 1983/84 59

12. Monthly opening stocks, current supply, total availability, and sales of urea in Bangladesh, July 1977 to June 1984..... 60

13. Monthly opening stocks, current supply, total availability, and sales of triple superphosphate (TSP) in Bangladesh, July 1977 to June 1984..... 63

14. Monthly opening stocks, current supply, total availability, and sales of muriate of potash (MP) in Bangladesh, July 1977 to June 1984..... 65

15. Growth of fertilizer consumption and changes in ratio of official price of nitrogen to procurement price of rice, 1960/61 to 1983/84..... 68

Chapter 2. FERTILIZER DEVELOPMENT AND PRICE IN INTERNATIONAL PERSPECTIVE, by Bruce Stone

1. Fertilizer nutrient consumption per hectare of total cropped area in various districts of Bangladesh in the early 1980s..... 77

2. Fertilizer nutrient application per sown hectare in China, 1983..... 78

Chapter 3. STRUCTURE, DYNAMICS, AND RELATED POLICY ISSUES OF FERTILIZER SUBSIDY IN BANGLADESH, by Raisuddin Ahmed

1. Model for estimating economic subsidy..... 132

2. Urea prices in 1981 constant U.S.$ (1958-81 actual and 1982-95 projected)..... 156

3. TSP prices, 1981 constant U.S. $ (1967-81 actual and 1982-95 projected)..... 157

4. Ratios of moving average rice and urea prices in domestic and world markets, 1973/74 to 1983/84..... 163

5. Ratios of rice and urea prices in domestic and world markets, 1972/73 to 1983/84..... 164

Chapter 3--Continued

6. Percent of deviation of normalized monthly prices of rice from annual averages, Bangladesh..... 168

Chapter 4. FERTILIZER CONSUMPTION, PRICING, AND FOODGRAIN PRODUCTION IN BANGLADESH, by Mahabub Hossain

1. Opening stocks and sales of urea, by month, 1978-84..... 214

2. Opening stocks and sales of TSP/DAP, by month, 1978-84.. 215

3. Ratio of actual opening stocks to sales targets for urea and TSP/DAP, by month, 1978-84..... 216

4. Trends in approaches to irrigation development, 1960/61 to 1982/83..... 263

Chapter 5. AGRONOMIC AND ENVIRONMENTAL CONSTRAINTS ON FERTILIZER EFFECTIVENESS, by S. M. H. Zaman

1. Yield response of rice to phosphorus..... 288

2. Yield response of rice to sulfur..... 298

3. Zinc and sulfur deficiencies in Bangladesh..... 303

4. Response of wheat to soil and foliar application of zinc in India..... 305

5. Yield response of rice to zinc..... 308

6. Economics of zinc fertilization in India, 1981..... 309

7. Relationships between rice yields and application rates of organic materials..... 313

8. Agroecological zones of Bangladesh..... 315

9. Initial infestation areas of yellow stem borer, rice hispa, and brown planthopper..... 322

Chapter 6. NATIONAL FERTILIZER SUPPLY AND SUPPLY ADJUSTMENT PLANNING IN BANGLADESH, by A. Samad

1. Seasonal variation in fertilizer sales, 1979/80 - 1983/84..... 345

Chapter 6--Continued

2. Monthly opening stock levels and sales of urea, 1977-84 347

3. Monthly opening stock levels and sales of TSP/DAP, 1977-84..... 348

4. Required and actual monthly opening stocks of urea and MP, December 1983 - January 1985..... 353

5. Required and actual monthly opening stocks of TSP/DAP, December 1983 - January 1985..... 354

Chapter 7. SUPPLY AND DISTRIBUTION OF FERTILIZERS IN BANGLADESH, by Md. Abul Quasem

1. Monthly ratios of farm-gate to ex-PDP prices and opening stocks to sales for urea, 1981-84..... 364

2. Monthly ratios of farm-gate to ex-PDP prices and opening stocks to sales for TSP/DAP, 1981-84..... 365

3. Monthly opening stocks, total availability, and farm-gate to ex-PDP price ratios for urea, 1981-84..... 368

4. Monthly opening stocks, total availability, and farm-gate to fertilizer price ratios for TSP/DAP, 1981-84..... 369

5. Fertilizer distribution under the old marketing system, 1977/78..... 371

6. Fertilizer distribution under the new marketing system, 1983/84..... 372

7. Monthly ratios of farm-gate to ex-PDP urea prices in Bangladesh and Dhaka District, 1981-84..... 396

8. Monthly ratios of farm-gate to ex-PDP urea prices in Bangladesh and Noakhali District, 1981-84..... 396

9. Monthly ratios of farm-gate to ex-PDP urea prices in Bangladesh and Rajshahi District, 1981-84..... 396

10. Monthly ratios of farm-gate to ex-PDP TSP prices in Bangladesh and Dhaka District, 1981-84..... 397

11. Monthly ratios of farm-gate to ex-PDP TSP prices in Bangladesh and Noakhali District, 1981-84..... 397

Chapter 7--Continued

12. Monthly ratios of farm-gate to ex-PDP TSP prices in Bangladesh and Rajshahi District, 1981-84..... 397

Chapter 8. THREE NOTES ON FERTILIZER SUBSIDY REMOVAL IN BANGLADESH, by Abu Abdullah

1. Fertilizer use and agricultural credit, 1976/77 to 1983/84..... 441

2. Fertilizer use and agricultural credit by district in Dhaka Division, 1976/77 - 1982/83..... 442

3. Fertilizer use and agricultural credit by district in Chittagong Division, 1976/77 - 1982/83..... 443

4. Fertilizer use and agricultural credit in Khulna Division, 1976/77 - 1982/83..... 444

5. Fertilizer use and agricultural credit by district in Rajshahi Division, 1976/77 - 1982/83..... 445

6. Fertilizer use and agricultural credit by district in Dhaka and Chittagong Districts, 1976/77 - 1982/83.... 446

FOREWORD

These collected papers represent part of the output from an intensive study conducted between September 1984 and March 1985 in Bangladesh and Washington, D.C. The study was a collaborative effort commissioned by the Bangladesh Ministry of Agriculture and organized by the International Food Policy Research Institute (IFPRI) and the Bangladesh Institute of Development Studies (BIDS).

The eight members of the Fertilizer Pricing Study Team that performed the required analysis were drawn from a variety of relevant institutions. Abu Abdullah, Mahabub Hossain, and Md. Abul Quasem came from the Bangladesh Institute of Development Studies in Dhaka. Abdullah prepared analyses of political economic issues, distributional questions, and agricultural credit; Hossain of fertilizer consumption, pricing, and foodgrain production; and Quasem of supply and distribution of fertilizers. Raisuddin Ahmed of the International Food Policy Research Institute was responsible for investigating the structure and dynamics of fertilizer subsidy, and Bruce Stone drafted the summary report and edited the technical papers. In addition, special analytical expertise was contributed by S. M. H. Zaman, then director of the Bangladesh Rice Research Institute at Joydebpur, A. Samad, consultant to the Ministry of Agriculture of Dhaka, and Gunvant M. Desai, professor at the Indian Institute of Management at Ahmedabad. (Desai, however, is now with IFPRI.) Zaman analyzed agronomic and environmental constraints on fertilizer effectiveness; Desai examined policy issues for long-term growth of fertilizer use in Bangladesh, and Samad looked at national supply and supply adjustment planning.

The entire study was conducted on the basis of analysis of a wide range of primary and secondary materials, and through consultation with a number of individuals, including staff of the following organizations: the Bangladesh Ministry of Agriculture, the Bangladesh Ministry of Finance, the Bangladesh Master Plan Organization, the Bangladesh Department of Agricultural Extension, the Bangladesh Agricultural Development Corporation, the Bangladesh Chemical Industries Corporation, the Bangladesh Agricultural Research Council, the International Fertilizer Development Center, the Agency for International Development, the World Bank, and others.

Special mention must be made of the critical contributions of Rehman Sobhan, director of BIDS, and John W. Mellor, director of

IFPRI, who took particular interest in the issues and in the quality of the finished product.

During the process of the study, the team incurred debts to individuals too numerous to mention for assistance and provision of basic materials. Of particular usefulness was an extensive survey of fertilizer use in Bangladesh conducted by the International Fertilizer Development Center in cooperation with the Bangladesh Agricultural Research Council.

During the fall of 1984 the team assembled in Dhaka, gathered research materials, met with individuals, conducted preliminary analyses, engaged in extensive discussions, and formulated a detailed study plan for cooperative research.

A preliminary report was filed at the end of November 1984. In January 1985, the team regrouped at IFPRI in Washington, D.C., where they continued to assemble their technical reports on various aspects of the fertilizer pricing issue. In addition to the original study team members, Mary McFadden of IFPRI synthesized a draft technical report from comprehensive analytic materials provided by Dr. Zaman (who was unable to meet with the team in Washington), in close collaboration with team members and Peter Oram of the IFPRI staff.

While internal discussion and revision of the technical reports continued, an outline for the summary was formulated, which responded directly to the terms of reference for the project although it was based extensively on the technical reports. Drafts of both the revised technical reports and the summary report were submitted in March. Internal discussion of the summary report continued in March and April, with the revised version finally approved by both BIDS and IFPRI and accepted by the Ministry of Agriculture in early May 1985.

Because the report was of a confidential nature on a controversial issue and produced under contract with the Bangladesh government, access to the 602-page, two-volume study was limited to the Secretaries of Agriculture and of Finance of the Government of Bangladesh, to members of the study team, and to the two principal research organizations, IFPRI and BIDS. However, because of the considerable demand for a wider distribution of this unusually comprehensive policy study of fertilizer pricing issues, the Bangladesh Ministry of Agriculture has agreed to allow IFPRI to republish the collection of technical reports, which composed the second volume of the study. To these reports, a brief section previously included in the summary report (Volume I) has been added, which broadly compares the pricing environment and rate of growth of fertilizer application in Bangladesh with those of other Asian countries, with particular emphasis on the People's Republic of China, a poor developing country for which the long-term rate of fertilizer application growth has been especially rapid. Although the technical

papers have been edited for this republication, their messages remain the same.

It must be emphasized that the reader should not infer conclusions in the original summary report from examinations of this republication of the technical papers, for which the individual authors take sole responsibility. The final wording and recommendations in the summary were the subject of considerable debate among study team members who often exhibited conflicting views on the implications of the collected data and analyses. Yet in the process of this debate, I am confident that each of us has absorbed a share of opposing viewpoints and that the process has served to sharpen our comprehension of this complex topic.

The papers in this volume were produced under time pressure for a governmental audience. Their special contribution lies in the design and execution of the overall work, which utilized individuals of strongly differing viewpoints and a variety of skills and experience to study the numerous ramifications of the fertilizer pricing issue in the context of practical policy decisions of a particular developing country at a specific point in time. In the process, however, the complexity of the requirements of sustained success in rapid growth of fertilizer use in developing countries was revealed. It is with pride that I present this unusual collection of papers on fertilizer pricing issues in Bangladesh.

Bruce Stone

Washington, D.C.
November 1987

1. POLICY ISSUES FOR LONG-TERM GROWTH OF FERTILIZER USE IN BANGLADESH

Gunvant M. Desai

This paper discusses policy issues relevant to sustained rapid growth in Bangladesh's fertilizer consumption. The second section is an overview of fertilizer consumption as it has evolved over the years. It also provides a comparative perspective on the performance of Bangladesh among developing countries. The third section discusses policy requirements of long-term rapid growth in fertilizer use, keeping in mind various features of, and major forces behind, the past growth.

The paper concludes that, notwithstanding the policy of phasing out fertilizer subsidies adopted by the government, the potential for growth of fertilizer use is large. Realization of this potential, however, requires a new policy orientation. The emphasis on prices needs to be replaced by concentration on the productivity and efficiency of fertilizer use as key target variables.

Factors affecting growth in fertilizer use need to be viewed not in isolation from each other, but as a set of interacting variables that can be manipulated through policy. The dominant aim of these policies should be faster development and well-coordinated working of systems that influence the rate of growth of fertilizer use.

OVERVIEW OF FERTILIZER CONSUMPTION

Consumption in 1983/84

Fertilizer consumption in Bangladesh exceeded 500,000 metric tons of nutrients in 1983/84. In terms of materials, it was more than 1 million metric tons. Consumption reached 63 kilograms of net cultivated area and 41 kilograms per hectare of total cropped areas.

The view that Bangladesh's fertilizer consumption is among the world's lowest is somewhat misleading. While Bangladesh's fertilizer consumption per hectare is considerably lower than that in many developed countries, it is higher than average consumption in a large number of developing countries.

Comparison with Other Developing Countries

On the basis of 1981/82 fertilizer consumption per hectare of arable land and land under permanent crops, Bangladesh ranks 42nd among the 113 developing countries for which data are readily available.[1] Its consumption in that year was 9 percent lower than the average for all developing countries. However, if only developing market economies are considered (that is, if centrally planned economies are excluded from developing countries), then Bangladesh's consumption was 36 percent higher than the group's average.

Among the 34 developing countries of Asia, Bangladesh ranks 15th. But most of the developing countries with higher consumption than Bangladesh are either located in East Asia or in the Middle East. Among countries in South or Southeast Asia, Bangladesh's fertilizer consumption per hectare is lower than that of Singapore, Malaysia, Sri Lanka, Indonesia, and Pakistan. On the other hand, it is considerably higher than that of Nepal, Burma, Thailand, the Philippines, and a few others.

Bangladesh's fertilizer consumption per hectare of gross cultivated area in 1983/84 was about 8 percent lower than that of India. But it compares very favorably with states in East India (Table 1). Among these, only West Bengal's consumption was as high as that of Bangladesh, and consumption in Bihar, Orissa, Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura was considerably lower than in Bangladesh.

That fertilizer consumption in Bangladesh was generally higher than in East India is also illustrated by Figures 1 and 2, which show levels of fertilizer consumption per hectare of gross cultivated area in the districts of East India and Bangladesh, respectively.

Not only is fertilizer consumption in Bangladesh higher than in a majority of the developing countries, but its growth has also been faster. In 1981/82 Bangladesh ranked third among the 40 developing countries that applied less than 5 kilograms of fertilizer per hectare in the early 1960s.

Trends of Growth in Consumption

Table 2 shows the growth of fertilizer consumption in Bangladesh from 1952/53 to 1983/84. The period can be broadly divided as: 1952/53 to 1959/60, 1959/60 to 1970/71, 1970/71 to 1974/75, 1974/75 to 1977/78, and 1977/78 to 1983/84.

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[1]Based on data from Food and Agriculture Organization of the United Nations, FAO Fertilizer Yearbook, various issues (Rome: FAO, various years).

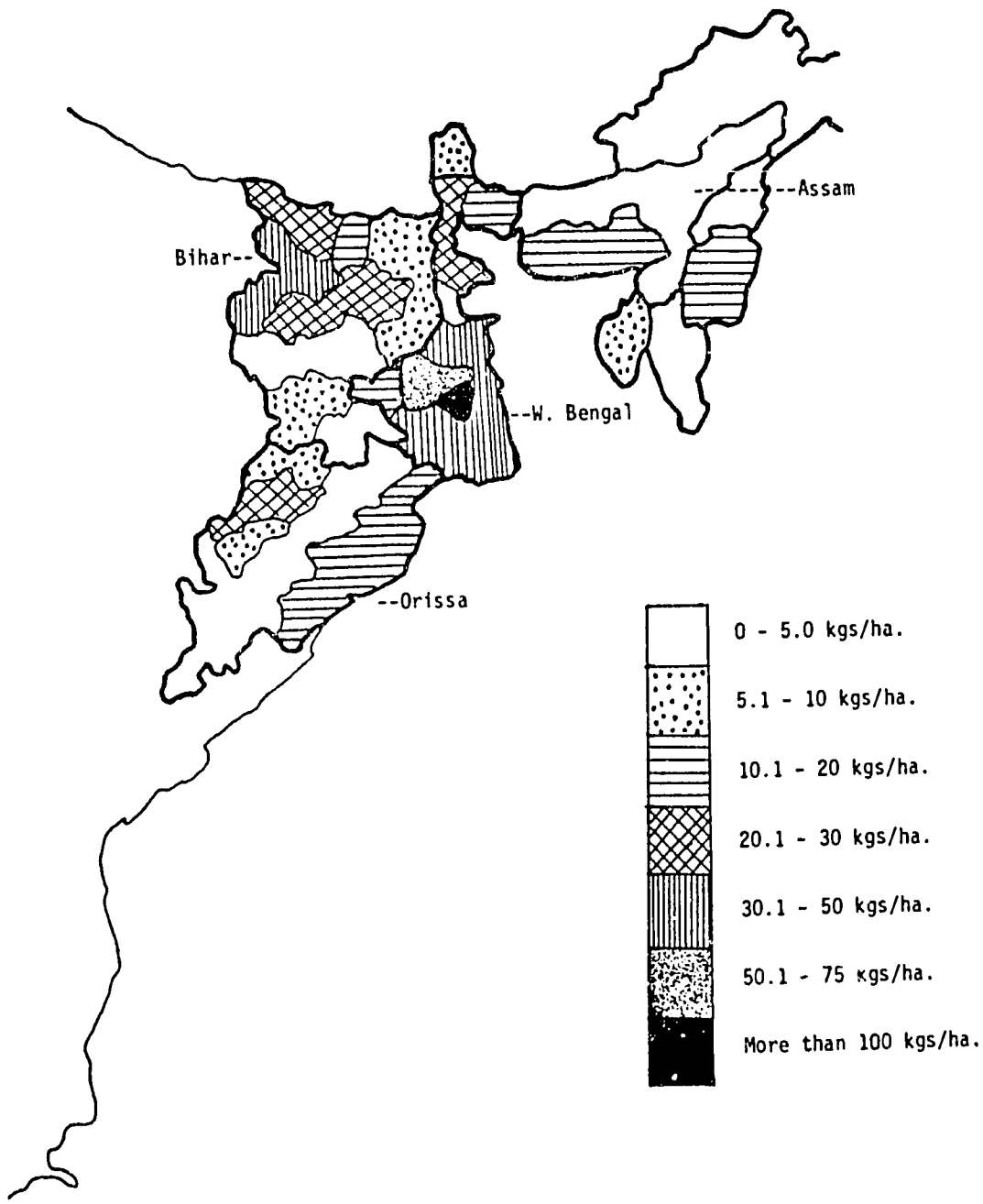
Table 1--Growth of fertilizer use in Bangladesh vis-à-vis India and major states of East India, 1961/62 to 1983/84

Year	Bangla-desh	Major States in East India				India
		West Bengal	Bihar	Orissa	Assam	
	(kilograms of nutrients per hectare of gross cropped area)					
1961/62	2.0	3.8	1.3	0.8	...	2.2
1962/63	2.2	3.3	1.8	0.9	0.1	2.9
1963/64	4.4	4.8	2.4	1.1	0.2	3.5
1964/65	4.1	6.5	3.1	1.3	1.0	4.9
1965/66	4.9	6.4	3.2	1.3	2.2	5.1
1966/67	6.1	5.1	3.6	2.5	1.9	7.0
1967/68	7.6	6.7	3.9	2.8	2.2	9.4
1968/69	8.2	8.0	6.1	2.9	3.3	11.1
1969/70	10.0	7.4	9.9	3.1	2.4	12.2
1970/71	11.4	11.0	9.0	3.3	3.1	13.6
1971/72	9.9	13.1	10.1	7.1	2.9	16.1
1972/73	15.1	13.0	11.5	8.1	3.3	17.1
1973/74	14.9	13.3	9.0	8.6	2.6	16.7
1974/75	10.8	16.2	10.8	6.9	1.9	15.7
1975/76	17.0	16.3	12.0	6.1	1.9	16.9
1976/77	19.6	20.0	15.2	8.6	1.3	20.4
1977/78	26.8	21.8	17.3	8.1	1.8	24.9
1978/79	27.6	30.9	17.1	8.7	2.4	29.2
1979/80	31.6	30.6	16.2	8.1	2.1	30.0
1980/81	32.3	35.9	18.0	9.2	2.8	31.5
1981/82	30.9	32.8	18.0	9.9	3.3	34.6
1982/83	34.6	33.1	18.5	10.8	4.1	36.6
1983/84	41.1	42.5	26.7	13.0	5.7	44.5

Sources: Bangladesh: Based on data from Bangladesh Ministry of Agriculture, Bangladesh Agriculture in Statistics (Dhaka, 1974); Bangladesh Bureau of Statistics, Ministry of Planning, Statistical Pocket Book of Bangladesh, 1980 (Dhaka: BBS, 1981); and Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, June 1984.

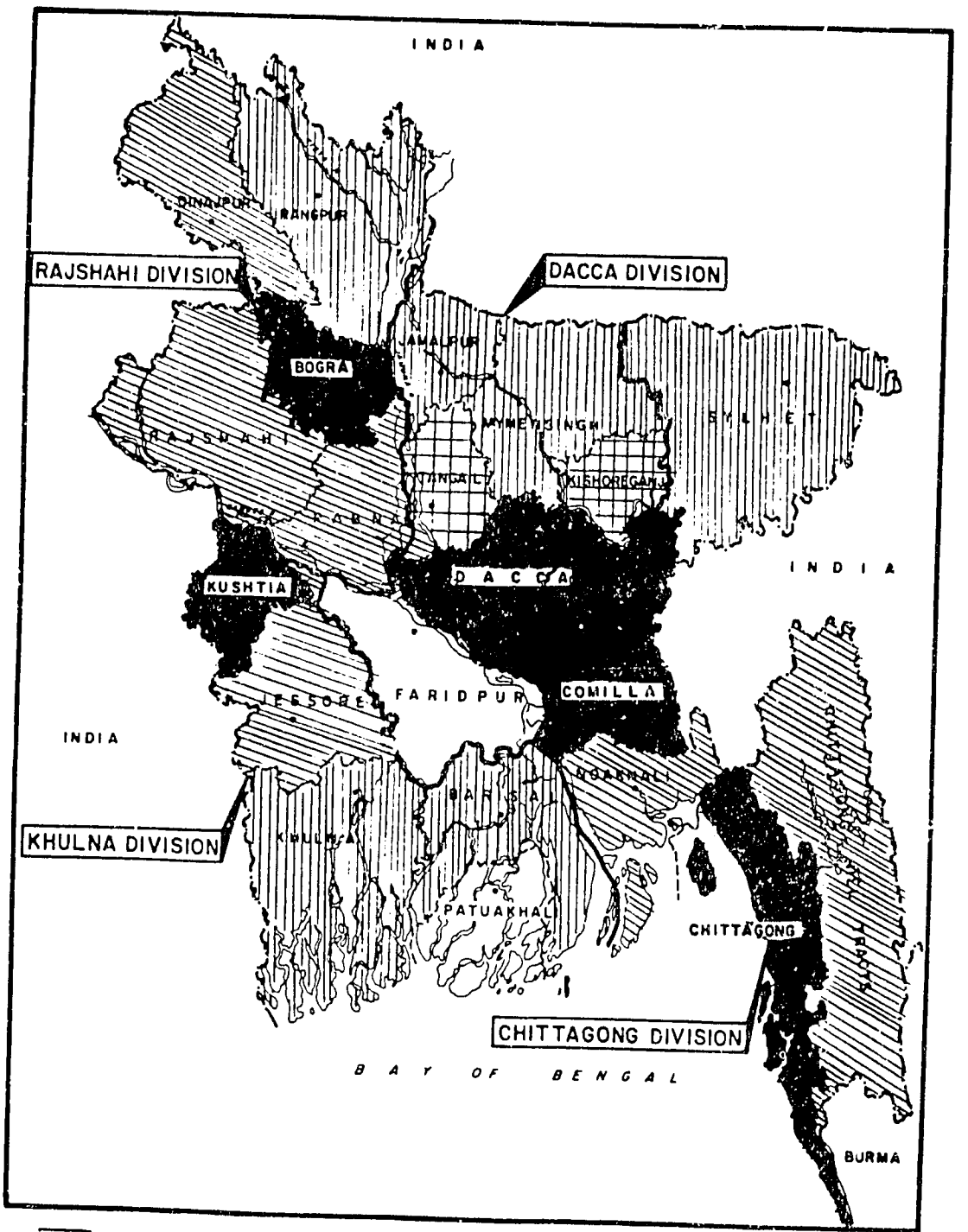
India: Based on data from Fertilizer Association of India, Fertilizer Statistics (various issues); and India Ministry of Agriculture, Indian Agriculture in Brief (New Delhi).

Figure 1--Fertilizer nutrient consumption per hectare of total cropped area in various districts of Bihar, West Bengal, Orissa, Assam, and other Northeastern Indian states in the early 1980s



Note: No districts fall between 75.1 and 100 kilograms per hectare.

Figure 2--Fertilizer nutrient consumption per hectare of total cropped area in various districts of Bangladesh in the early 1980s



5.1 - 10 kgs/ha.

10.1 - 20 kgs/ha.

20.1 - 30 kgs/ha.

30.1 - 50 kgs/ha.

50.1 - 75 kgs/ha.

Table 2--Fertilizer consumption in Bangladesh, 1952/53 to 1983/84

Year	Consumption				
	N	P_2O_5	K_2O	Total	$N:P_2O_5:K_2O$
	(1,000 metric tons)				
1952/53	1.8	...	...	1.8	1:0.00:0.00
1953/54	2.7	...	...	2.7	1:0.00:0.00
1954/55	3.6	...	...	3.6	1:0.00:0.00
1955/56	2.3	...	...	2.3	1:0.00:0.00
1956/57	5.2	...	...	5.2	1:0.00:0.00
1957/58	7.1	0.5	...	7.6	1:0.07:0.00
1958/59	8.0	0.5	...	8.5	1:0.06:0.00
1959/60	10.5	0.9	...	11.4	1:0.09:0.00
1961/62	19.3	3.0	0.5	22.8	1:0.16:0.03
1962/63	24.4	2.0	1.0	27.4	1:0.08:0.04
1963/64	36.6	11.1	2.0	49.7	1:0.30:0.05
1964/65	34.5	9.1	2.0	45.6	1:0.26:0.06
1965/66	38.9	9.8	2.3	51.0	1:0.25:0.06
1966/67	56.5	16.1	5.1	77.7	1:0.28:0.09
1967/68	71.1	22.5	7.0	100.6	1:0.32:0.10
1968/69	74.7	24.7	7.6	107.0	1:0.33:0.10
1969/70	91.8	30.6	9.2	131.6	1:0.33:0.10
1970/71	99.2	35.0	10.4	144.6	1:0.35:0.10
1971/72	79.3	28.1	8.5	115.9	1:0.35:0.11
1972/73	128.8	41.5	11.3	181.6	1:0.33:0.09
1973/74	122.3	43.8	11.2	177.3	1:0.36:0.09
1974/75	82.3	35.6	10.7	128.6	1:0.43:0.13
1975/76	145.8	51.4	13.2	210.4	1:0.35:0.09
1976/77	163.2	56.7	13.6	233.5	1:0.35:0.08
1977/78	223.2	89.4	43.3	355.9	1:0.40:0.19
1978/79	219.9	83.0	29.0	331.9	1:0.38:0.13
1979/80	250.5	96.4	53.8	400.7	1:0.38:0.21
1980/81	262.0	100.5	52.3	414.8	1:0.38:0.20
1981/82	242.5	97.4	56.9	396.8	1:0.40:0.23
1982/83	289.4	94.8	74.1	458.3	1:0.33:0.26
1983/84	342.6	163.4	37.5	543.5	1:0.48:0.11

Sources: 1952/53 to 1964/65 data are from Bangladesh Ministry of Agriculture, Bangladesh Agriculture in Statistics (Dhaka, 1974); 1965/66 to 1982/83 from Bangladesh Bureau of Statistics, Ministry of Planning, Statistical Pocket Book of Bangladesh, 1983 (Dhaka: BBS, 1984); and 1983/84 from Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, June 1984.

Total consumption grew from less than 2,000 metric tons of nutrients in 1952/53 to about 11,000 metric tons in 1959/60. Thereafter it accelerated, reaching 145,000 metric tons in 1970/71. More than 60 percent of growth during this period was recorded after 1965/66. Between 1970/71 and 1974/75 there were fluctuations in the upward trend. Fertilizer consumption reached 182,000 metric tons in 1972/73 but then dropped by 1974/75 to 129,000 metric tons, which was lower than in 1970/71.

The period between 1974/75 and 1977/78 recorded impressive growth, from 129,000 to 356,000 metric tons. Consumption in 1977/78 was nearly three times consumption in 1974/75, when fertilizer use was abnormally low owing to a particularly severe supply bottleneck. But growth in sales during the following three years must still be considered rapid. Fertilizer use in 1977/78 was twice that of the previous peak of 1972/73. Between 1977/78 and 1983/84, total consumption further increased from 356,000 to 544,000 metric tons (that is, by 53 percent). More than 75 percent of the growth during this period, however, occurred in the last two years. Yet another noteworthy point is that after reaching 400,000 metric tons in 1979/80, consumption stalled in 1980/81 and 1981/82 before reaching 544,000 metric tons in 1983/84.

These facts clearly indicate that a variety of factors other than changes in crop and fertilizer prices have governed the past growth in fertilizer use. On the demand side, diffusion of fertilizer use at a growing number of locations, accelerated growth of use in the Aus and Aman seasons (in addition to more intensive use during the Boro season), irrigation development, and the spread of high-yielding varieties (HYVs) clearly seem to have been important.

From the supply side, geographical expansion in the distribution system and fairly consistent growth in aggregate fertilizer supplies, as well as the changeover from the old to the new marketing system in the late 1970s, appear to be behind historical trends in the growth of fertilizer consumption. It is especially important to recognize all these forces explicitly while developing policies for sustained rapid growth in fertilizer consumption.

Consumption Vis-à-vis Potential

In 1980, the International Fertilizer Development Center (IFDC) estimated Bangladesh's agronomic potential for fertilizer use to be 1.70 million long tons of urea plus 1.46 million long tons of triple superphosphate or diammonium phosphate (TSP/DAP) and 0.82 million

long tons of muriate of potash (MP), a total of 3.98 million long tons of these fertilizer materials.[2]

In terms of nutrients, the potential works out to a little more than 2 million metric tons. On the basis of total cropped land, the potential amounts to about 150 kilograms of nutrients per hectare. This rate seems quite consistent with information in readily available literature on the response function environment in Bangladesh.[3]

The above estimate of the agronomic potential is not an unchanging number since it is based on cropped area, its distribution among various crops, and fertilizer recommendations. Notwithstanding possible overestimation in such an estimate, it provides a useful backdrop in the process of developing a perspective on the level and growth of actual fertilizer consumption. This is so because growth in fertilizer consumption occurs as a result of the conversion of this potential into actual fertilizer use.

Bangladesh's actual fertilizer consumption in 1983/84 was about 28 percent of the estimated potential--41 percent for urea, 24 percent for TSP/DAP, and only 8 percent for MP. These findings indicate that despite impressive growth in fertilizer consumption, Bangladesh has used less than 30 percent of its estimated agronomic potential of fertilizer use.

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[2]The estimate was based on major soil classifications by thanas, cropped area in 1977/78, and fertilizer recommendations made in 1979 by the Bangladesh Agricultural Research Council (BARC). For details, see International Fertilizer Development Center, Second Evaluation of the Bangladesh New Marketing System (Muscle Shoals, Ala.: IFDC, 1980).

[3]See, for instance, Kazi M. Badruddoza, "Experience in Farmers' Fields--Fertilizer Trials and Use in Bangladesh," in Proceedings: First Review Meeting, I.N.P.U.T.S. Project (Increasing Productivity Under Tight Supplies), ed. Saleem Ahmed and Muhammad Sadiq (Honolulu, Hawaii: East-West Center, 1976), pp. 339-350. The article provides results of more than 10,000 fertilizer trials on farmers' fields conducted by the Soil Fertility and Soil Testing Institute between 1970 and 1975. The trials covered six crops (rice, wheat, sugarcane, potatoes, mustard, and groundnuts). Nearly 80 percent of the trials were on local and improved varieties of paddy grown in Aus, Aman, and Boro seasons under irrigated as well as rainfed land. Nearly 70 percent of all trials were on rainfed land sown with local varieties of paddy.

Badruddoza's results show that net returns to fertilizer use were maximized with nutrient application of around 160 pounds per acre on local varieties of paddy under rainfed conditions, 160 to 240 pounds per acre on improved varieties of rice and wheat, 310 to 375 pounds per acre on sugarcane and potatoes, and 120 to 135 pounds per acre on mustard and groundnuts.

The use of this potential in terms of different nutrients has proceeded at an uneven pace. This is clearly brought out by Table 2, which shows a time series for the consumption of the three nutrients, accompanied by the N:P:K ratio. The N:P:K ratio implied by the potential estimated by IFDC is roughly 1:0.75:0.55.

Thus, although there is substantial untapped potential for further rapid growth in nitrogen consumption, it would be imprudent for efforts to raise fertilizer use to focus indiscriminately on this nutrient alone. This would be the case from the economic, as well as the agronomic, viewpoint, since additional crop production from nitrogen use depends on the use of other nutrients in specific soil groups and at high rates of nitrogen application.

The total fertilizer potential in a country is a summation of the potentials for use on different crops at various locations. Similarly, growth in the aggregate fertilizer consumption is an outcome of growth in use on various crops at different locations. The historical experiences of virtually all countries indicate that fertilizer use grows at different speeds on different crops. Even on the same crop, it grows at a different pace at different locations.[4]

It is, therefore, important to review the past growth in fertilizer use from these angles, since it reveals the composition of use at different times, the factors behind it, and a profile of the potential that has remained untapped. Such an understanding could then be used to evolve policies for further sustained growth in fertilizer use.

Share of Different Crops in Total Consumption

Fertilizer use in Bangladesh began on tea gardens in the early 1950s. It spread to other crops during the second half of the 1950s. Raisuddin Ahmed estimated, under a reasonable set of assumptions, that by 1960/61 rice had emerged with the dominant share of total fertilizer consumption (Table 3). Since Ahmed's estimates exclude application on tea plantations (between 2 and 10 thousand tons per year), the share of rice in the early 1960s could have been less than 70 percent. It grew to about 80 percent by the late 1960s. Thus acceleration in fertilizer consumption during the 1960s was due primarily to rapid growth of fertilizer use on rice.

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[4]Gunvant M. Desai, Sustaining Rapid Growth in India's Fertilizer Consumption: A Perspective Based on Composition of Use, Research Report 31 (Washington, D.C.: International Food Policy Research Institute, 1982); and Gunvant M. Desai and Gurdev Singh, Growth in Fertilizer Use in Districts of India: Performance and Policy Implications (Ahmedabad: Center for Management in Agriculture, Indian Institute of Management, 1973).

Table 3--Share of crops in total fertilizer consumption in Bangladesh, 1960/61 to 1973/74

Year	Total Consumption	Rice				Other Crops	Total
		Aus	Aman	Boro	Total		
	(long tons of nutrients)	(percent of total consumption)					
1960/61	20,183	28.4	34.8	13.6	76.8	23.2	100
1961/62	19,718	26.3	35.1	13.6	75.0	25.0	100
1962/63	24,702	27.9	35.2	13.8	76.9	23.1	100
1963/64	47,924	27.4	34.8	14.3	76.5	23.5	100
1964/65	43,834	28.1	34.7	13.6	76.4	23.6	100
1965/66	50,289	27.1	35.6	14.0	77.7	22.3	100
1966/67	74,668	23.1	33.7	17.3	74.1	25.9	100
1967/68	97,598	23.8	34.9	19.8	78.5	21.5	100
1968/69	104,224	19.8	36.3	23.4	79.5	20.5	100
1969/70	129,626	19.3	34.1	25.3	79.7	20.3	100
1970/71	143,206	19.0	29.7	27.1	75.8	24.2	100
1971/72	114,904	20.0	26.5	29.1	75.6	24.4	100
1972/73	179,230	16.7	24.6	33.5	74.8	25.2	100
1973/74	172,695	18.6	23.4	36.3	78.3	21.7	100

Sources: Developed from Raisuddin Ahmed, Foodgrain Production in Bangladesh: An Analysis of Growth: Its Sources and Related Policies (Dhaka: Bangladesh Agricultural Research Council, 1977), Appendix Tables 1.3(a) and 1.3(b).

Notes: Total consumption excludes application on tea gardens. Comparison of total consumption estimates here with those of the Food and Agricultural Organization of the United Nations suggest that annual consumption on tea plantations must have varied from 2,000 to 10,000 tons. Thus, the shares of crops would actually be lower than those shown here.

Ahmed's estimates show that the relative shares of Aus and Aman paddy in total fertilizer consumption decreased between the early 1960s and the early 1970s. During the same period, the share of Boro paddy increased substantially. This was because the absolute amount of fertilizer used on Boro paddy increased by 22-fold, while the quantity of fertilizer applied to Aus and Aman paddy rose 5- to 6-fold. The growth of fertilizer use on Boro paddy was faster because of the rapid growth in Boro paddy area (which, in turn, was principally due to irrigation development), the diffusion of HYVs of rice in the Boro season, and a strategy of increasing rice production by emphasizing the Boro season.

None of these factors was the main driving force behind the 5- to 6-fold growth in fertilizer consumption on Aus and Aman paddy, which, owing to larger initial area, was associated with a larger absolute increment of fertilizer use than was Boro paddy between 1960/61 and 1973/74. Instead, applications on Aus and Aman paddy grew mainly because much of the untapped potential for fertilizer use began to be converted into farmers' actual demand for fertilizers. This demand was met by the establishment of the East Pakistan Agricultural Development Corporation (now the Bangladesh Agricultural Development Corporation [BADC]) in 1962/63 and the consequent growth in the fertilizer distribution network. Following the introduction of the Rapid Soil Fertility Survey Scheme in 1957 throughout East and West Pakistan, it became scientifically established that in the response function environment of the 1950s, the untapped potential for fertilizer use was sizable.[5] About 4,500 experiments were conducted between 1957 and 1962 in Bangladesh (then East Pakistan).

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[5]Efforts to generate scientific knowledge about the response of crops to fertilizer use through experimentation and testing on farmers' fields were advocated as early as 1947 by M. U. Ghani, who was the Agricultural Chemist to the Government of East Bengal. These efforts, however, did not succeed until the mid-1950s, when the government of Pakistan asked the Food and Agriculture Organization of the United Nations for technical assistance in organizing fertilizer trials on cultivators' fields.

This led to the launching of the Rapid Soil Fertility Survey Scheme in 1957. Its aims were to generate information on crop responses to fertilizer use, to encourage farmers to take up fertilizer use through demonstrations, to make fertilizer recommendations, to obtain information about the potential increase in production that could be achieved through fertilizer use (information required for the formulation of agricultural development plans) and to specify agricultural areas where fertilizers could be used to the best advantage. For details, see J. G. Vermaat, Report to the Government of Pakistan on Soil Fertility Investigation, Report No. 1887, Project PAK/TE/LA (Rome: Food and Agriculture Organization of the United Nations, 1964).

About 90 percent of the experiments were on paddy and the remaining 10 percent were on wheat, sugar, potatoes, and mustard.

The experiments on paddy were conducted in all three seasons and were spread over six soil tracts covering the entire country. Results of these experiments established that the response function environment of rice was quite favorable. Even at 120 pounds of nutrients per acre the average response ratio was 8 to 9 pounds of paddy per pound of nutrient.

While the resporse of paddy to nitrogen was the highest (12.5 to 14.5 pounds of paddy per pound of nitrogen at 40 pounds of nitrogen per acre), it was also quite high for phosphate and potash (10 to 11 pounds of paddy per pound of phosphate, and 7 to 9 pounds of paddy per pound of potash at 40 pounds of these nutrients per acre).

Similarly, paddy yield response to fertilizer was confined neither to a single season (like Boro) nor to limited land areas or soil types. Since under the prevailing price environment a unit of nutrient did not cost more than 1.66 units of paddy, fertilizer use was perceived to be quite profitable for farmers.[6]

The explanations of acceleration in the growth in Bangladesh's fertilizer consumption during the 1960s usually focus on growth of fertilizer use on Boro paddy and emphasize factors such as growth in Boro paddy area, development of irrigation, and diffusion of HYVs. All this is understandable given the dramatic growth in fertilizer use on Boro paddy. But such explanations bypass the forces that generated growth of fertilizer use on Aus and Aman paddy--forces discussed above.

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[6]Vermaat, who has reported the results of fertilizer trials conducted under the Rapid Soil Fertility Survey Scheme, estimated that East Pakistan's rice production could be raised by 60 to 80 percent through fertilizer use alone. One may debate the accuracy of this estimate, as it involves generalization to all paddy land of average response ratios. But from details of the evidence generated by the scheme and comparable evidence from India, it is clear that in the response function environment in Bangladesh in the late 1950s and the early 1960's there was a large potential for growth in fertilizer use.

There were two main reasons for this. First, fertilizer use had just begun; in the late 1950s, use was less than two kilograms per hectare of total cropped land. Second, because of heavy subsidization of fertilizers, the price environment was extremely favorable. For example, around 1960 a unit of nitrogen was about three times more expensive (in terms of rice) in West Bengal, India than in East Pakistan.

This could be misleading because it is clear from Ahmed's estimates in Table 3 that Boro paddy accounted for only 39 percent of the increment in total fertilizer consumption between 1960/61 and 1973/74. Another 39 percent of the increment was due to growth in consumption of Aus and Aman paddy, and the remaining 22 percent was due to growth in fertilizer consumption for crops other than paddy.

Explicit recognition of the forces behind growth in fertilizer use on these crops could have led to policies to strengthen them and generate even faster growth, particularly on Aus and Aman paddy.

An indicative fertilizer consumption profile by crop can be developed for the 1979-81 period using the proportions of crop areas fertilized, average rates of application based on survey findings available in IFDC-BARC reports, and official statistics about the area under different crops.

Such a profile shows the following distribution of total fertilizer consumption in the early 1980s: rice, 81.5 percent; wheat, 7.4 percent; and the remaining crops, 11.1 percent. The 81.5 percent share of rice is comprised of 21.7 percent on Aus paddy, 39.8 percent on Aman paddy, and 20.0 percent on Boro paddy.

Two important conclusions emerge from the above findings. First, the share of rice in total fertilizer consumption increased marginally during the 1970s. This was because it was already quite high (between 75 and 80 percent) by the late 1960s, as Ahmed's estimates suggest. Second, and more importantly, unlike trends during the 1960s, the relative shares of Aus and Aman paddy in total fertilizer consumption increased during the 1970s, and that of Boro paddy decreased. Of course, total consumption on paddy grown in each season (including Boro) increased substantially in absolute terms because of the vast growth in aggregate fertilizer consumption.

The above reversal of the relative importance of the three paddy crops in total fertilizer consumption in the 1970s is not surprising. Total paddy area was distributed over the three seasons as roughly 30 percent in Aus, 58 percent in Aman, and 12 percent in Boro. Obviously the dominance of Boro paddy, as the dynamic component among shares of total fertilizer consumption, could not long be sustained with such a small share of total paddy area, especially when fertilizer use on Aus and Aman paddy was already under way and gathering momentum during the 1960s.

What other factors facilitated acceleration in the growth of fertilizer use on Aus and Aman paddy during the 1970s?

Available information suggests that this question cannot be answered mainly in terms of HYVs since by 1981/82 they covered only about 16 percent of the rice area in both these seasons. Against this, the findings available from the IFDC-BARC reports show that as

much as 50 to 52 percent of the Aus and Aman rice area was fertilized. Nor does the explanation lie predominantly with irrigation development, inasmuch as rice during these two seasons is grown mainly on rainfed areas.

Thus, diffusion of fertilizer use on local varieties and increases in rates of application emerge as important factors. These two processes were facilitated by rapid growth in aggregate supply of fertilizers (financed to a considerable extent by foreign aid), establishment of a widespread network for delivery of fertilizers to farmers, and continuation of the generally favorable price environment, despite upward adjustments in fertilizer prices.

The last point is brought out by Table 4, which presents a time series of official prices for nitrogen and for procurement of rice and wheat in both Bangladesh and India for the 1967/68 to 1983/84 period. Readily available information also indicates that the fertilizer price environment in Bangladesh has been more favorable than in many other developing countries.

Proportions of Areas Fertilized and Rates of Application

Growth in total fertilizer consumption occurs as a result of increases in proportions of cropped area fertilized and upward movements in rates of application. It is, therefore, useful to examine past growth performance from these angles. However, firm estimates based on large sample surveys were not available for Bangladesh until the late 1970s. Despite their limitations, the following findings for the early and mid-1970s seem worth noting before focusing on evidence available for recent years.

Assuming that farmers who use fertilizers apply 50 percent of the recommended rates, Ahmed estimated that during the 1971-74 period, only 7 percent of Aus areas, 4 percent of Aman areas, and 18 percent of Boro paddy areas were fertilized. However, findings for 1976/77, based on a widespread but small sample survey, indicate that actual rates might have been lower than 50 percent of recommended rates. Correspondingly, proportions of areas fertilized might have been higher than estimated by Ahmed.

In a sample of 20 clusters of 384 farms distributed over 10 out of 20 districts, Jabbar found that in 1976/77 about 70 percent of sample farmers had used fertilizer and that 51 percent of the area under all crops was fertilized.[7] The proportion of area planted with each crop that was fertilized was HYV Boro paddy, 99 percent; local

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[7]M. A. Jabbar, "Fertilizing Behaviour of a Sample of Bangladesh Farms," Bangladesh Journal of Agricultural Economics 2 (No. 2, 1979): 57-71.

Table 4--Ratios of official prices of nitrogen to procurement prices of rice and wheat in Bangladesh and India, 1967/68 to 1983/84

Year	Bangladesh		India	
	Rice[a]	Wheat[b]	Rice[a]	Wheat[b]
1967/68	0.78	n.a.	2.19-2.72	1.93-2.82
1968/69	0.74	n.a.	2.24-2.79	2.31-2.46
1969/70	0.74	n.a.	2.37-3.06	2.70
1970/71	0.74	n.a.	2.37-2.99	2.70
1971/72	0.58	n.a.	2.32-2.87	2.64
1972/73	0.81	n.a.	2.40-2.86	2.75
1973/74	1.05	n.a.	2.18	2.78-3.00
1974/75	0.91	n.a.	3.94	4.14
1975/76	0.91	1.51	3.64	3.83
1976/77	1.09	1.76	3.44	3.62
1977/78	0.98	1.63	2.93	3.06
1978/79	1.12	1.77	2.65	2.98
1979/80	1.32	2.27	2.22	2.74
1980/81	1.41	2.17	2.77	3.72
1981/82	1.41	2.12	2.97	3.93
1982/83	1.53	2.38	2.81	3.60
1983/84	n.a.[c]	n.a.	2.24-2.37	3.09

Sources: Based on Raisuddin Ahmed, Foodgrain Production in Bangladesh: An Analysis of Growth: Its Sources and Related Policies (Dhaka: Bangladesh Agricultural Research Council, 1977); Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983); Fertilizer Association of India, Fertilizer Statistics, 1982/83 (New Delhi: FAI, 1983); and India, Economic Survey, 1983/84 (New Delhi, Controller of Publications, 1984).

Notes: Nitrogen prices are based on urea for both countries. Where n.a. appears, data are not available.

[a]This is the ratio of the official price of nitrogen to the procurement price of rice.

[b]This is the ratio of the official price of nitrogen to the procurement price of wheat.

[c]Fertilizer prices were decontrolled throughout Bangladesh beginning April 1, 1983.

Boro paddy, 48 percent; Aus paddy, 42 percent; transplanted Aman paddy, 52 percent; jute, 33 percent; and tobacco, 60 percent.

These findings suggest two things. First, the diffusion of fertilizer use was much wider than estimated by Ahmed for 1971-74 and was significant for local varieties of paddy in the Aus and Aman seasons as well as in Boro. Second, Jabbar's findings reveal that even in 1976/77, the actual rates of application on fertilized land were considerably lower than the recommended rates of 50 percent Ahmed assumed for 1971-74. The actual rates were 30 to 37 percent of the recommended rates on Aus, transplanted Aman, and HYV Boro paddy.

Total fertilizer consumption divided by the average rate of application found by Jabbar--100 kilograms of fertilizer materials (about 41 kilograms of nutrients) per hectare of fertilized land--produces an estimate of 5.24 million hectares of fertilized area for 1976/77. This is roughly 42 percent of Bangladesh's gross cropped area in that year. On the other hand, if the average rate on all fertilized land was higher than revealed by Jabbar's small sample survey, then by 1976/77 less than 42 percent of gross cropped area would be fertilized.

Much of the uncertainty about how many farmers used fertilizers, what proportions of crop areas were fertilized, and at what rates has been removed by the farm-level surveys conducted for the IFDC-BARC study on Agricultural Production, Fertilizer Use, and Equity Considerations. These surveys were carried out in 10 cropping seasons from 1979 Aman to 1982 Aman. The survey locations (thanas) were spread all over the country, covering all districts except Patuakhali and the Chittagong Hill Tracts. At each location about 120 farms were selected by stratified random sampling. The following paragraphs highlight some of the major findings of these surveys.

About 65 percent of Bangladesh's farmers used fertilizers during the reference period of the surveys. About 50 percent of the planted area was fertilized. The average rate of application was 74 pounds of nutrients per acre of fertilized area.[8]

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[8]These national findings are reported on page 16 of IFDC, Bangladesh Policy Options for the Development of the Fertilizer Sector (Muscle Shoals, Ala.: IFDC, 1982). One method of checking the reliability of the national figures is to multiply the survey-based estimates of the proportion of area fertilized and the average rates of application per fertilized acre by official estimates of total area, and thus arrive at an estimate of total fertilizer consumption.

There is, however, one difficulty. The definition of "planted area" is not available in the above report. If it is "gross or total cropped area," then the total estimated consumption is about 35

On average, about 77 percent of Bangladesh's wheat area, 57 percent of Boro paddy area, 51 percent of Aman paddy area, 51 percent of Aus paddy area, and 31 percent of jute area were fertilized (Table 5). The average rates of application in terms of fertilizer materials per fertilized acre under these crops were wheat, 155 pounds; Boro paddy, 181 pounds; Aman paddy, 111 pounds; Aus paddy, 131 pounds; and jute, 81 pounds. The percentage of area fertilized was more than the percentage of area sown with HYVs for all crops except wheat, indicating that fertilizer use was not confined to HYVs.

On the other hand, virtually all area under wheat was sown with HYVs, but fertilizer use had spread to only 77 percent of the sown area. The diffusion of fertilizer use on wheat, however, was not confined to irrigated wheat, since only 33 percent of the area under the crop was irrigated. Against this, fertilizer use had not yet spread to all irrigated area under Boro paddy; fertilized area was 21 percentage points lower than the area of Boro paddy irrigated.

These findings are for all sample locations taken together. Within these aggregates, there were vast variations in both the percentages of cropped area fertilized and the average rates of application on the same crop among different locations (Tables 6 through 10 and Figures 3 through 7).

Nor were the changes (in these two determinants of fertilizer use) uniform for all crops or locations. This is stressed because during the three-year survey period, fertilizer prices (in both nominal and relative terms) increased. Despite this escalation in fertilizer prices, there were many locations where either the proportion of area fertilized, or the average rate of application, or both, had increased. Thus the conclusion that emerges from these findings is that temporal changes in fertilizer use are governed by a variety of factors, whose importance varies by location and crop.

Yet another conclusion suggested by the findings is that there were many locations where fertilizer use spread much less than the aggregative findings indicated. Such locations deserve attention in

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(Footnote 8, continued)

percent higher than the official figure of total fertilizer consumption during the reference period of the surveys. On the other hand, if the term "planted area" means "net cropped area," then the total estimated consumption is about 12 percent lower than the official figure for total fertilizer consumption.

After evaluating different alternatives, it seems reasonable to conclude that by around the late 1970s or early 1980s, nearly 50 percent of Bangladesh's gross cropped area was fertilized, at an average rate of 55 to 60 pounds of nutrients per fertilized acre.

Table 5--Findings of IFDC-BARC surveys on percentage of area fertilized and average rates of application for Aus, Aman, and Boro paddy, wheat, and jute, 1979-82

Crop	Season	Year	Number of Sample Locations	Crop Area in Sample	Crop Area Fertilized	Average Rate	Crop Area: Irrigated	Crop Area: Sown with HYVs
				(acres)	(percent)	(pounds of materials/ fertilized acre)	(percent)	
Paddy	Aus	1980	15	1,972	47.9	132	10.5	19.5
Paddy	Aus	1981	15	1,759	54.1	132	11.9	22.8
Paddy	Aus	1982	15	1,708	51.7	126	15.4	27.8
Weighted average			15	1,813	51.1	131	12.5	23.1
Paddy	Aman	1979[a]	10	2,274	60.5	117	3.7	20.5
Paddy	Aman	1980	10	2,445	49.7	110	0.8	23.4
Paddy	Aman	1981	10	2,236	44.2	104	4.2	27.1
Weighted average			10	2,318	51.4	111	2.8	23.6
Paddy	Boro	1979/80	8	573	59.5	185	75.0	58.4
Paddy	Boro	1980/81	8	467	57.5	145	79.2	55.7
Paddy	Boro	1981/82	8	488	52.1	213	80.2	50.8
Weighted average			8	509	56.5	181	77.9	55.2
Wheat	...	1979/80	10	661	78.6	155	42.7	95.9
Wheat	...	1980/81	10	542	80.4	163	23.7	99.8
Wheat	...	1981/82	10	337	68.0	141	25.8	92.7
Weighted average			10	513	76.9	155	32.3	96.6
Jute	...	1980	9	414	32.0	77	...	0
Jute	...	1981	9	372	25.1	103	...	0
Jute	...	1982	9	442	35.1	72	...	...
Weighted average			9	409	30.9	81	...	...

Source: Developed from the data in Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Note: Only those locations for which findings are available for three years are considered.

[a]These data are occasionally criticized as less reliable, owing to survey quality control difficulties during the season when the study began.

Table 6--Fertilizer use by sample farmers on Aus paddy in Bangladesh, 1980-82

Location of Sample District and Thana	Aus Paddy 1980					Aus Paddy 1981					Aus Paddy 1982				
	Area					Area					Area				
	Total (acres)	Irri-gated (percent of area)	Under HYVs (percent of area)	Fertil-ized (percent of area)	Rate (lbs./acre)	Total (acres)	Irri-gated (percent of area)	Under HYVs (percent of area)	Fertil-ized (percent of area)	Rate (lbs./) acre	Total (acres)	Irri-gated (percent of area)	Under HYVs (percent of area)	Fertil-ized (percent of area)	Rate (lbs./acre)
Comilla, Chandina	153	0	8	74	195	130	7	23	96	160	127	7	22	96	88
Bogra, Nandigram	128	1	22	97	120	139	23	43	100	151	141	49	64	100	195
Dhaka, Kapasia	95	0	11	51	71	97	0	24	76	86	104	0	15	98	84
Kushtia, Mirpur	309	62	71	73	270	220	69	66	67	307	209	70	69	69	294
Tangail, Modhupur	150	0	4	69	86	97	0	10	55	91	56	0	4	6	83
Mymensingh, Phulpur	154	0	0	87	46	177	0	2	79	54	159	0	1	56	57
Noakhali, Sonagazi	21	0	29	100	109	127	0	45	99	118	130	0	47	98	123
Dinajpur, Chirirbandar	205	0	15	14	64	159	0	13	13	54	175	4	24	12	83
Pabna, Atghoria	151	6	12	15	110	114	0	8	45	84	91	26	28	42	155
Jessore, Jhikargacha	157	0	30	24	117	110	0	19	21	57	146	3	30	23	96
Barisal, Jhalakathi	98	0	0	1	200	56	0	1	5	120	75	0	9	23	157
Rangpur, Kurigram	144	3	4	37	78	166	10	12	21	105	98	3	5	25	60
Sylhet, Balagonj	44	0	0	1	100	52	0	1	2	300	50	0	2	21	50
Faridpur, Nagarkanda	33	0	0	2	100	34	0	0	0	0	65	0	0	3	67
Khulna, Fakirhat	130	0	0	24	125	81	0	0	18	214	82	0	1	46	57

Source: Developed from data in Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Note: The rates are given in terms of fertilizer materials per acre of fertilized land.

Table 7--Fertilizer use by sample farmers on Boro paddy in Bangladesh, 1979/80 - 1981/82

Location of Sample District and Thana	Boro Paddy, 1979/80					Boro Paddy, 1980/81					Boro Paddy, 1981/82				
	Area					Area					Area				
	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate
	(acres)	(percent of area)			(lbs/ acre)	(acres)	(percent of area)			(lbs/ acre)	(acres)	(percent of area)			(lbs/ acre)
Chittagong, Ramu	104	55	100	97	309	95	82	98	99	287	98	97	100	100	262
Dhaka, Kapasia	77	36	36	38	229	66	26	34	32	58	66	4	18	14	157
Tangail, Modhupur	59	98	100	99	252	50	92	100	94	229	56	99	100	98	323
Mymensingh, Phulpur	84	94	77	96	94	41	82	73	96	183	42	90	91	99	187
Jessore, Jhikargacha	27	68	100	98	330	27	100	100	100	327	40	97	100	100	313
Barisal, Jhalakathi	23	93	100	100	312	32	100	100	99	247	4	73	100	100	244
Sylhet, Balagonj	172	98	9	5	140	136	100	3	5	5	162	98	...	4	175
Faridpur, Nagarkanda	27	0	51	50	306	20	0	8	8	12	20	10	0	0	0

Source: Developed from data in Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Note: Rates are given in terms of fertilizer materials per acre of fertilized land.

Table 8--Fertilizer use by sample farmers on Aman paddy in Bangladesh, 1979-81

Location of Sample District and Thana	Aman Paddy, 1979					Aman Paddy, 1980					Aman Paddy, 1981				
	Area					Area					Area				
	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate
	(acres)	(percent of area)			(lbs/acre)	(acres)	(percent of area)			(lbs/acre)	(acres)	(percent of area)			(lbs/acre)
Chittagong, Ramu	353	0	68	78	127	361	0	68	52	133	347	0	76	24	88
Comilla, Chandina	169	2	15	73	160	116	0	14	21	157	136	0	12	76	79
Bogra, Nandigram	388	1	5	89	138	412	0	8	95	94	401	10	17	100	114
Tangail, Modhupur	178	10	45	78	142	176	0	33	77	112	152	0	28	71	94
Noakhali, Sonagazi	134	0	35	97	180	136	0	30	94	93	141	0	38	98	110
Dinajpur, Chirirbandar	286	0	2	19	63	308	0	3	7	43	273	0	7	9	78
Pabna, Atghoria	237	15	17	69	141	217	5	20	59	171	189	13	34	79	167
Jessore, Jhikargacha	132	18	4	70	139	123	8	19	66	8	143	21	9	85	55
Barisal, Jhalakathi	227	0	1	22	68	212	0	0	2	100	155	0	0	13	62
Sylhet, Balagonj	170	0	1	1	30	147	0	0	4	75	161	0	1	3	167
Khulna, Fakirhat	...	...	...	...	...	237	0	43	45	198	138	0	47	49	171

Source: Developed from data in Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Note: Rates are given in terms of fertilizer materials per acre of fertilized land.

Table 9--Fertilizer use by sample farmers on wheat in Bangladesh, 1979/80 - 1981/82

Location of Sample District and Thana	Wheat, 1979/80					Wheat, 1980/81					Wheat, 1981/82				
	Area					Area					Area				
	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate
	(acres)	(percent of area)			(lbs/ acre)	(acres)	(percent of area)			(lbs/ acre)	(acres)	(percent of area)			(lbs/ acre)
Comilla, Chandina	71	0	100	82	254	44	28	99	99	261	40	13	96	97	261
Bogra, Nandigram	11	47	100	100	229	26	79	100	100	258	10	90	97	97	288
Kushtia, Mirpur	52	34	100	97	206	76	0	100	98	135	48	67	100	65	177
Tangail, Modhupur	68	97	100	96	219	58	80	100	96	254	22	93	100	96	272
Mymensingh, Phulpur	25	24	51	92	97	21	7	100	83	78	4	20	100	73	81
Dinajpur, Chirirbandar	93	99	100	95	89	44	0	100	84	119	30	0	100	65	111
Pabna, Atghoria	123	38	100	82	173	89	14	100	89	181	47	24	100	72	147
Jessore, Jhikargacha	96	34	100	78	177	44	59	100	82	189	21	37	100	74	111
Rangpur, Kurigram	59	27	100	81	125	59	16	100	88	124	42	1	86	84	87
Faridpur, Nagarkanda	63	0	76	0	0	81	0	99	18	78	73	0	77	29	41

Source: Developed from data in Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Note: Rates are given in terms of fertilizer materials per acre of fertilized land.

Table 10--Fertilizer use by sample farmers on jute in Bangladesh, 1980-82

Location of Sample District and Thana	Jute 1980					Jute 1981					Jute 1982				
	Area					Area					Area				
	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate	Total	Irri-gated	Under HYVs	Fertil-ized	Rate
	(acres)	(percent of area)			(lbs/acre)	(acres)	(percent of area)			(lbs/acre)	(acres)	(percent of area)			(lbs/acre)
Comilla, Chandina	8	0	0	68	204	13	0	0	100	217	18	0	0	90	111
Kushtia, Mirpur	38	1	0	29	76	29	0	0	2	100	41	...	0	8	125
Tangail, Modhupur	16	0	0	69	83	14	0	0	59	88	11	0	0	3	67
Mymensingh, Phulpur	35	0	0	89	52	22	0	0	48	90	29	0	0	50	44
Dinajpur, Chirirbandar	64	0	0	8	63	41	0	0	13	46	56	0	0	13	54
Pabna, Atghoria	40	0	0	48	125	32	0	0	50	146	42	...	0	52	73
Jessore, Jhikargacha	63	0	0	12	125	78	0	0	29	93	110	0	0	31	100
Rangpur, Kurigram	76	0	0	18	56	61	0	0	16	44	54	0	0	11	36
Faridpur, Nagarkanda	74	0	0	38	42	82	0	0	9	156	81	0	0	64	45

Source: Developed from data in Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Note: Rates are given in terms of fertilizer materials per acre of fertilized land.

Figure 3--Percentage of area fertilized, and average rates of application on Aus paddy by sample farmers at different locations in 1980, 1981, and 1982

(%AF = Percent crop area fertilized, AR = Average rate of application, pounds of materials per fertilized acre)

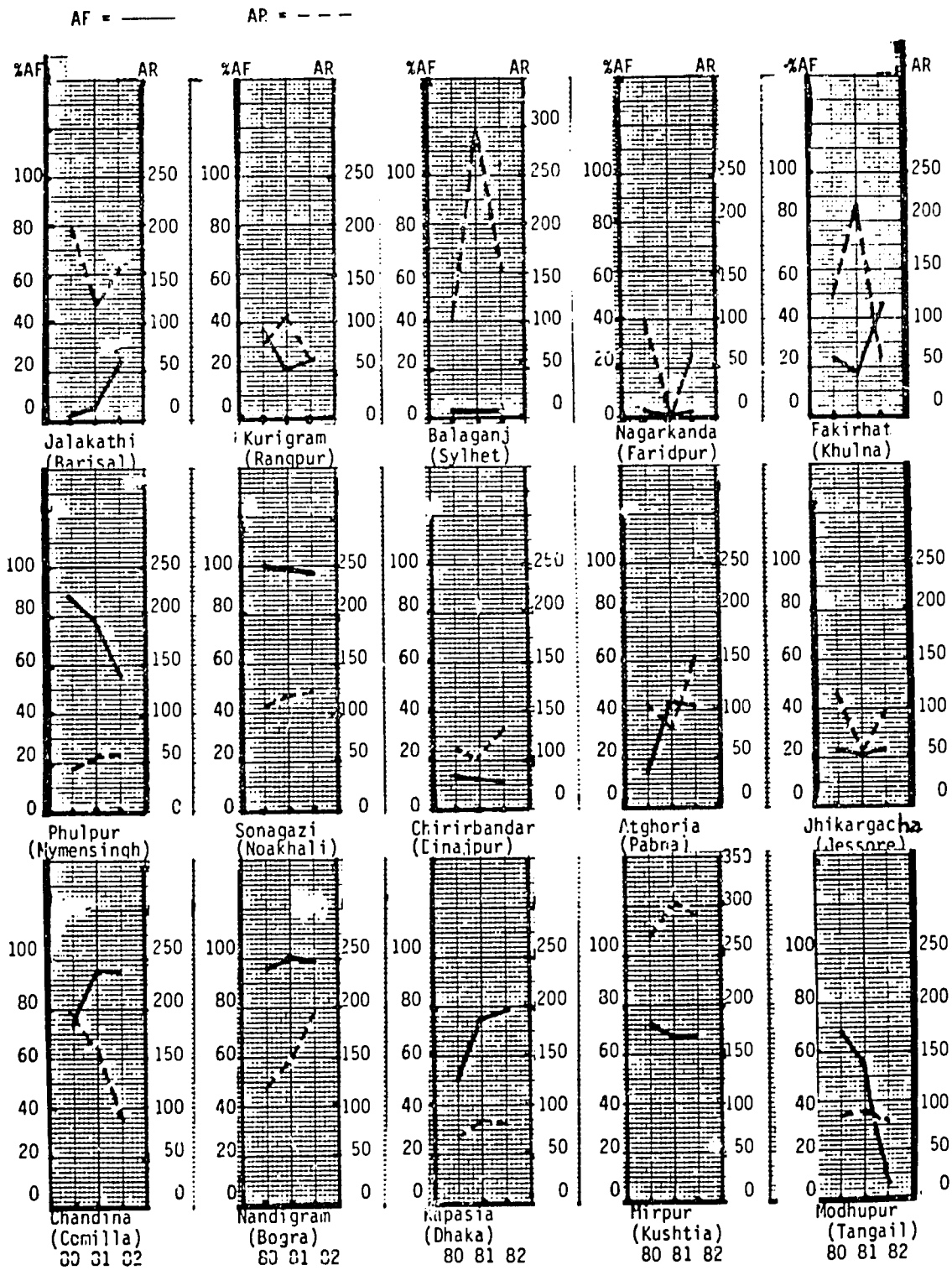


Figure 4--Percentage of area fertilized, and average rates of application on Aman paddy by sample farmers at different locations in 1979, 1980, and 1981

(%AF = Percent crop area fertilized, AR = Average rate of application, pounds of materials per fertilized acre)

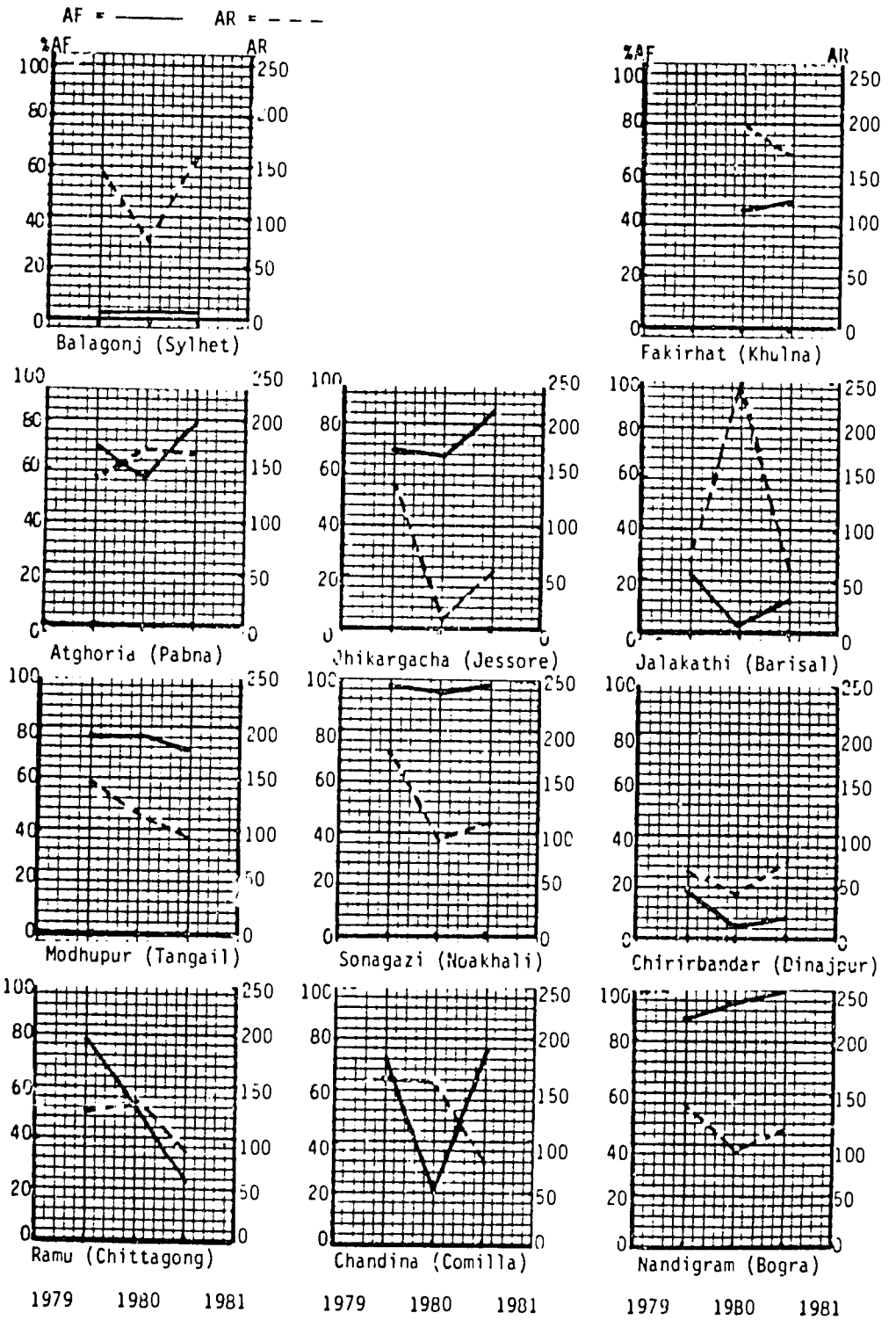


Figure 5--Percentage of area fertilized, and average rates of application on Boro paddy by sample farmers at different locations in 1979/80, 1980/81, and 1981/82

(%AF = Percent crop area fertilized, AR = Average rate of application, pounds of materials per fertilized acre)

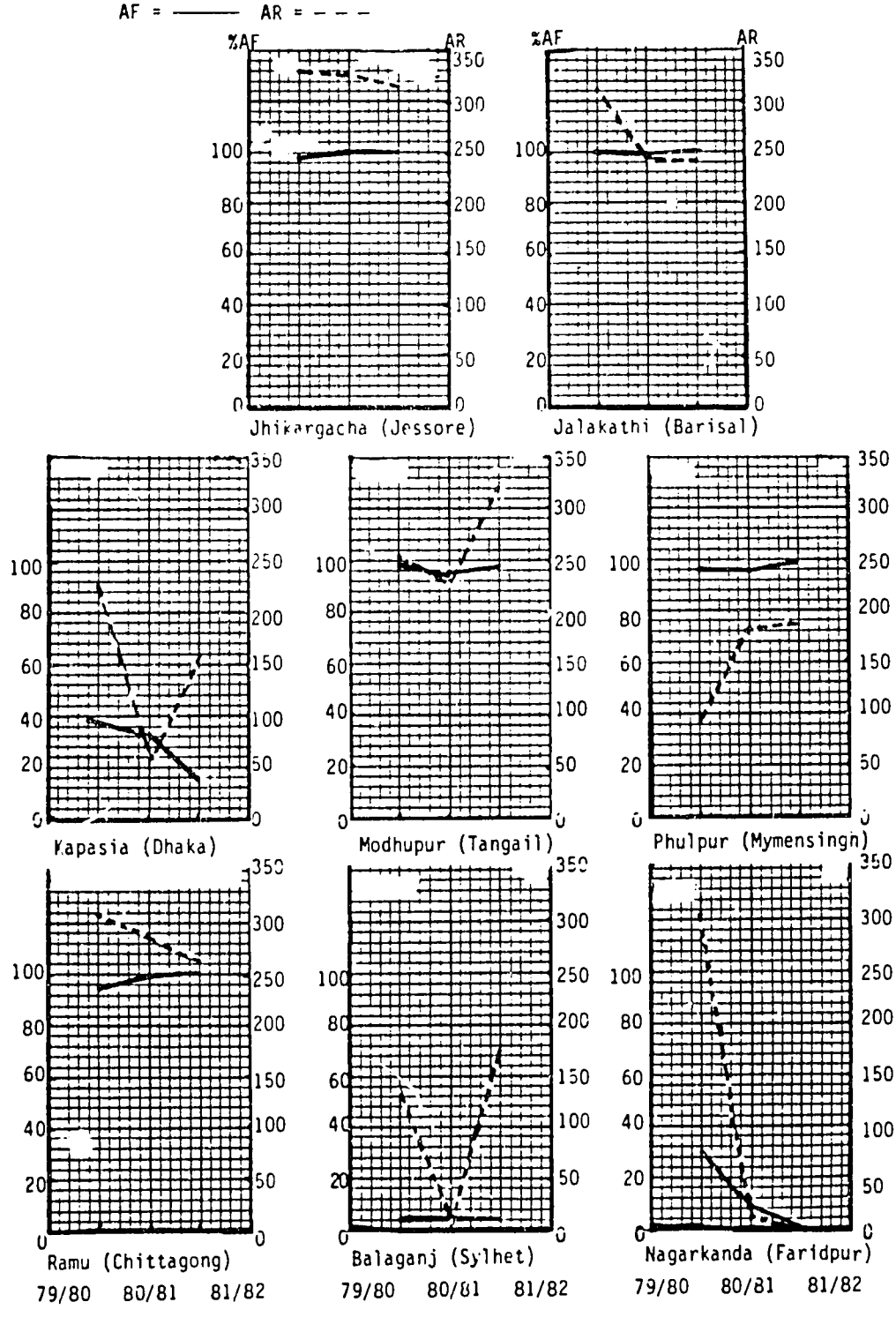


Figure 6--Percentage of area fertilized and average rates of application on wheat by sample farmers at different locations in 1979/80, 1980/81, and 1981/82

(%AF = Percent crop area fertilized, AR = Average rate of application, pounds of materials per fertilized acre)

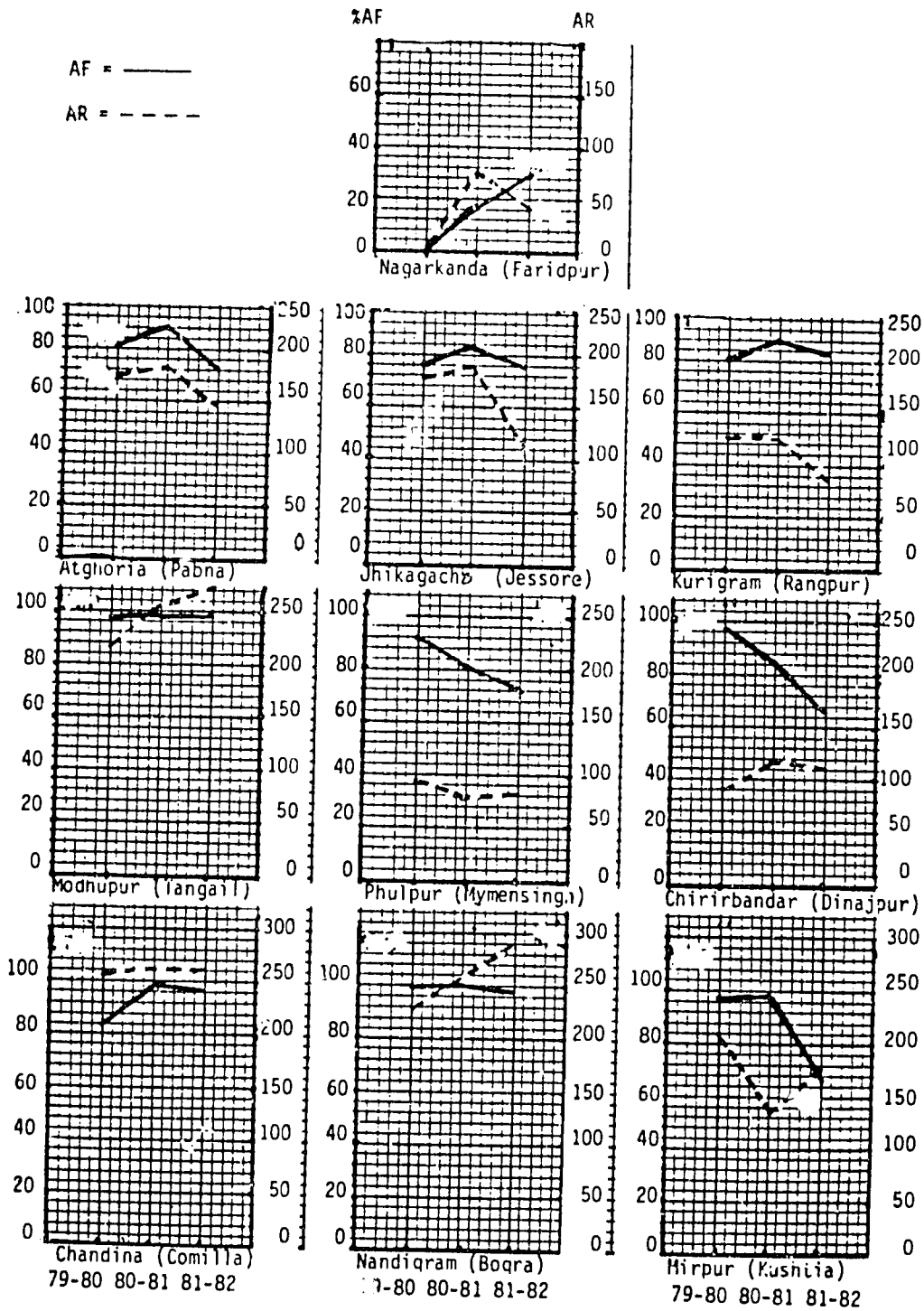
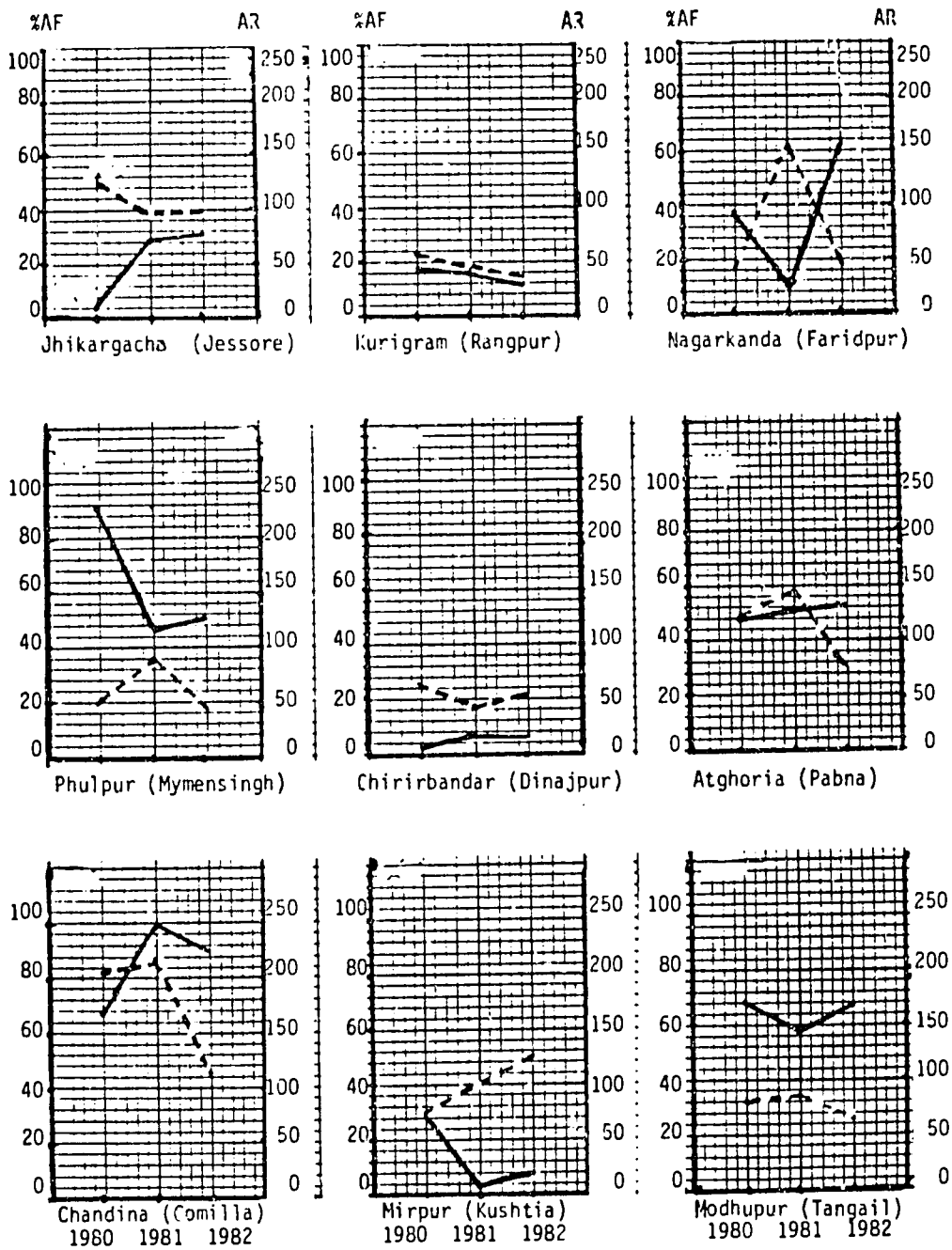


Figure 7--Percentage of area fertilized and average rates of application by sample farmers at different locations in 1980,1981, and 1982

(%AF = Percent crop area fertilized, AR = Average rate of application, pounds of materials per fertilized acre)

AF = ——— AR = - - - -



developing policies for sustained rapid growth in Bangladesh's fertilizer consumption. This is especially important because both fertilizer diffusion and rates of application are already high in some of the locations that contributed to past growth in consumption.

Growth Performance of Districts in Fertilizer Consumption

On the basis of 1983/84 fertilizer consumption per unit of land, 1969/70 to 1983/84 trends in fertilizer consumption, and the proportion of the agronomic potential of fertilizer use tapped by 1983/84, the 21 districts of Bangladesh can be divided into three groups:

Group A (5 districts): Bogra, Kushtia, Dhaka, Comilla, and Chittagong.

Group B (10 districts): Dinajpur, Rangpur, Jamalpur, Mymensingh, Kishoreganj, Rajshahi, Pabna, Tangail, Jessore, and the Chittagong Hill Tracts.

Group C (6 districts): Sylhet, Faridpur, Khulna, Barisal, Noakhali, and Patuakhali.

Table 11 shows 1983/84 fertilizer consumption by district (in terms of kilograms of fertilizer materials per hectare of total cropped area), total consumption in 1983/84 as a proportion of agronomic potential,[9] the shares of each district in Bangladesh's fertilizer consumption in 1969/70, 1978/79, and 1983/84, and each district's share in total cropped area in 1981/82. Figure 8 shows trends in fertilizer consumption from 1969/70 to 1983/84.[10] Several major points emerge from the table and the figure.

In 1983/84, Group A had the highest fertilizer consumption per hectare of total cropped area--more than 135 kilograms of fertilizer materials. Group B came next with per hectare consumption between 65

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[9]The estimates of agronomic potential of fertilizer use by district in Table 11 were formulated by IFDC in 1980. They are based on major soil classifications by thanas, cropped area in 1977/78, and fertilizer recommendations made by BARC in 1979. Since these might have changed by 1983/84, estimates of potential tapped by 1983/84 must be considered no more than indicative.

[10]Since the objective of Figure 8 is to highlight trends in the total fertilizer consumption of districts, total consumption in each district is divided by its total cropped area in one year (1977/78, for convenience in plotting trends). Therefore, 1983/84 consumption shown in the figure differs marginally from the data in Table 11. Mymensingh district in Figure 8 includes Mymensingh, Jamalpur, and Kishoreganj districts, as separate time-series data are not available for each.

Table 11--Fertilizer use by Bangladesh district as a proportion of potential, 1983/84 and changes in district-wide shares, 1969/70 - 1983/84

Group/ District	1983/84 Consumption[a]	Share in Total Consumption			Share of Total Cropped Area	1983/84 Consumption as a Share of Potential			
		1969/70	1978/79	1983/84	1981/82	Urea	TSP/DAP	MP	Total[b]
	(kilograms/hectare)				(percent)				
Group A									
Bogra	187	6.2	6.4	8.1	3.7	73	50	18	54
Kushtia	144	2.8	3.8	4.6	2.7	74	47	22	54
Dhaka	146	9.9	9.3	9.5	5.6	66	42	9	45
Comilla	136	12.1	15.3	10.7	6.6	65	41	15	45
Chittagong	166	16.3	9.7	6.6	3.4	75	20	6	41
Average or total	153	47.3	44.5	39.5	22.0	69	39	13	47
Group B									
Dinajpur	96	5.0	4.5	6.1	5.4	38	41	19	36
Rangpur	68	4.6	5.4	7.5	9.5	30	23	7	23
Mymensingh[c]	86	10.9	12.3	11.7	12.7	40	16	4	24
Jamalpur	83	...	3.4	3.5	40	44	19	6	27
Mymensingh	65	...	...	3.3	4.4	34	10	2	17
Kishoreganj	88	...	5.7	5.0	4.8	49	21	5	30
Rajshahi	101	4.8	5.6	7.7	6.5	42	29	8	30
Pabna	101	2.5	3.9	5.1	4.4	49	37	10	36
Tangail	100	2.2	3.7	4.3	3.7	52	31	11	36
Jessore	76	3.0	4.4	4.9	5.5	47	24	9	31
Chittagong Hill Tracts	77	1.2	0.4	0.7	0.8	31	19	7	22
Average or total	80	34.2	40.2	48.0	48.5	47	11	8	28

(continued)

Table 11--Continued

Group/ District	1983/84 Consumption[a]	Share in Total Consumption 1969/70	1978/79	1983/84	Share of Total Cropped Area 1981/82	1983/84 Consumption as a Share of Potential Urea	TSP/DAP	MP	Total[b]
	(kilograms/hectare)				(percent)				
Group C									
Sylhet	37	4.6	2.7	3.4	7.7	22	8	3	13
Faridpur	32	1.2	1.9	2.2	5.8	21	9	5	13
Khulna	36	2.8	1.3	1.8	4.1	21	8	2	13
Barisal	38	3.9	3.1	2.2	4.9	19	7	1	11
Noakhali	51	5.1	4.1	2.4	3.9	20	12	1	13
Patuakhali	14	0.9	1.0	0.5	2.9	9	2	0	5
Average or total	36	18.5	14.1	12.5	29.3	19	8	2	12
All districts	86	100	98.8[d]	100	100	41	24	8	28

Sources: Based on data from World Bank, Bangladesh Food Policy Issues (Washington, D.C.: World Bank, 1979); Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983); Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, June 1984; and International Fertilizer Development Center, Second Evaluation of the Bangladesh New Marketing System (Muscle Shoals, Ala.: IFDC, 1980).

[a]This is the amount of fertilizer materials spread over total cropped area in 1981/82, the latest year for which the data for total cropped area are readily available.

[b]This is based on IFDC estimates of agronomic potential. See the text and footnotes to the text for details.

[c]This includes Jamalpur and Kishoreganj.

[d]Data by district are not available for 1.2 percent of total consumption.

Figure 8--Fertilizer consumption trends in various districts of Bangladesh

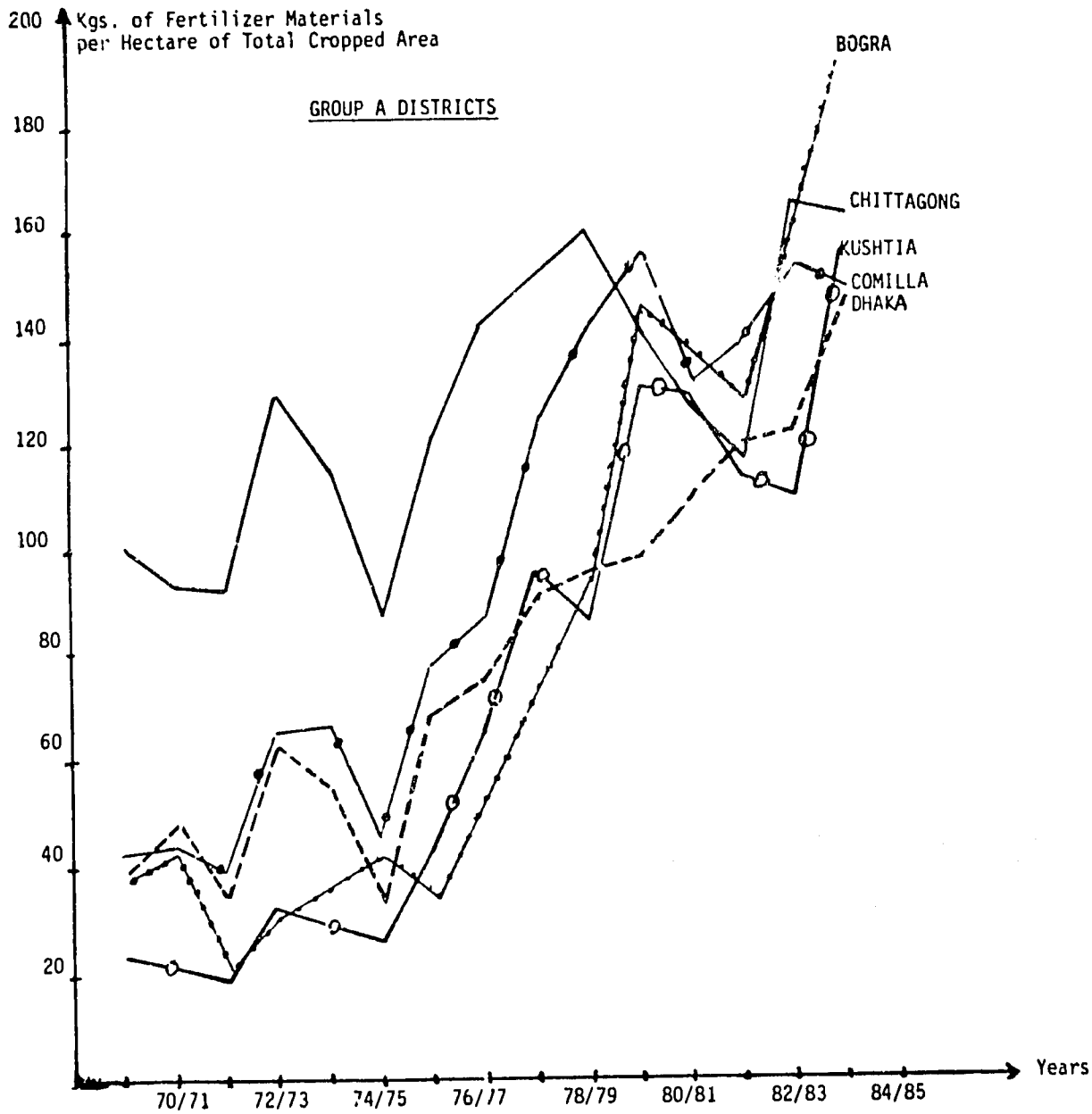
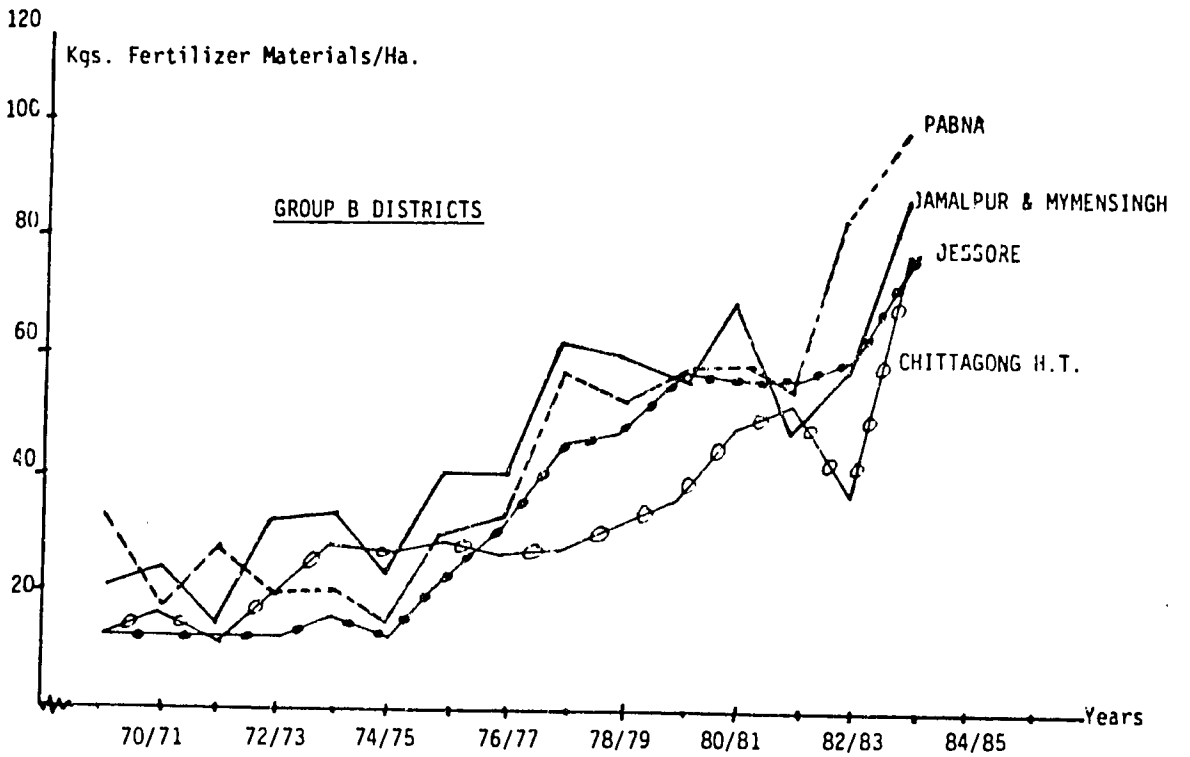


Figure 8--Continued



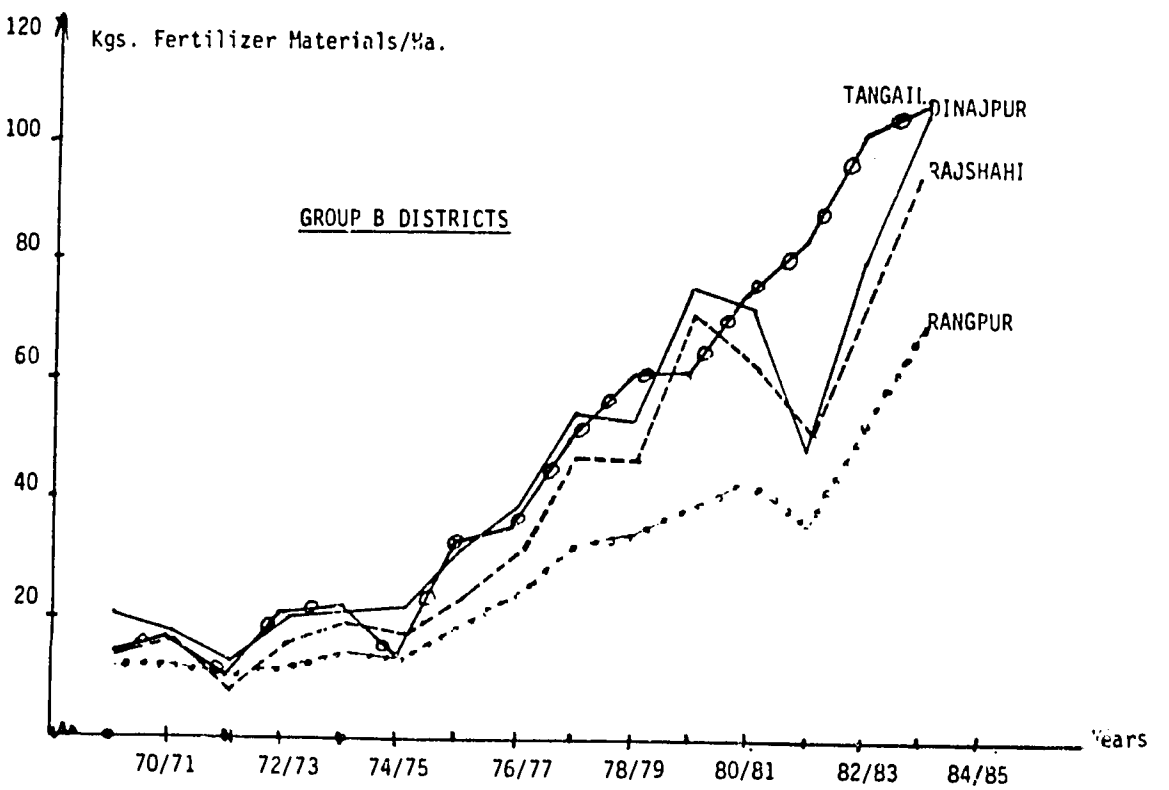
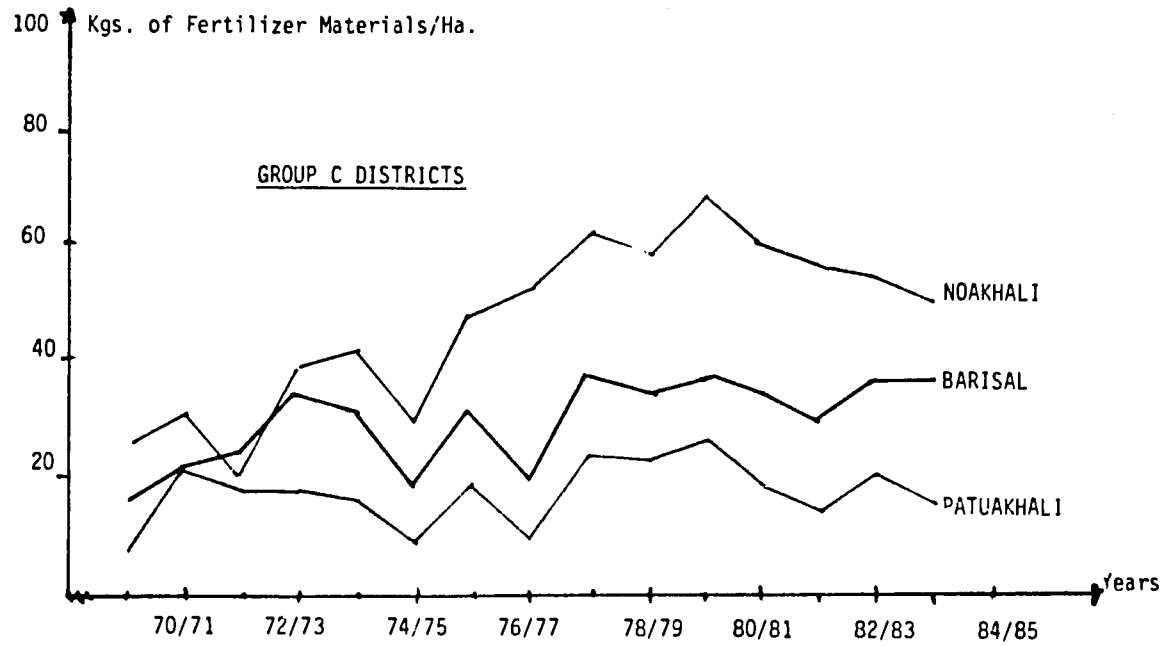
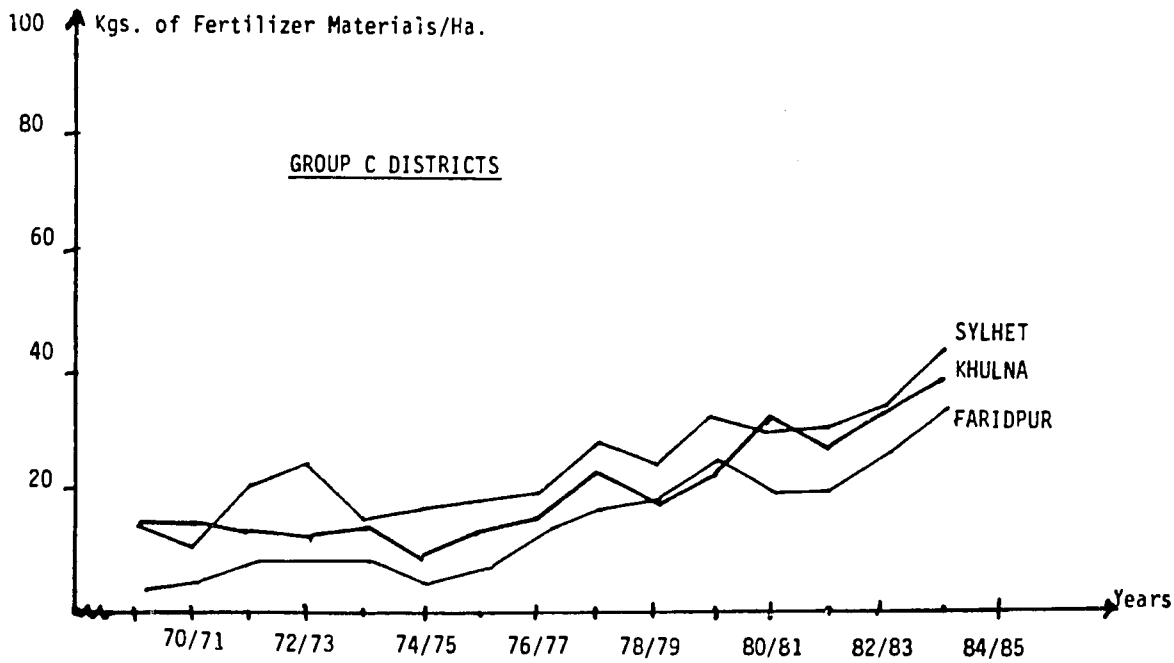


Figure 8--Continued





and 101 kilograms of materials. Group C had the lowest consumption per hectare--14 to 51 kilograms of fertilizer materials.

Thus, there was very wide variation in fertilizer consumption among the districts of Bangladesh. Two consequences of this variation were the geographical concentration of fertilizer use and the wide variation in the extent to which agronomic potential for fertilizer use was tapped in different districts.

The five Group A districts, with 22 percent of the country's total cropped area, had a 40 percent share of total fertilizer consumption in 1983/84. At the other extreme, the six Group C districts had only 13 percent of total fertilizer consumption, even though they accounted for 29 percent of the total cropped area. Only the Group B districts had shares of total fertilizer consumption (48 percent) and total cropped area (49 percent) that were comparable.

Between 1969/70 and 1983/84, the relative shares in total fertilizer consumption of both Group A and Group C declined--that of Group A by 8 percentage points and that of Group C by 6 percentage points. Concurrently, the share of Group B increased by 14 percentage points. Even in more recent years, this trend in the relative shares of the three groups of districts has continued. Thus, for instance, between 1978/79 and 1983/84, the shares of Group A and Group C fell, whereas that of Group B increased. Chittagong and Comilla in Group A and Noakhali and Barisal in Group C were mainly responsible for the decline in the shares of the two groups. In Group B, all districts except the Chittagong Hill Tracts had a higher share in 1983/84 than in 1969/70.

The decline in the relative shares of Chittagong and Comilla is understandable. Growth in fertilizer use gathered momentum in these districts earlier than in most other districts. Consequently, they accounted for as much as 28.4 percent of total fertilizer consumption despite encompassing only 10 percent of the total cropped area. When consumption growth in other districts accelerated, the relative shares of Chittagong and Comilla were bound to decline. More so because the pace of growth in their consumption slackened, once their consumption became relatively high and they used a high proportion of their agronomic potential. No such explanation applies to the decline in shares of Noakhali and Barisal (the two Group C districts), since their consumption in 1983/84 was only 11 to 13 percent of their agronomic potential.

There are now large differences between the three groups of districts in the extent to which they have realized their agronomic potential for fertilizer use. In 1983/84, total fertilizer consumption in Group A was approximated at 47 percent of its agronomic potential. Among the five districts, the proportions varied between 41 and 54 percent. For urea, it was 69 percent, ranging from 65 to 75 percent among the five districts. In contrast, total fertilizer

consumption in Group C was only 12 percent of its agronomic potential, and in none of the districts did the proportion exceed 13 percent. Even in the case of urea, consumption was less than 20 percent of the estimated potential for the group as a whole and did not surpass 22 percent in any district. Group B fell between Groups A and C with total consumption at 28 percent of the total potential and total urea consumption at 47 percent of the estimated potential for urea use. Within Group B, utilization of the total potential ranged from 17 to 36 percent and that of urea from 30 to 52 percent.

One could question the dependability of the above findings by arguing that they are based on district-wide sales data: since there have been no restrictions on movements between districts in recent years, these data may not accurately represent differences in the consumption of the districts. There may be some validity to this criticism, but its importance is limited. Fertilizer movements between districts were begun only after the phased introduction of the New Marketing System, commencing in 1978. As Table 11 demonstrates, the 1978/79 pattern of fertilizer use was similar to the one described above for 1983/84. Changes in the pattern of use between 1969/70 and 1978/79 also appear to have been similar to those implied by the changes between 1978/79 and 1983/84. Most importantly, trends in fertilizer consumption of districts throughout the 1969/70 to 1983/84 period (Figure 8) lend support to the findings in Table 11.

The major features of the 1969/70 to 1981/82 trends in fertilizer consumption of the districts can be summarized as follows. First, for the period as a whole, consumption in Groups A and B was rising far more rapidly than in Group C. In fact, in two out of the six districts of Group C (namely, Barisal and Patuakhali) it hardly grew at all after the early 1970s. Second, there was no growth or very slow growth in fertilizer use for a stretch of three to seven years after the mid-1970s in Chittagong and Comilla (Group A districts) and in Pabna, Jessore, and Mymensingh (including Jamalpur and Kishoreganj). Third, there was a clear downward turn in the consumption trends of Noakhali and Patuakhali (Group C districts) after 1979/80. Finally, trends in total fertilizer consumption growth for Bangladesh were dominated by the consumption trends in Group A districts until the late 1970s. Subsequently, however, national growth trends have been increasingly dominated by acceleration among many of the Group B districts.

These features of the geographical pattern of growth in Bangladesh's fertilizer consumption are not unique. The experiences of India, China, and even the United States have been fundamentally similar. This should not be surprising since fertilizer consumption does not begin and gather momentum at all locations within a country at the same time. The variations in this pattern are governed by a variety of factors--not all of which are behind fertilizer response functions (such as extent of irrigation, cropping patterns, and HYV diffusion).

Many other factors behind supply and distribution (such as fertilizer allocation policy, density of the distribution network, efficiency in the workings of the distribution system at different locations) plus physical infrastructure (road network and warehouse capacity, for example) are also significant. The relative importance of these factors behind the geographical patterns of growth in fertilizer consumption also differs between countries and even between locations within a country.

In order to develop meaningful policies for long-term development of the fertilizer sector in Bangladesh, it is imperative to take account of the above findings. Two points seem particularly important. First, efforts are required to generate momentum in the consumption trends of Group C districts. These districts account for about 32 percent of the country's cultivable area and 29 percent of total cropped area. IFDC estimated their share of the nation's total agronomic potential for fertilizer use to be nearly 30 percent. Only one-eighth of this potential was tapped by 1983/84. Of still greater significance, there is no sign of acceleration in the consumption trends of most of these districts. Even with urea, the most commonly used fertilizer, only 19 percent of the total potential of these districts was tapped by 1983/84. Clearly, long-term future growth in Bangladesh fertilizer consumption cannot be sustained while realization of such a large portion of the potential remains low and stagnant year after year.

It may appear that society's payoff on efforts to raise fertilizer use in these districts is generally lower than in Group A and Group B, because of lower potential in terms of crop responses to fertilizer use. Even if this were true, it is important to note that additional production from one unit of fertilizer use on unfertilized land in Group C may be higher than can be achieved by further raising the high rates of application on fertilized land in Group A. This is an empirical question and can be settled by examining appropriate data. Efforts required to generate momentum could take various directions, discussed in the next section.

The second point to recognize is that even in Groups A and B, where total fertilizer consumption has been increasing rapidly, the pace of growth has been much higher for nitrogen use than for phosphate use, and growth in the use of potash has been sluggish. Thus in some of these districts, where as much as 60 to 70 percent of the agronomic potential for nitrogen has been realized, the proportion of phosphate potential realized is considerably less, and that of potash is negligible. In these districts, further growth of even nitrogen use, especially if it were achieved by raising rates of application on fertilized land, would be dependent on accelerating the application of phosphates and potash.

This growth, in turn, may be more dependent on generating knowledge about the different nutrient requirements of specific

locations, and using this knowledge to convince farmers that higher returns can come from appropriate changes in fertilizer practices, rather than from price subsidies for phosphate and potash fertilizers.

If subsidies, by themselves, could accomplish this task, then fertilizer use in Chittagong would have a more balanced consumption pattern. In 1983/84, urea consumption in the district was 75 percent of its potential, while the proportion for TSP/DAP was only 20 percent, and the proportion for MP was just 6 percent.

POLICIES FOR LONG-TERM GROWTH IN FERTILIZER USE

Policies for long-term growth in fertilizer use should be based on a critical appreciation of the various features of, and the major forces behind, the past pace and pattern of growth in fertilizer consumption. This is especially important if these policies are to generate growth in fertilizer use that is sustained, rapid, and both profitable to farmers and manageable for the society at large.

Before turning to these policies, it may be useful to discuss the major strengths and problem areas in Bangladesh, which are revealed by the overview and the appropriate framework for policy discussions.

Major Strengths and Problem Areas

Both fertilizer consumption per unit of land and growth in aggregate consumption have been higher in Bangladesh than in a majority of the developing countries. Bangladesh's performance is impressive. In less than three decades fertilizer use has been adopted by nearly two-thirds of the nation's farmers (a large majority of whom are poor and operate very small farms), use has spread to about half of the gross cultivated area of the country (most of which is unirrigated), and fertilizer use on even local varieties of the dominant food crop is not uncommon. Few countries can claim such a record.

The above features are considered strengths because they indicate widespread understanding among farmers about the general benefits fertilizer use gives under farming circumstances typical of Bangladesh. Another cause for optimism is that this unusual record indicates the existence of operating processes and systems capable of achieving such fortuitous results.

Yet another positive feature is that much of the agronomic potential of fertilizer use remains untapped. (Even if one discounts by 50 percent the estimate of this potential formulated by IFDC, Bangladesh would have tapped only about half of the discounted potential.) This indicates that even without dramatic breakthroughs

in crop varieties or growth in irrigation, further growth in fertilizer consumption may be possible. Growth in fertilizer use during 1982/83 and also during 1984/85, which occurred despite adverse changes in the price environment, supports such a position.

At the same time, the bulk of past growth in fertilizer consumption resulted from tapping those parts of the total potential on which farmers' returns to fertilizer use were relatively high, because of superior or rapidly improving response functions. Similarly, the bulk of past growth has occurred in places where it was relatively easy to facilitate because the physical and institutional infrastructure relevant to growth in fertilizer use was more developed. While agronomic potential of such locations is by no means exhausted, further growth in consumption may not be as easy to achieve. High marginal returns to fertilizer use through increases in rates of application depend on increasing sophistication in fertilizer use--something which requires location-specific research and extension.

It is also clear from the district findings that sustained rapid growth in future fertilizer use also calls for generating momentum in the consumption trends of Group C districts. Policies required for this effort are apt to be quite different from those required to maintain the momentum of growth in consumption in Group A and Group B districts.

A Framework to Discuss Policy Requirements

Policy requirements for long-term rapid growth in Bangladesh fertilizer consumption can be discussed from two perspectives. One would be to view growth in fertilizer use as driven by growth in farmers' demand for fertilizer, and to consider the latter as being determined by changes in variables that affect farmers' returns on fertilizer use. This approach underlies many empirical studies in which factors governing growth in fertilizer consumption are identified by considering fertilizer consumption as a function of such agroeconomic variables as irrigation, area sown with fertilizer-responsive crop varieties, cropping patterns, and prices of crops as well as fertilizers. The estimated growth parameters of different explanatory variables are then used to draw policy conclusions.

In the context of sustained rapid growth in Bangladesh's fertilizer consumption, the above approach leads to such questions as: How much change is required every year in the variables shifting fertilizer response functions upward, or in the ratios of fertilizer to crop prices, to increase fertilizer consumption by the desired amount? Which policies will produce these changes? Are these policies sustainable?

This approach and the questions it suggests constrain the discussion of policies required to generate the desired rate of

growth in fertilizer consumption. This is mainly because the approach implies the growth in fertilizer use is determined by changes in the variables affecting fertilizer response functions and by changes in the prices of fertilizers and crops to the exclusion of all other dynamic elements. It is absurd to downplay the importance of these variables. But it is one thing to recognize their importance and another to maintain that under all circumstances changes in these variables are necessary to generate growth in fertilizer use. Both a priori reasoning and the experiences of many countries clearly suggest that such an interpretation of growth in fertilizer consumption is mechanistic and could lead to imprudent (if not altogether unrealistic) price policy prescriptions, if the possibilities for continuous upward shifts in response functions are limited.

Yet another limitation of this approach is that it does not explain many features of the past pace and pattern of fertilizer consumption growth in Bangladesh, nor does it provide a useful context for addressing the task of tapping the unrealized fertilizer potential through institutional development and policy formation.

A more comprehensive context for discussing policy requirements for long-term growth would involve recognition of the importance of both variables that affect the economic potential for fertilizer use, and those that affect realization of that potential. The economic potential for fertilizer use in a country is determined by fertilizer response functions, prices of crops, and costs of fertilizer: that is, the agroeconomic variables that determine profitability of fertilizer use. Actual fertilizer use is the combined result of the conversion of this potential into farmers' demand for fertilizer and of satisfaction of this demand by successful operation of fertilizer supply and distribution systems. Thus, besides agroeconomic variables, three types of processes and interactions among them influence actual fertilizer use. First are processes that convert the potential into farmers' fertilizer demand by generating knowledge about fertilizer response functions, spreading this knowledge among farmers, and providing adequate credit to enable them to purchase fertilizers. Second are processes that establish the fertilizer distribution system and govern its operation in making fertilizers available to farmers at geographically dispersed locations. Last are processes that determine the aggregate supply of fertilizers through domestic production and imports.

These three types of processes are governed by the workings of particular subsystems. These include agricultural research and extension, agricultural credit, fertilizer distribution, the domestic fertilizer industry, and fertilizer imports. In these terms, actual fertilizer consumption is determined not only by the agroeconomic variables, but also by the development and operation of all the above subsystems.

Even farmers' decisions about whether to use fertilizers, on which crops, and at what rates are influenced by both agroeconomic variables and the operation of agricultural research, extension, and credit systems. Rationality of farmers does not mean their omniscience. Even rational farmers need knowledge about how crops respond to fertilizer use--knowledge generated by the research system and delivered by the extension system. In addition, an adequate supply of credit is necessary to convert fertilizer response functions into farmers' effective demand schedules for fertilizers. Even this is not enough. Actual use of fertilizers would still depend on whether enough fertilizers are available to farmers at the right place and time--something which depends on the development and efficiency of the operation of the fertilizer distribution and supply systems.

This more comprehensive context appears appropriate to a discussion of the policy requirements of the long-term growth of Bangladesh fertilizer consumption. It does not focus exclusively either on variables like irrigation, HYVs, and the agroclimatic environment, which determine the responses of crops to fertilizer use, or on the prices of crops and fertilizers, which determine the economic potential for and the returns to fertilizer use. Nor does it bypass these variables and their influence on the pace and pattern of growth in fertilizer use. But it does identify processes and systems that convert the potential into farmers' effective demand for fertilizers, as well as those that meet this demand at geographically dispersed locations, thus converting fertilizer potential into actual fertilizer use. In this manner, the approach facilitates meaningful examination of all major elements that bear on sustained rapid growth in fertilizer use and on the healthy development of the entire fertilizer system.

Important Policy Issues and Suggestions

To use the above approach in an empirical analysis, it is necessary to examine the operation of all systems that affect the growth of fertilizer use and interactions between these subsystems, in order to identify deficiencies and work out policies to eliminate them. Such comprehensive research is not undertaken here. Thus, what follows is not a detailed prescription of policies. It is a set of policy issues and suggestions that seem to be relevant on the basis of an examination of readily available information and data.

For continuous growth in farmers' demand for fertilizers, it is just as important to focus on converting unrealized potential as on continuously raising the potential. In these efforts, agricultural research and extension systems are obviously the critical agencies. They need to be strengthened to undertake efforts in the directions discussed below.

In order to generate additional fertilizer demand through conversion of the unrealized potential, the first step would be to develop a profile of this potential (by crops, seasons, locations, agroclimatic conditions, and so forth) and examine its economic viability from farmers' viewpoints. Such an exercise is required in Group C and Group B districts for all three nutrients and in Group A districts for phosphates and potash. The data from fertilizer trials, experiments, and soil fertility investigations carried out so far may be adequate, at least for beginning this exercise. These data must be deliberately analyzed at disaggregated levels to identify when the responses of crops to different nutrients make the application of the nutrients profitable to farmers in various types of localities under existing and anticipated price environments.

From the accumulated agricultural research, critical aspects of fertilizer practices that influence responses of crops to fertilizers must be identified (aspects such as the details of timing and placement, complementarity between different nutrients and micronutrient and soil amendment needs). This knowledge should also be generated for disaggregated locations because of the highly varied agroclimatic environment of Bangladesh. It should then be used to develop location-specific action strategies to shift response functions upwards. The importance of developing such strategies cannot be overemphasized. This differs from concentrating exclusively on the introduction of new crop varieties. The importance of agronomic research for raising the productivity and efficiency of fertilizer use is enhanced, and not reduced, when HYVs are introduced, as the experience of the last 15 years clearly reveals. What is stressed here is that such agronomic research-based strategies might also improve the responses of existing varieties to fertilizer use, and thus do not make upward shifts in response functions dependent exclusively on the adoption of HYVs and water control development.

In a long-term perspective, however, there are no alternatives to shifting response functions upward through such technological changes as the development of new crop varieties and water control potential. Thus there cannot be two opinions about strengthening these efforts.

Location-specific strategies to maintain the momentum of growth in fertilizer consumption in Groups A and B and to accelerate growth in Group C need to be based on knowledge about the response function environment mentioned above. The other important plank of this strategy should be to deliver this knowledge to farmers in a sustained and effective manner. The most appropriate agency for this is the agricultural extension system. While other entities, like the fertilizer dealers, may be encouraged to help deliver such knowledge to farmers, they cannot effectively substitute for the extension system. If experience in other developing countries is any guide in Bangladesh, much remains to be done to improve the efficacy of the

extension system in providing adequate scientific knowledge to farmers about fertilizer practices. This requires a much closer and decentralized interface between agricultural research and extension systems--which is lacking in most developing countries, perhaps including Bangladesh. Development of this interface should proceed as rapidly as possible. Introduction of the Training and Visit System may have made a beginning in this direction, but whether the current manner of operation is adequately serving this objective needs to be examined.

Inadequate provision of institutional credit does not seem to have been a major constraint in the past growth of fertilizer consumption in Bangladesh. Perhaps this was because of high fertilizer subsidies and relatively low rates of application, both of which reduce the cash requirements of fertilizer use. In the future, growth of fertilizer demand will be more dependent on the flow of institutional credit to farmers for the following reasons: the rates of application on fertilized land (especially in Group A) are quite high; the fertilizer subsidy is being phased out; farmers who are not yet using fertilizer may have more severe liquidity constraints; and the initial returns to fertilizer use on land not yet fertilized are likely to be lower than on land already fertilized. Thus there seems to be a clear need to expand flows of institutional credit to farmers in order to sustain rapid growth in fertilizer demand. Efforts to do this, however, need to be coordinated with efforts to generate additional fertilizer demand. They also need to be coordinated with local fertilizer delivery systems. Without such coordination, the budgetary burden of fertilize subsidies would only be replaced by that of rural loan defaults.

The available information clearly shows that Bangladesh has one of the most widespread and dense networks of fertilizer distribution systems among developing countries. This remains so even if only "active" retailers and wholesalers are considered. Thus, for instance, Bangladesh has four to five times more fertilizer outlets than any Indian state of comparable size. Despite this, a variety of literature has indicated that the timely availability of fertilizers to many farmers has not ceased to be a problem. Although no comprehensive study has been made of this difficulty, discussions with a few dealers and PDP officials suggest that supplies are sometimes inadequate when dealers get fertilizers from BADC thana and district outlets. It appears that this, in turn, may be largely because dealers procure fertilizers as late as possible in order to minimize the cost of carrying inventories. Efforts are being made to remedy this deficiency of the distribution system through providing incentives to dealers to pick up fertilizers during off-seasons. However, the stocking behavior of wholesalers still appears to be minimal when national supplies are normal. The main plank of these efforts should be enlargement of fertilizer distribution credit to dealers. But even this may not suffice everywhere. Thus, there may be no alternative to BADC carrying larger inventories at locations close to the

retail level. It must, however, be recognized that by itself, this strategy will not generate a sustained acceleration of consumption. These efforts by BADC, therefore, must be coordinated with the efforts of the agricultural extension and credit systems to generate growth in fertilizer demand.

The monthly data on opening stocks, supplies, and sales for the seven-year period from 1977/78 to 1983/84 reveal hardly any association with those at the national level (Tables 12-14 and Figures 9 to 14). Thus it cannot be concluded that changes in aggregate demand were driving changes in aggregate supplies or that changes in aggregate supplies were driving changes in aggregate sales. The data also show that the ratios of total monthly availability (monthly opening stocks and monthly supplies) to monthly sales were generally high (Table 15). If, despite these high ratios, the timely availability of fertilizers to farmers in particular localities was still a problem, then much could still be done to improve the workings of the distribution system. Efforts in this direction are required not only to make enough fertilizer available to farmers at the right time and place, but also to lower fertilizer distribution costs and thus lower farmers' fertilizer prices.

Figures 9-14 and Tables 12-15 also show that the aggregate availability of fertilizers was comfortable in most years between 1977/78 and 1983/84. Aggregate growth in fertilizer sales during the period (based on 1977/78) averaged 7.8 percent per year, a respectable rate, but hardly rapid or adequate to Bangladesh's requirements. It is therefore pertinent to ask why sales growth was not more rapid, since it was constrained neither by aggregate supplies nor by the agronomic potential for fertilizer use. The answer cannot lie with the price environment or changes in that environment for two reasons. First, the environment was still quite favorable. As shown in Table 4, the cost of a kilogram of nitrogen was still less than 1.5 kilograms of rice (the cost of a kilogram of urea was less than 1.1 kilograms of paddy). Second, and more important, fertilizer use grew substantially between 1977/78 and 1983/84 despite, on balance, adverse changes in the price environment (Figure 15). Thus, the explanation for the absence of still faster growth of actual fertilizer consumption, despite comfortable aggregate fertilizer availability and sizable untapped potential, seems to lie in a lack of well-coordinated efforts by agricultural research, extension, and credit systems to convert the potential into farmers' demand and by the fertilizer distribution system to meet this demand at geographically dispersed locations. It is important to be aware of these areas of implied deficiencies when formulating future policies. The enlargement of aggregate fertilizer supply is a necessary but not a sufficient condition for generating sustainable rapid growth in fertilizer consumption. It has to be supplemented by well-coordinated demand-creation activities of the nature described above and by continuous improvements in the operations of the fertilizer distribution system.

Table 12--Monthly opening stocks, current supply, availability, sales and closing stocks of urea in Bangladesh, 1977/78 - 1983/84

Year/ Month	Opening Stocks	Current Supply	Total Avail-ability	Sales	Closing Stocks	Share of Sales in Total Avail-ability	Share of Opening Stocks in Total Avail-ability
	(1,000 long tons of fertilizer materials)					(percent)	
1977/78							
July	65	31	96	20	76	20.8	67.7
August	76	50	126	35	91	27.8	60.3
September	91	25	116	55	61	47.4	78.4
October	61	26	87	33	54	37.9	70.1
November	54	12	66	25	41	37.9	81.8
December	41	62	103	37	66	35.9	39.8
January	66	49	115	41	74	35.7	57.4
February	74	84	158	48	110	30.4	46.8
March	110	71	181	52	129	28.7	61.1
April	129	39	168	34	134	20.2	76.8
May	134	20	154	41	113	26.6	87.0
June	113	13	126	58	68	46.0	89.7
1978/79							
July	68	16	84	23	61	27.4	81.0
August	61	46	107	25	82	23.4	57.0
September	82	68	150	60	90	40.0	54.7
October	90	46	136	52	84	38.2	66.2
November	84	56	140	41	99	29.3	60.0
December	99	77	176	44	132	25.0	56.3
January	132	74	206	39	167	18.9	63.2
February	167	57	224	43	181	19.2	74.6
March	181	53	234	48	186	20.5	77.4
April	186	44	230	26	204	11.3	80.9
May	204	29	233	26	207	11.2	87.6
June	207	51	258	42	216	16.3	80.2

(continued)

Table 12--Continued

Year/ Month	Opening Stocks	Current Supply	Total Avail-ability	Sales	Closing Stocks	Share of Sales in Total Avail-ability	Share of Opening Stocks in Total Avail-ability
	(1,000 long tons of fertilizer materials)					(percent)	
1979/80							
July	216	17	233	28	205	12.0	92.7
August	205	33	238	25	213	10.5	86.1
September	213	42	255	57	198	22.4	83.5
October	198	46	244	48	196	19.7	81.1
November	196	62	258	39	219	15.1	76.0
December	219	94	313	38	275	12.1	70.0
January	275	76	351	58	293	16.5	78.3
February	293	92	385	62	323	16.1	76.1
March	323	35	358	55	303	15.3	90.2
April	303	30	333	25	308	7.5	91.0
May	308	27	335	37	298	11.0	91.9
June	298	31	329	64	265	19.5	90.6
1980/81							
July	265	31	296	23	273	7.8	89.5
August	273	37	310	33	277	10.6	88.1
September	277	47	324	78	246	24.1	85.5
October	246	14	260	34	226	13.1	94.6
November	226	14	240	36	204	15.0	94.2
December	204	23	227	53	174	23.3	89.9
January	174	28	202	59	143	29.2	86.1
February	143	37	180	54	126	30.0	79.4
March	126	51	177	60	117	33.9	71.2
April	117	43	160	28	132	17.5	73.1
May	132	47	179	49	130	27.4	73.7
June	130	33	163	63	100	38.7	79.8

(continued)

Table 12--Continued

Year/ Month	Opening Stocks	Current Supply	Total Avail-ability	Sales	Closing Stocks	Share of Sales in Total Avail-ability	Share of Opening Stocks in Total Avail-ability
	(1,000 long tons of fertilizer materials)					(percent)	
1981/82							
July	100	32	132	20	112	15.2	75.8
August	112	32	144	26	118	18.1	77.8
September	118	9	127	74	53	58.3	92.9
October	53	28	81	43	38	53.1	65.4
November	38	24	62	40	22	64.5	61.3
December	22	92	114	33	81	28.9	19.3
January	81	103	184	44	140	23.9	44.0
February	140	74	214	61	153	28.5	65.4
March	153	134	287	67	220	23.3	53.3
April	220	54	274	31	243	11.3	80.3
May	243	49	292	31	261	10.6	83.2
June	261	37	298	49	249	16.4	87.6
1982/83							
July	249	24	273	17	256	6.2	91.2
August	256	23	279	28	251	10.0	91.8
September	251	32	283	79	204	27.9	88.7
October	204	78	282	41	241	14.5	72.3
November	241	39	280	41	239	14.6	86.1
December	239	20	259	47	212	18.1	92.3
January	212	29	241	44	197	18.3	88.0
February	197	39	236	71	165	30.1	83.5
March	165	32	197	96	101	48.7	83.5
April	101	26	127	33	94	26.0	79.5
May	94	57	151	54	97	35.8	62.3
June	97	63	160	67	93	41.9	60.6

(continued)

Table 12--Continued

Year/ Month	Opening Stocks	Current Supply	Total Avail-ability	Sales	Closing Stocks	Share of Sales in Total Avail-ability	Share of Opening Stocks in Total Avail-ability
	(1,000 long tons of fertilizer materials)					(percent)	
1983/84							
July	89	43	132	13	119	9.8	67.4
August	119	85	204	36	168	17.6	58.4
September	168	49	217	94	123	43.3	77.4
October	123	69	192	37	155	19.3	64.1
November	155	61	216	47	169	21.8	71.8
December	169	58	227	71	156	31.3	74.4
January	156	60	216	50	166	23.1	72.2
February	166	62	228	81	147	35.5	72.8
March	147	54	201	107	94	53.2	73.1
April	94	59	153	57	96	37.3	61.4
May	96	69	165	41	124	24.8	58.2
June	124	54	178	63	115	35.4	69.7

Source: Data developed from Bangladesh Ministry of Agriculture and U.S. Agency for International Development, Joint Bangladesh and U.S. Government Evaluation of the Fertilizer Distribution Improvement Project, USAID Report 388-0024 (Dhaka: November 1982); and Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, June 1983 and June 1984, issued August 7, 1983 and August 8, 1984, respectively.

Table 13--Monthly opening stocks, current supply, availability, sales, and closing stocks of triple superphosphate (TSP) in Bangladesh, 1977/78 - 1983/84

Year/ Month	Opening Stocks	Current Supply	Total Availability	Sales	Closing Stocks	Share of Sales in Total Availability	Share of Opening Stocks in Total Availability
	(1,000 long tons of fertilizer materials)					(percent)	
1977/78							
July	114	15	129	11	118	8.5	88.4
August	118	0	118	18	100	15.3	100.0
September	100	0	100	9	91	9.0	100.0
October	91	0	93	16	77	17.2	100.0
November	77	7	84	23	61	27.4	91.7
December	61	14	75	26	49	34.7	81.3
January	49	4	53	18	35	34.0	92.5
February	35	5	40	16	24	40.0	87.5
March	24	43	67	12	55	17.9	35.8
April	55	40	95	18	77	18.9	57.9
May	77	18	95	14	81	14.7	81.1
June	81	4	85	12	73	14.1	95.3
1978/79							
July	73	20	93	11	82	11.8	78.5
August	82	7	89	18	71	20.2	92.5
September	71	12	83	15	68	18.1	85.5
October	68	14	82	30	52	36.6	82.9
November	52	4	56	30	26	53.6	92.9
December	26	62	88	22	66	25.0	29.5
January	66	29	95	16	79	16.8	69.5
February	79	34	113	17	96	15.0	69.9
March	96	15	111	18	93	16.2	86.5
April	93	26	119	17	102	14.3	78.2
May	102	13	115	10	105	8.7	88.7
June	105	7	112	8	104	7.1	93.8

(continued)

Table 13--Continued

Year/ Month	Opening Stocks	Current Supply	Total Avail-ability	Sales	Closing Stocks	Share of Sales in Total Avail-ability	Share of Opening Stocks in Total Avail-ability
	(1,000 long tons of fertilizer materials)					(percent)	
1979/80							
July	104	7	111	14	97	12.6	93.7
August	97	3	100	19	81	19.0	97.0
September	81	34	115	13	102	11.3	70.4
October	102	47	149	27	122	18.1	68.5
November	122	9	131	41	90	31.3	93.1
December	90	16	106	29	77	27.4	84.9
January	77	18	95	28	67	29.5	81.1
February	67	64	131	20	111	15.3	51.1
March	111	31	142	14	128	9.9	78.2
April	128	22	150	16	134	10.7	85.3
May	134	15	149	14	135	9.4	89.9
June	135	3	138	12	126	8.7	97.8
1980/81							
July	126	7	133	18	115	13.5	94.7
August	115	48	163	20	143	12.3	70.6
September	143	34	177	12	165	6.8	80.8
October	165	18	183	28	155	15.3	90.2
November	155	13	168	41	127	32.3	92.3
December	127	10	137	36	101	26.3	92.7
January	101	22	123	23	100	18.7	82.1
February	100	13	113	22	91	19.5	88.5
March	91	47	138	13	125	9.4	65.9
April	125	38	163	21	142	12.9	76.7
May	142	11	153	13	140	8.5	92.8
June	140	40	180	8	172	4.4	77.8

(continued)

Table 13--Continued

Year/ Month	Opening Stocks	Current Supply	Total Avail-ability	Sales	Closing Stocks	Share of Sales in Total Avail-ability	Share of Opening Stocks in Total Avail-ability
	(1,000 long tons of fertilizer materials)					(percent)	
1981/82							
July	172	27	146	15	131	10.3	81.5
August	131	7	138	18	120	13.0	94.9
September	120	5	125	12	113	9.6	96.0
October	113	10	123	45	78	36.6	91.9
November	78	7	85	34	51	40.0	91.8
December	51	21	72	18	54	25.0	70.8
January	54	35	89	17	72	19.1	60.7
February	72	19	91	14	77	15.4	79.1
March	77	38	115	9	106	7.8	67.0
April	106	19	125	13	112	10.4	84.8
May	112	5	117	6	111	5.1	95.7
June	111	17	128	8	120	6.3	86.7
1982/83							
July	120	1	121	7	114	5.8	99.2
August	114	4	118	8	110	6.8	96.6
September	110	8	118	6	112	5.1	93.2
October	112	12	124	24	100	19.4	90.3
November	100	10	110	37	73	33.6	90.9
December	73	44	117	28	89	23.9	62.4
January	89	93	182	23	159	12.6	48.9
February	159	14	173	26	147	15.0	91.9
March	147	2	149	12	137	8.1	98.7
April	137	1	138	11	127	8.0	99.3
May	127	5	132	10	122	7.6	96.2
June	122	6	128	13	115	10.2	95.3

(continued)

Table 13--Continued

Year/ Month	Opening Stocks	Current Supply	Total Availability	Sales	Closing Stocks	Share of Sales in Total Availability	Share of Opening Stocks in Total Availability
	(1,000 long tons of fertilizer materials)					(percent)	
1983/84							
July	118	24	142	7	135	4.9	83.1
August	135	3	138	13	125	9.4	97.8
September	125	22	147	7	140	4.8	85.0
October	140	13	153	22	131	14.4	91.5
November	131	5	136	50	86	36.8	96.3
December	86	25	111	33	78	29.7	77.5
January	78	38	116	27	89	23.3	67.2
February	89	33	122	34	88	27.9	73.0
March	88	6	94	13	81	13.8	93.6
April	81	7	88	17	71	19.3	92.0
May	71	7	78	16	62	20.5	91.0
June	62	13	75	19	56	25.3	82.7

Sources: Data developed from Bangladesh Ministry of Agriculture and U.S. Agency for International Development, Joint Bangladesh and U.S. Government Evaluation of the Fertilizer Distribution Improvement Project, USAID Report 388-0024 (Dhaka: USAID, November 1982); and Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, June 1983 and June 1984, issued August 7, 1983 and August 8, 1984, respectively.

Table 14--Monthly opening stocks, current supply, availability, sales, and closing stocks of muriate of potash (MP) in Bangladesh, 1977/78 - 1983/84

Year/ Month	Opening Stocks	Current Supply	Total Avail- ability	Sales	Closing Stocks	Share of Sales in Total Avail- ability	Share of Opening Stocks Total Avail- ability
	(1,000 long tons of fertilizer materials)					(percent)	
1977/78							
July	18	0	18	2	16	11.1	100.0
August	16	10	26	4	22	15.4	61.5
September	22	0	22	2	20	9.1	100.0
October	20	0	20	3	17	15.0	100.0
November	17	0	17	4	13	23.5	100.0
December	13	0	13	5	8	38.5	100.0
January	8	10	18	4	14	22.2	80.0
February	14	9	23	4	19	17.4	60.9
March	19	8	27	4	23	14.8	70.4
April	23	0	23	4	19	17.4	100.0
May	19	1	20	3	17	15.0	95.0
June	17	1	16	2	14	12.5	94.4
1978/79							
July	14	0	14	2	12	14.3	100.0
August	12	5	17	3	14	17.6	70.6
September	14	7	21	2	19	9.5	66.6
October	19	20	39	6	33	15.4	48.7
November	33	1	34	7	27	20.6	97.1
December	27	10	37	6	31	16.2	73.0
January	31	15	46	3	43	6.5	67.4
February	43	1	42	3	39	7.1	97.7
March	39	6	43	6	37	14.0	90.7
April	37	6	43	5	38	11.6	86.0
May	38	0	38	2	36	5.3	100.0
June	36	6	44	1	43	2.3	81.8

(continued)

Table 14--Continued

Year/ Month	Opening Stocks	Current Supply	Total Avail-ability	Sales	Closing Stocks	Share of Sales in Total Avail-ability	Share of Opening Stocks Total Avail-ability
	(1,000 long tons of fertilizer materials)					(percent)	
1979/80							
July	43	18	61	2	59	3.3	70.5
August	59	13	72	3	69	4.2	81.9
September	69	0	69	2	67	2.9	100.0
October	67	0	67	4	63	6.0	100.0
November	63	0	63	7	56	11.1	100.0
December	56	13	69	6	63	8.7	81.2
January	63	0	63	5	58	7.9	100.0
February	58	0	58	5	53	8.6	100.0
March	53	0	53	3	50	5.7	100.0
April	50	0	50	4	46	8.0	100.0
May	46	8	54	3	51	5.6	85.2
June	51	7	58	2	56	3.4	87.9
1980/81							
July	56	0	56	2	54	3.6	100.0
August	54	0	54	4	50	7.4	100.0
September	50	0	50	2	48	4.0	100.0
October	48	8	56	4	52	7.1	85.7
November	52	0	52	7	45	13.5	100.0
December	45	7	52	7	45	13.5	86.5
January	45	0	45	4	41	8.9	100.0
February	41	6	47	4	43	8.5	87.2
March	43	14	57	3	54	5.3	75.4
April	54	0	54	4	50	7.4	100.0
May	50	0	50	3	47	6.0	100.0
June	47	7	54	1	53	1.9	87.0

(continued)

Table 14--Continued

Year/ Month	Opening Stocks	Current Supply	Total Avail- ability	Sales	Closing Stocks	Share of Sales in Total Avail- ability	Share of Opening Stocks Total Avail- ability
	(1,000 long tons of fertilizer materials)					(percent)	
1981/82							
July	53	1	54	2	52	3.7	98.1
August	52	0	52	3	49	5.8	100.0
September	49	0	49	2	47	4.1	100.0
October	47	0	47	8	39	17.0	100.0
November	39	0	39	8	31	20.5	100.0
December	31	0	31	5	26	16.1	100.0
January	26	0	26	4	22	15.4	100.0
February	22	5	27	4	23	14.8	81.5
March	23	13	36	2	34	5.6	63.9
April	34	0	34	3	31	8.8	100.0
May	31	8	39	2	37	5.1	79.5
June	37	0	37	2	35	5.4	100.0
1982/83							
July	35	0	35	2	33	5.7	100.0
August	33	0	33	2	31	6.1	100.0
September	31	0	31	1	30	3.2	100.0
October	30	0	30	5	25	16.7	100.0
November	25	5	30	8	22	26.7	83.3
December	22	7	29	6	23	20.7	75.9
January	23	4	27	6	21	22.2	85.2
February	21	8	29	7	22	24.1	72.4
March	22	8	30	3	27	10.0	73.3
April	27	12	39	4	35	10.3	69.2
May	35	0	35	3	32	8.6	100.0
June	32	0	32	3	31	9.4	100.0

(continued)

Table 14--Continued

Year/ Month	Opening Stocks	Current Supply	Total Availability	Sales	Closing Stocks	Share of Sales in Total Availability	Share of Opening Stocks Total Availability
	(1,000 long tons of fertilizer materials)					(percent)	
1983/84							
July	29	0	29	1	28	3.4	100.0
August	28	0	28	3	25	10.7	100.0
September	25	5	30	1	29	3.3	83.3
October	29	19	48	4	44	8.3	60.4
November	44	15	59	11	48	18.6	74.6
December	48	0	48	8	40	16.7	100.0
January	40	10	50	6	44	12.0	80.0
February	44	0	44	10	34	22.7	100.0
March	34	0	34	5	29	14.7	100.0
April	29	1	30	6	24	20.0	96.7
May	24	9	33	4	29	12.1	72.7
June	29	30	4	4	24	13.3	96.7

Sources: Data developed from Bangladesh Ministry of Agriculture and U.S. Agency for International Development, Joint Bangladesh and U.S. Government Evaluation of the Fertilizer Distribution Improvement Project, USAID Report 388-0024 (Dhaka: USAID, 1982); and Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, June 1983 and June 1984, issued August 7, 1983 and August 8, 1984, respectively.

Figure 9--Opening stocks, current supply, total availability, and sales of urea in Bangladesh from 1977/78 to 1983/84

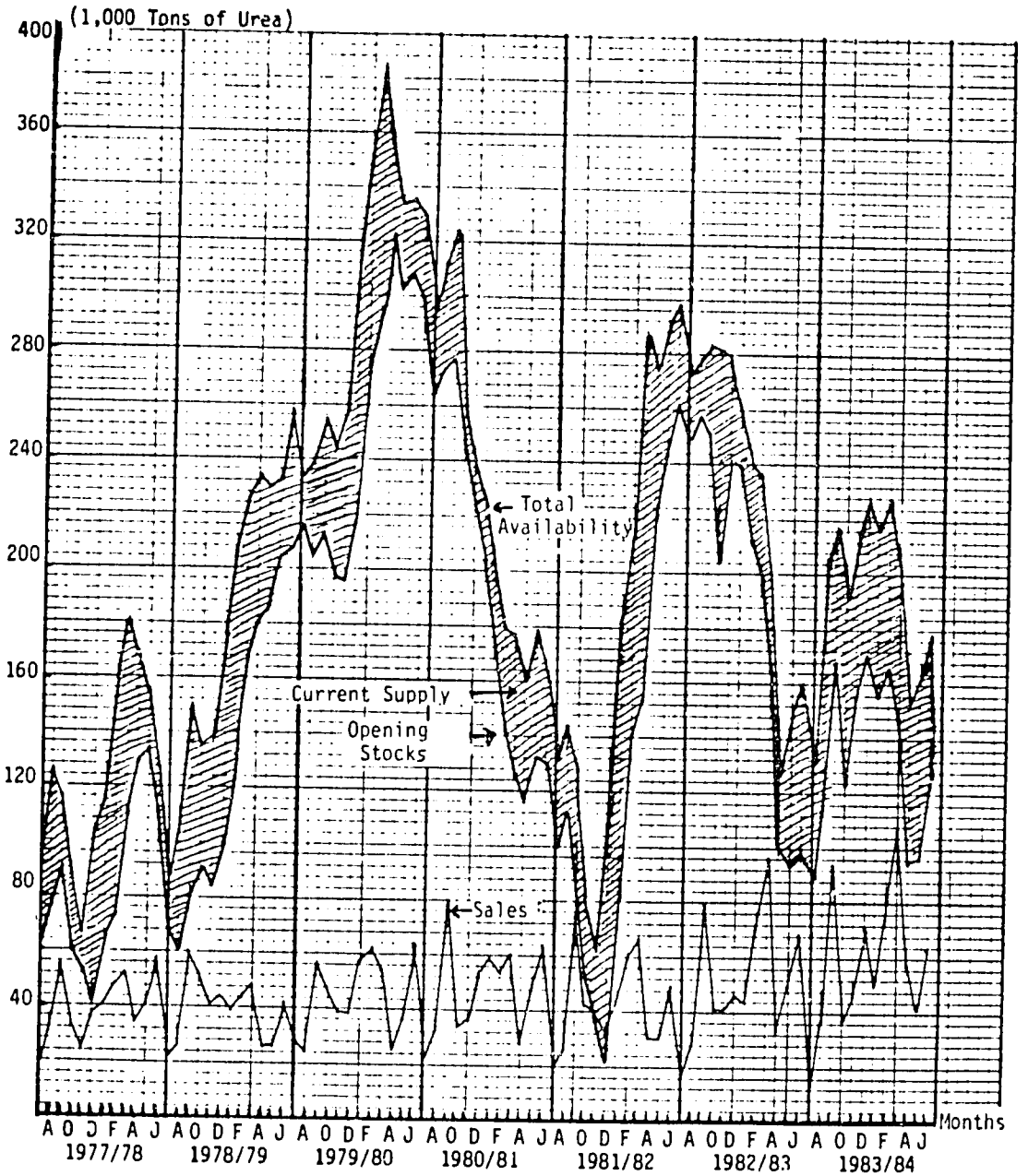


Figure 10--Opening stocks, current supply, total availability, and sales of triple superphosphate (TSP) in Bangladesh from 1977/78 to 1983/84

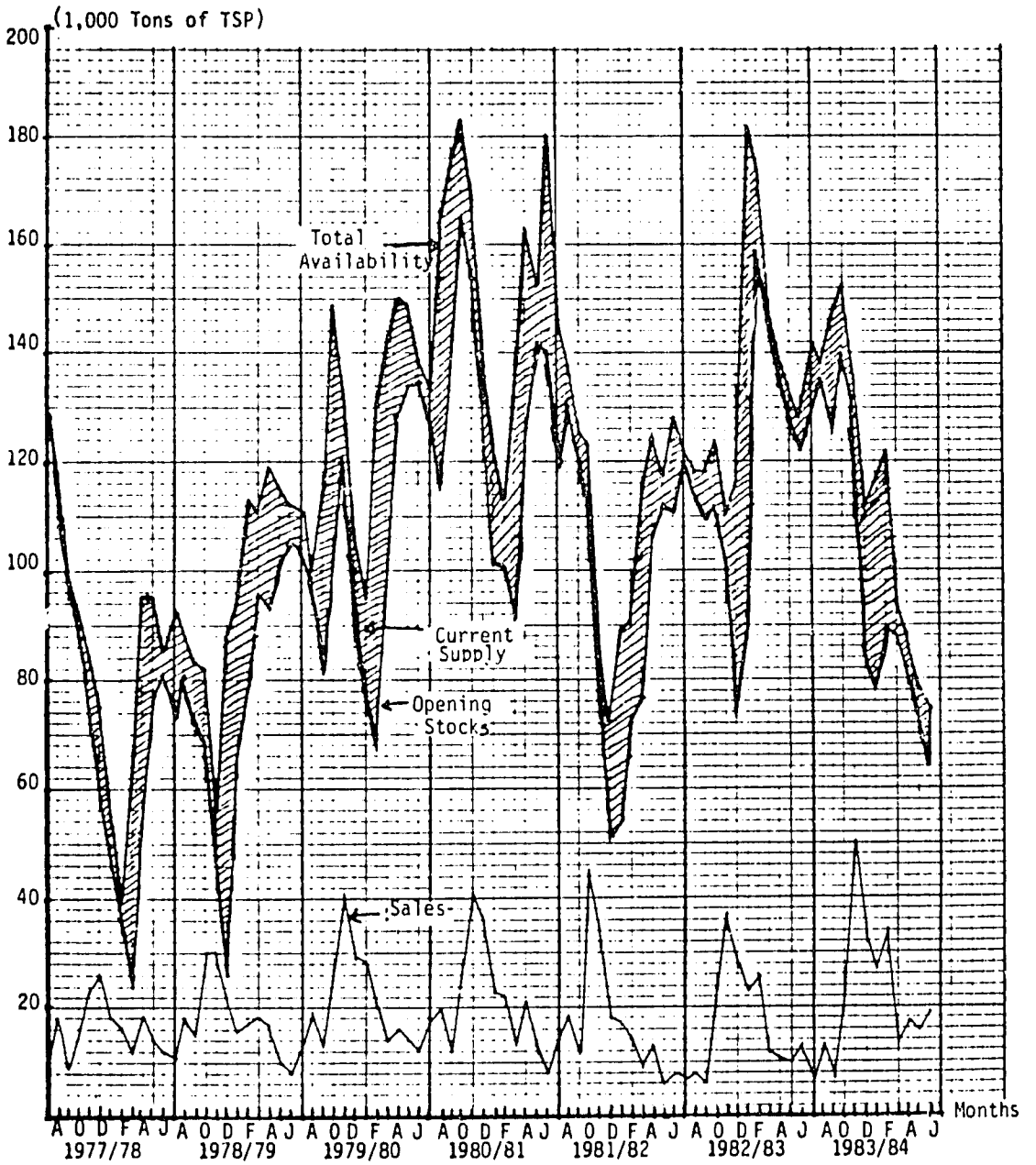


Figure 11--Opening stocks, current supply, total availability, and sales of muriate of potash (MP) in Bangladesh from 1977/78 to 1983/84

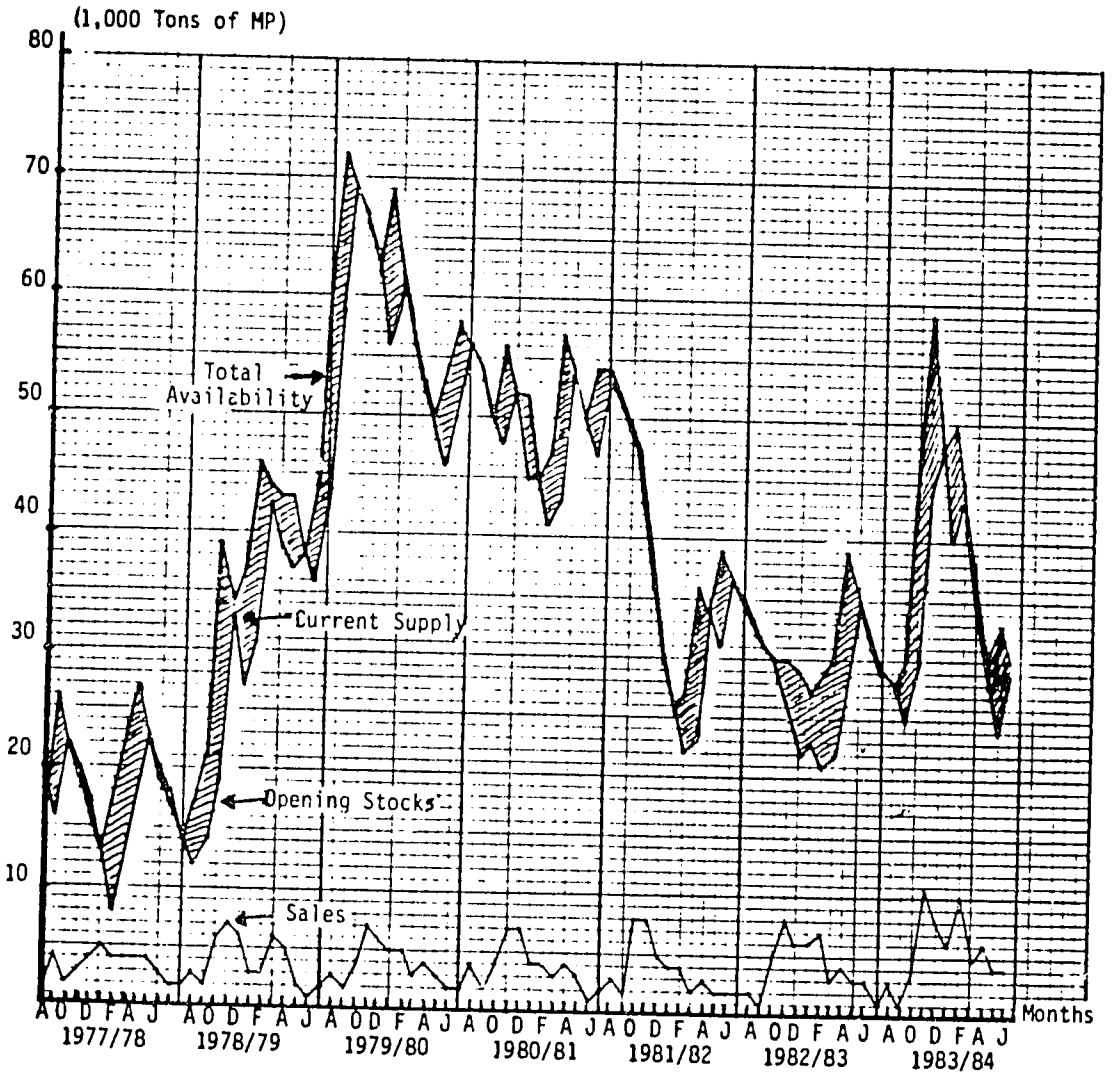
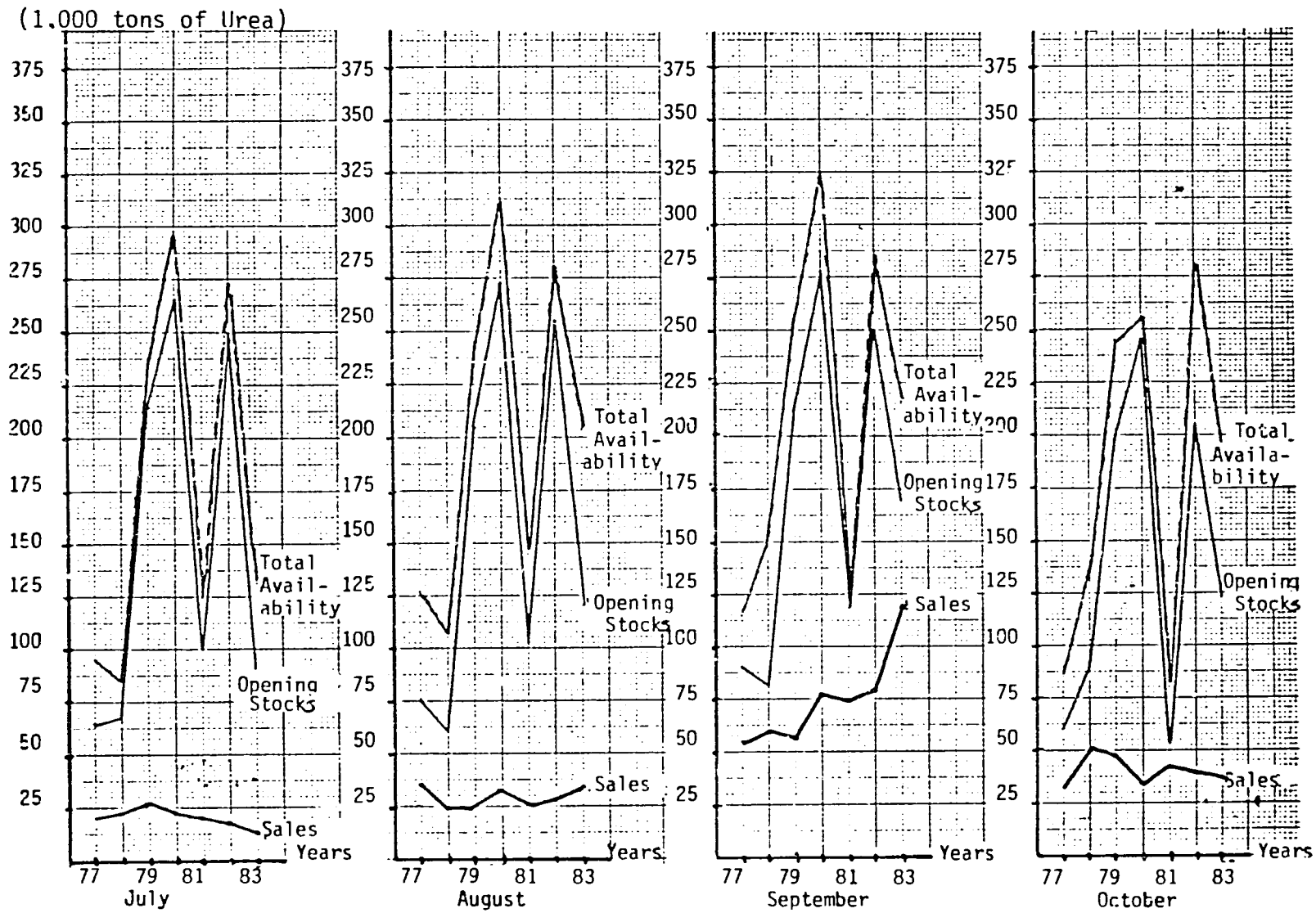


Figure 12--Monthly opening stocks, current supply, total availability, and sales of urea in Bangladesh, July 1977 to June 1984



Note: Current supply (stock replenishment) equals the vertical distance between total availability and opening stocks.

Figure 12--Continued

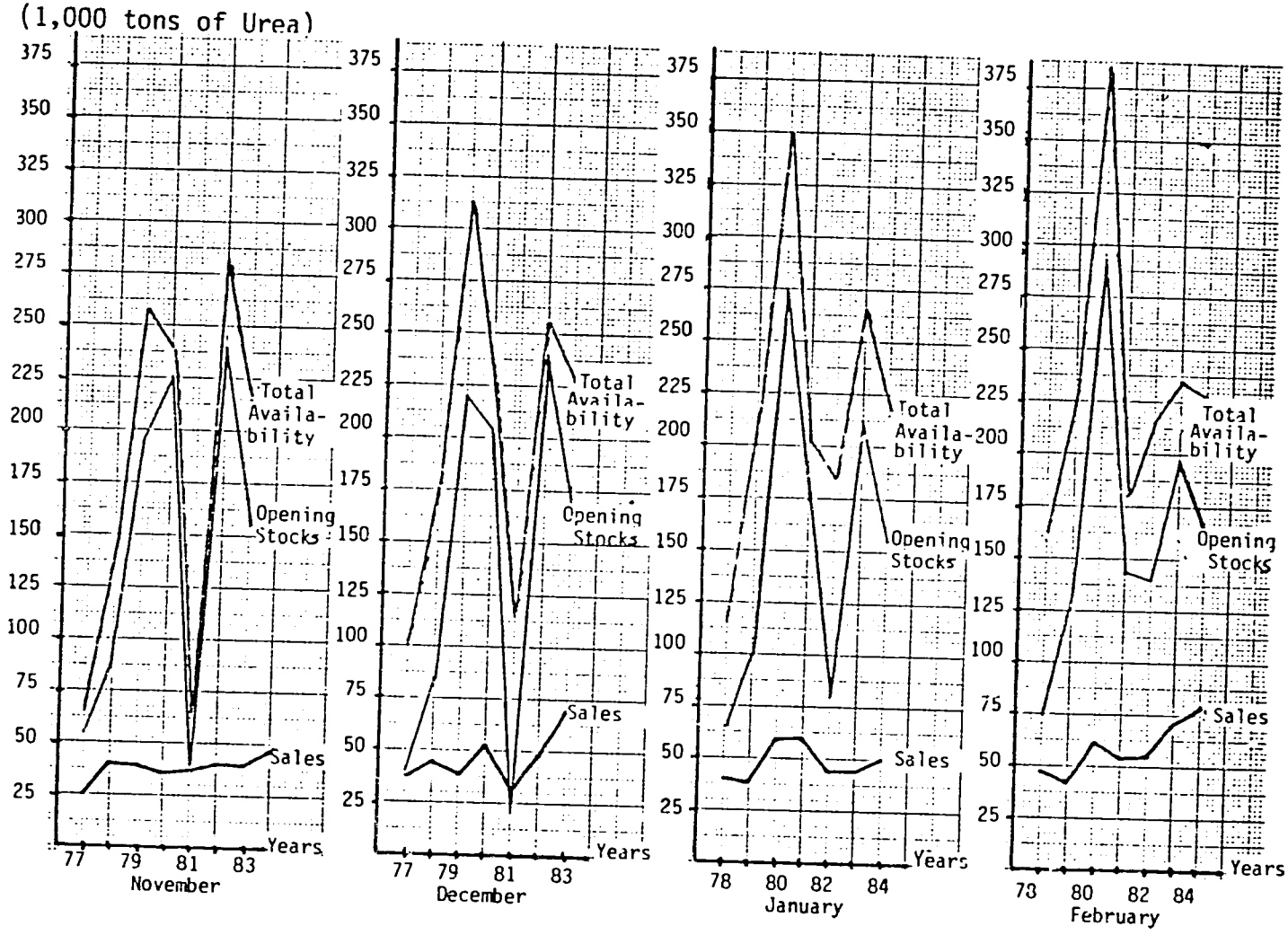


Figure 12--Continued

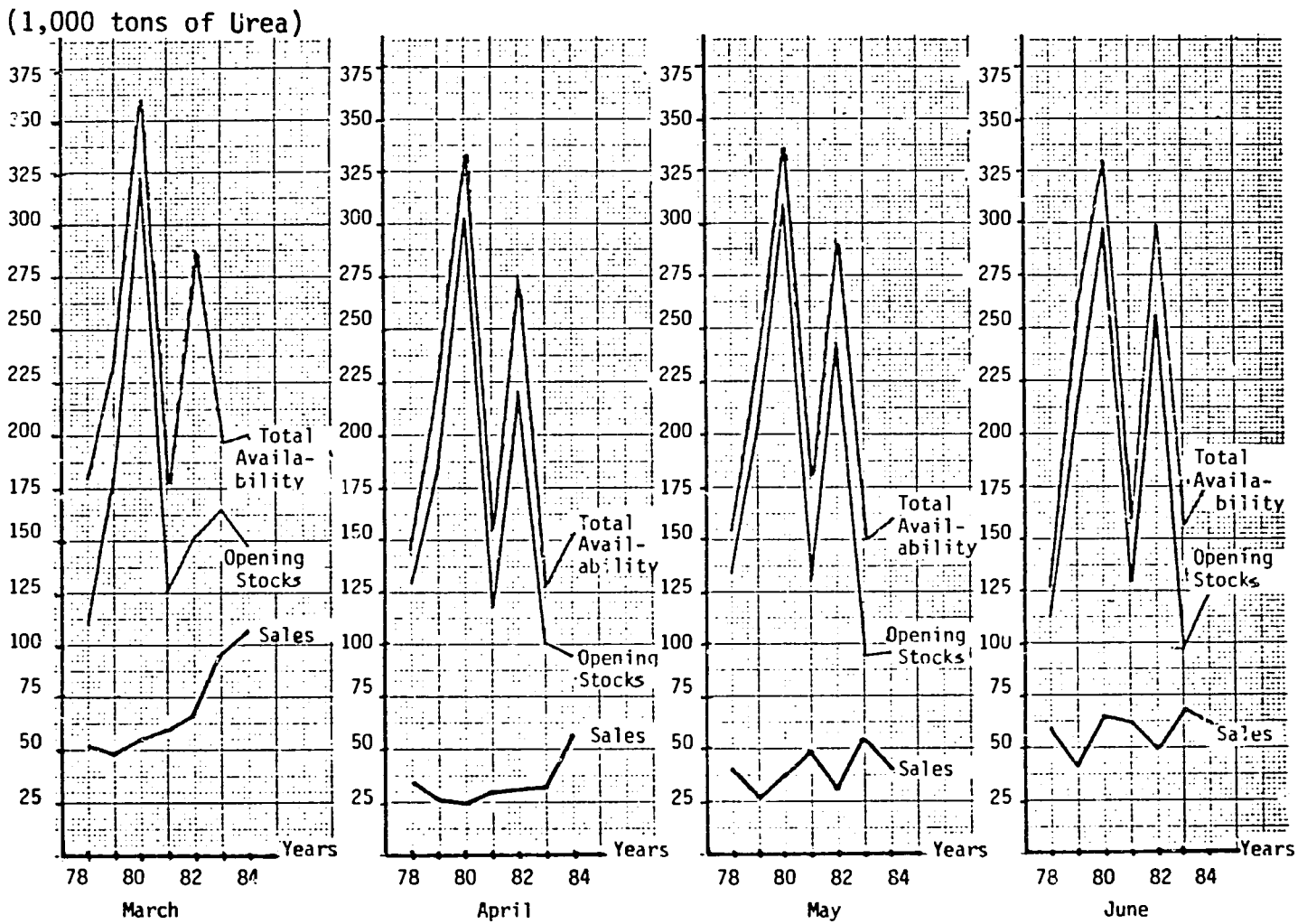
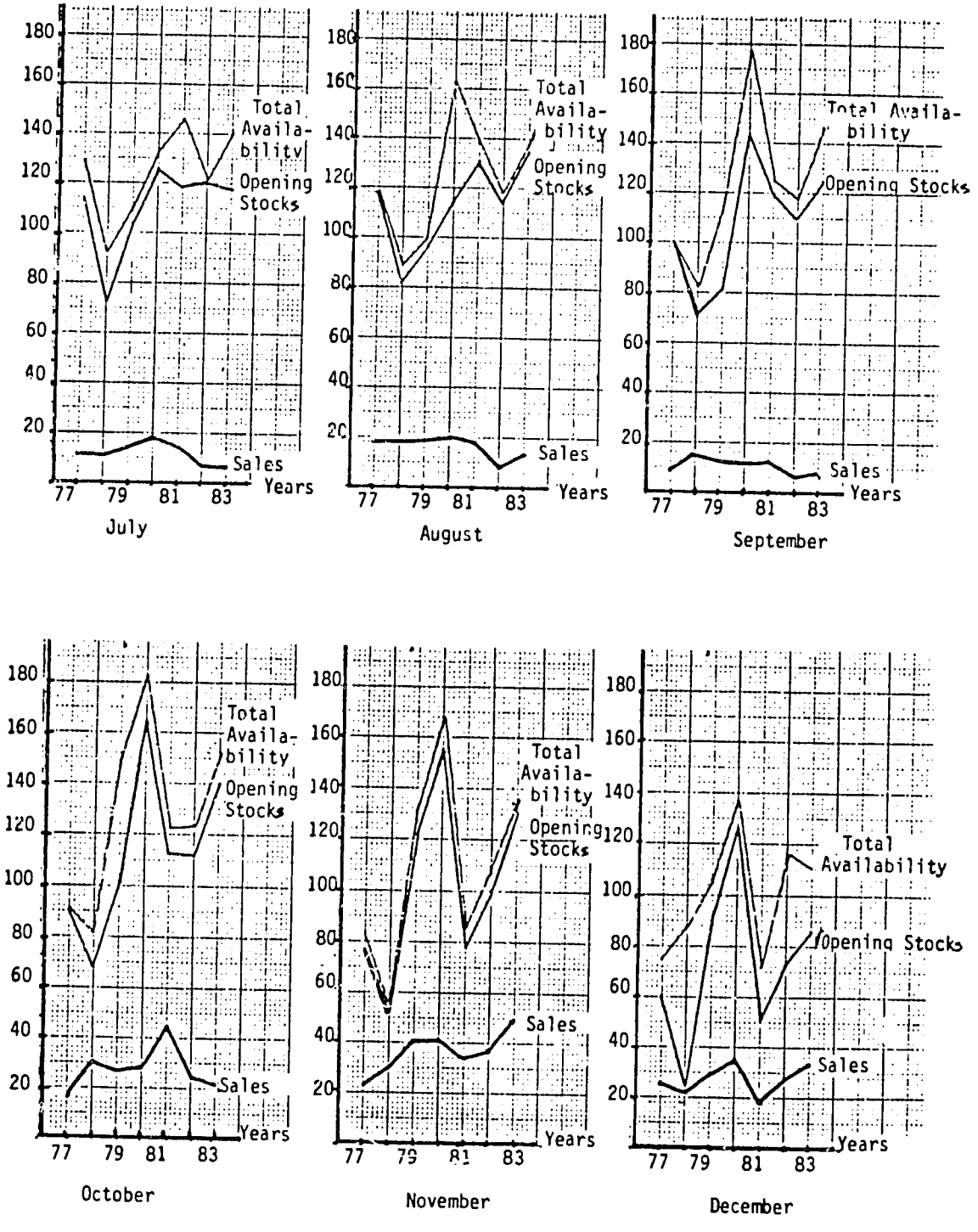


Figure 13--Monthly opening stocks, current supply, total availability, and sales of triple superphosphate (TSP) in Bangladesh, July 1977 to June 1984

(1,000 tons of TSP)



Note: Current supply (stock replenishment) equals the vertical distance between total availability and opening stocks.

Figure 13--Continued

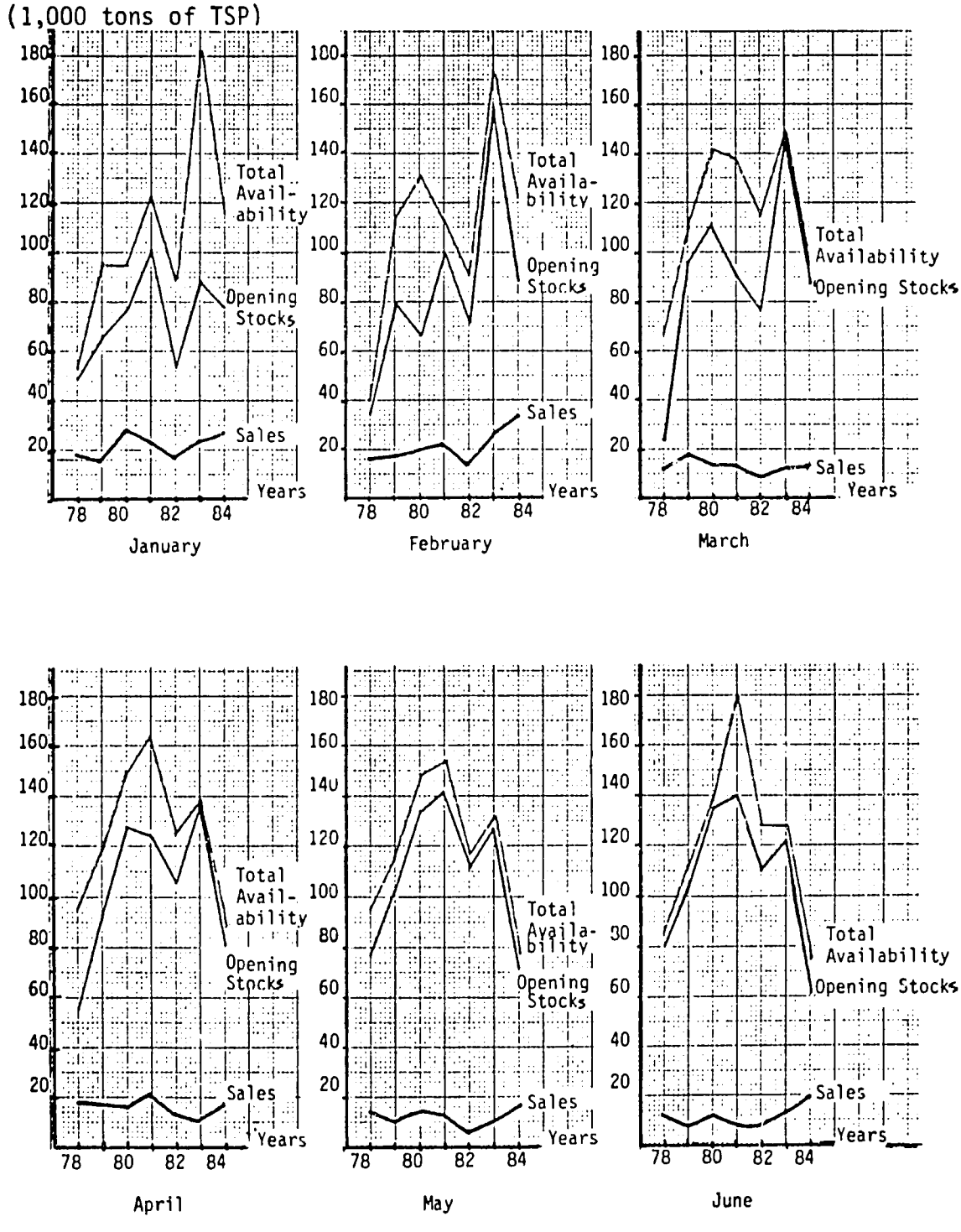
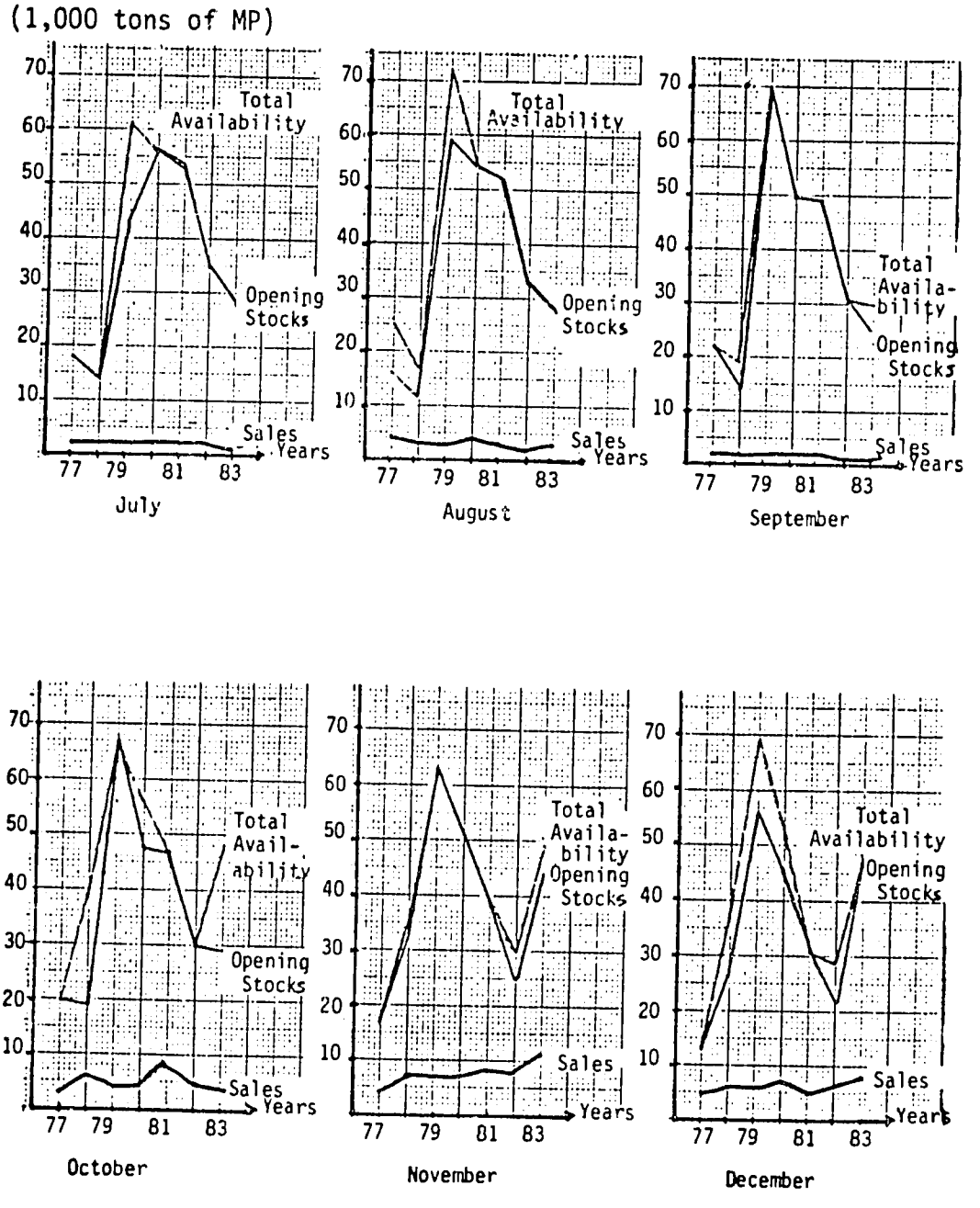


Figure 14--Monthly opening stocks, current supply, total availability, and sales of muriate of potash (MP) in Bangladesh, July 1977 to June 1984



Note: Current supply (stock replenishment) equals the vertical distance between total availability and opening stocks

Figure 14--Continued

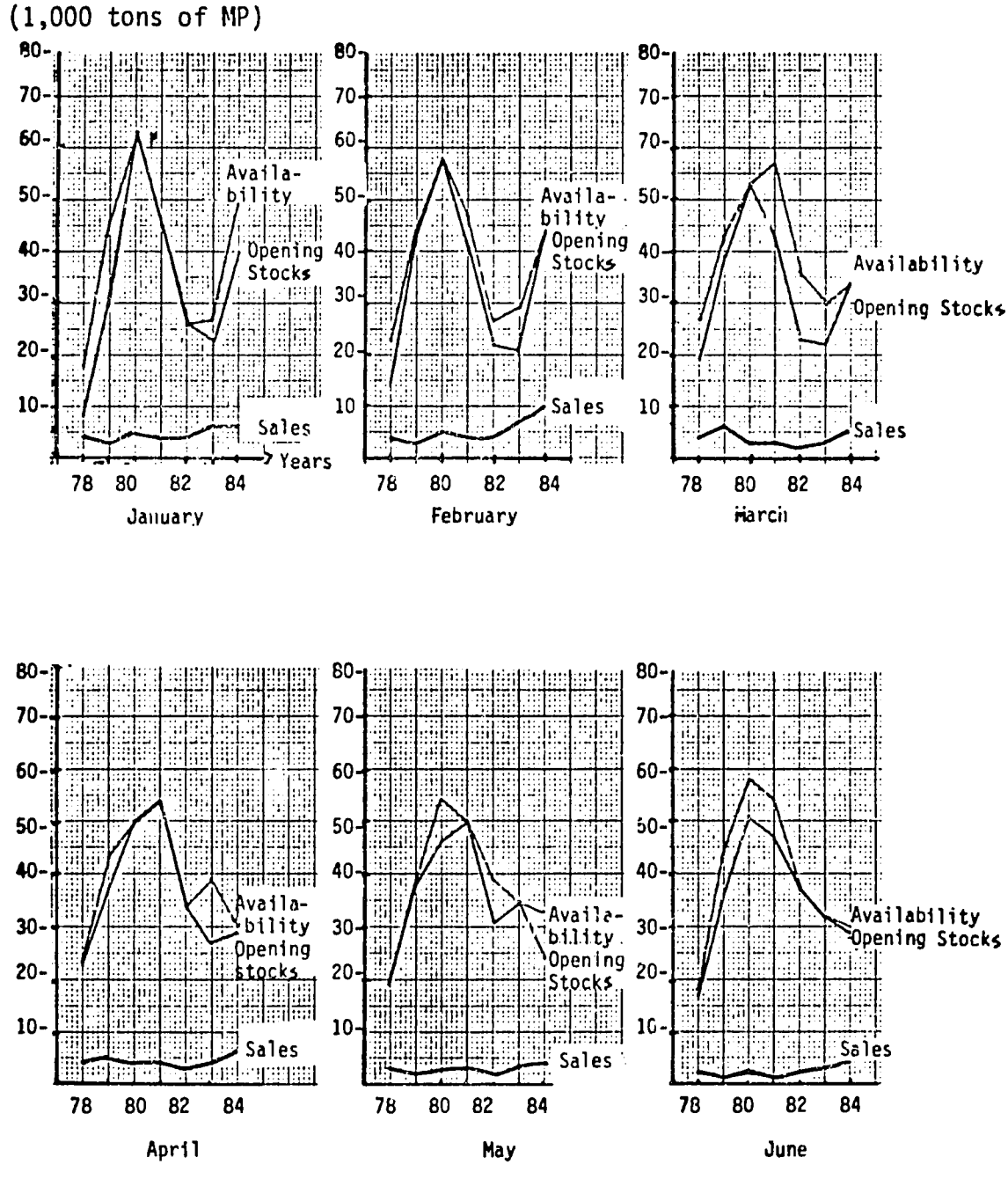


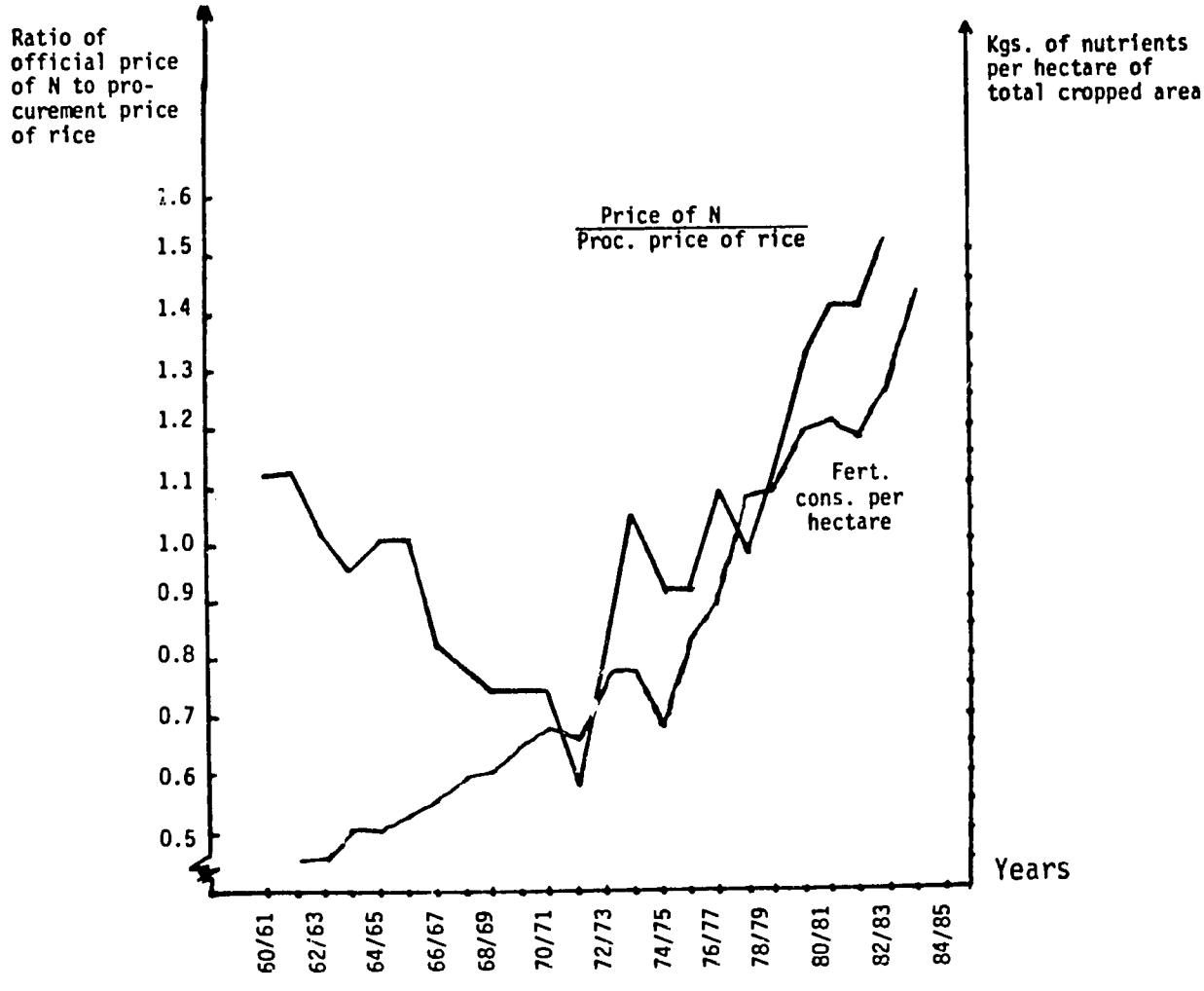
Table 15--Monthly sales, ratios of monthly opening stocks to monthly sales, and ratios of monthly availability to monthly sales of urea, TSP, and MP in Bangladesh, 1977/78 - 1983/84

Year	Product	Sales				Monthly Opening Stock/ Monthly Sales				Monthly Availability/ Monthly Sales			
		Average	Minimum	Maximum	C.V.	Average	Minimum	Maximum	C.V.	Average	Minimum	Maximum	C.V.
		(1,000 metric tons)											
1977/78	Urea	40	20	58	28	2.1	1.1	3.8	35.9	3.3	2.1	5.0	27.5
	TSP	16	9	26	30	5.1	2.0	11.1	58.5	6.0	2.5	11.8	48.1
	MP	4	2	5	25	5.7	2.0	11.0	45.8	6.5	2.6	11.0	32.9
1978/79	Urea	39	23	60	29	3.7	1.4	7.8	54.2	5.0	2.5	8.9	40.7
	TSP	18	8	30	38	5.3	1.2	13.1	61.4	6.6	4.0	14.1	50.4
	MP	4	1	7	51	10.3	3.2	36.0	86.3	12.4	5.7	43.5	83.2
1979/80	Urea	45	25	64	31	6.2	3.7	12.1	37.2	7.4	4.5	13.3	32.0
	TSP	21	12	41	41	6.0	2.8	11.3	46.1	7.1	3.2	11.5	39.7
	MP	4	2	7	41	17.2	9.0	34.5	41.2	19.0	9.0	34.5	43.1
1980/81	Urea	48	23	78	34	4.8	2.1	11.5	59.0	5.5	2.6	12.8	53.7
	TSP	21	8	41	44	7.4	3.5	17.5	53.7	8.9	3.1	22.7	59.1
	MP	4	1	7	46	17.1	6.4	47.0	63.6	18.3	7.4	52.6	65.1
1981/82	Urea	41	20	74	48	3.4	0.7	7.8	69.7	4.8	1.6	9.4	52.5
	TSP	17	6	45	62	7.5	2.3	18.7	63.2	8.9	2.5	19.6	56.9
	MP	4	2	8	51	10.1	3.0	31.0	78.4	10.9	3.8	31.0	69.3
1982/83	Urea	52	17	96	43	4.9	1.4	14.6	74.1	5.7	2.1	16.1	66.7
	TSP	17	7	50	56	6.8	2.6	17.9	76.9	7.8	2.7	20.8	77.4
	MP	4	1	8	51	10.1	3.0	31.0	78.4	10.9	3.8	31.0	69.3
1983/84	Urea	58	13	107	44	2.8	1.4	6.8	49.8	4.1	1.9	10.2	51.9
	TSP	22	7	50	56	6.8	2.6	17.9	76.9	7.8	2.7	20.8	77.4
	MP	5	1	11	58	9.8	4.0	29.0	80.5	11.1	4.4	30.3	78.1

Sources: Developed from data in Bangladesh Ministry of Agriculture and U.S. Agency for International Development, Joint Bangladesh and U.S. Government Evaluation of the Fertilizer Distribution Improvement Project, USAID Report 388-0024 (Dhaka: November 1982); and Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, June 1983 and June 1984.

Note: C.V. indicates coefficient of variation.

Figure 15--Growth of fertilizer consumption and changes in ratio of official price of nitrogen to procurement price of rice, 1960/61 to 1983/84



Note: Price data not available for 1983/84.

Thus at the present stage a new orientation is required for policies to create sustained rapid growth in Bangladesh's fertilizer consumption. The current emphasis on prices needs to be replaced by an emphasis on productivity and efficiency of fertilizer use as key target variables in policies designed to raise farmers' returns to fertilizer use and supplemented by adequate flows of institutional credit to enable them to buy fertilizers. Different factors affecting growth in actual fertilizer use need to be viewed, not in isolation from each other, but as a set of interacting variables that can be manipulated through appropriate policies. The dominant aim of these policies should be faster development and well-coordinated, efficient operation of systems of agricultural research, extension, and credit and of fertilizer production, import, procurement, stock management, and distribution.

2. FERTILIZER DEVELOPMENT AND PRICE IN INTERNATIONAL PERSPECTIVE

Bruce Stone

FERTILIZER USE IN BANGLADESH COMPARED WITH OTHER DEVELOPING COUNTRIES

Fertilizer use in Bangladesh exceeded 540,000 metric tons of nutrients in 1983/84 and 1985/86. In 1984/85 it reached 596,311 tons. In terms of materials, this was more than 1.26 million metric tons. Thus from 1983/84 to 1985/86 applications of manufactured nutrients ranged from 63 to 70 kilograms per hectare of net cultivated area and from 41 to 46 kilograms per hectare of total cropped area.[1] The view that Bangladesh's fertilizer consumption is among the world's lowest is inaccurate. While fertilizer consumption per hectare in Bangladesh is considerably lower than in many developed countries, it is higher than average levels in a large number of developing countries.

On the basis of 1983/84 data, fertilizer consumption per hectare of arable land and land under permanent crops in Bangladesh ranks 35th among the 126 developing countries for which data are readily available. Its consumption in that year was 10 percent higher than the average for all developing countries. If only developing market economies are considered (that is, if centrally planned economies are excluded from developing countries), then Bangladesh consumption was 71 percent higher than the group's average. Among the 35 developing countries of Asia (excluding Japan and Israel, but including Singapore and Korea), Bangladesh ranks 14th, slipping ahead of Pakistan in 1983/84. But most of the developing countries with higher consumption than Bangladesh are located in either East Asia or in the Middle East.[2] Among countries in South or Southeast Asia, Bangladesh's fertilizer consumption per hectare is lower than that of Singapore, Malaysia, Sri Lanka, and Indonesia, but it is considerably higher than that of Nepal, Burma, Thailand, the Philippines, and a few others (Table 1).

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[1]Bangladesh Bureau of Statistics, Statistical Bulletin of Bangladesh, Vol. 15 (October 1986), pp. 25 and 50-52.

[2]Food and Agriculture Organization of the United Nations, FAO Fertilizer Yearbook, 1984 (Rome: FAO, 1986), pp. 42-53.

Table 1--Consumption of fertilizer per hectare of arable land and land under permanent crops, various Asian countries, 1961-83

Country/ Fertilizer	1961-65	1967-68	1969-71	1972	1973	1974	1976	1977	1978	1979	1980	1981	1982	1983
	(kilograms per hectare)													
Bangladesh														
Nitrogen	3.5	8.1	9.8	14.2	13.9	9.1	18.2	24.7	24.9	28.5	29.8	27.6	33.5	37.5
Phosphate	0.7	2.5	3.4	4.6	4.8	3.9	6.7	9.9	11.8	12.9	13.3	13.2	14.3	17.8
Potash	0.2	0.7	1.0	1.2	1.2	1.2	1.6	2.8	4.6	3.2	3.2	3.1	3.4	4.2
Total	4.4	11.2	14.2	20.0	20.0	14.1	26.5	37.4	41.4	44.6	46.3	43.8	51.2	59.6
Burma														
Nitrogen	0.5	1.2	2.2	3.0	3.7	3.8	4.3	5.0	6.8	7.9	6.7	9.2	6.7	11.4
Phosphate	0.1	0.8	1.1	1.4	0.4	0.4	0.7	1.0	1.4	2.1	3.0	3.0	3.0	3.2
Potash	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.3	0.2	0.3	0.3	1.1	1.2
Total	0.7	2.3	3.4	4.6	4.2	4.5	5.1	6.2	8.5	9.3	10.0	12.5	16.7	15.8
Indonesia														
Nitrogen	6.2	10.2	9.3	22.3	21.9	17.8	18.1	24.0	32.0	32.0	44.4	51.0	50.1	51.7
Phosphate	2.0	2.8	2.3	4.7	5.8	6.2	5.7	5.8	8.3	7.8	14.2	16.4	18.2	17.5
Potash	0.2	0.5	0.4	1.9	2.5	1.7	1.5	2.0	4.6	4.3	4.5	7.0	6.8	5.3
Total	8.4	13.4	11.9	28.9	30.3	25.7	25.4	31.7	44.9	44.1	63.0	74.4	75.0	74.5
Japan														
Nitrogen	124.9	159.0	148.6	138.4	157.4	133.9	139.6	143.6	146.4	158.3	125.8	132.5	142.3	146.1
Phosphate	84.0	120.3	123.1	137.8	152.0	134.2	146.5	149.8	156.9	169.3	141.4	144.4	149.3	159.4
Potash	96.3	116.2	113.1	113.2	121.0	129.4	128.6	132.6	146.4	150.0	104.9	110.2	120.5	131.5
Total	305.2	395.5	384.9	389.5	430.4	397.6	414.7	426.1	449.6	477.7	372.1	387.2	412.1	437.0
Korea, Democratic People's Republic														
Nitrogen	54.7	66.3	94.7	109.7	116.2	120.0	177.8	200.4	241.0	242.2	245.5	250.2	260.6	254.5
Phosphate	23.6	33.4	41.9	51.2	39.5	59.0	58.5	57.5	57.2	57.0	56.7	57.6	57.3	56.8
Potash	n.a.	16.1	11.8	15.3	21.1	19.3	17.4	18.5	47.2	36.9	23.3	40.8	20.4	34.0
Total	78.3	115.8	148.4	176.2	176.9	198.3	253.7	276.3	345.4	336.0	325.5	348.0	338.3	345.2
Korea, Republic of														
Nitrogen	92.9	121.7	148.7	166.2	183.5	199.9	161.4	173.9	207.7	201.1	203.6	197.4	141.6	169.5
Phosphate	49.8	54.8	60.1	76.2	87.5	109.7	63.5	94.2	106.0	97.7	88.3	63.0	68.3	79.0
Potash	14.3	31.8	37.7	46.5	66.8	69.5	62.5	61.8	78.2	86.8	83.3	91.0	71.8	82.6
Total	157.0	208.3	246.6	288.9	337.8	379.1	287.4	330.0	391.9	385.7	375.7	351.3	281.7	331.1
Malaysia														
Nitrogen	5.7	7.8	15.6	13.4	18.4	16.6	21.2	23.8	16.5	32.0	32.3	29.5	31.8	38.2
Phosphate	1.2	2.3	[illegible]	8.7	10.8	13.1	15.9	16.6	14.0	23.5	27.6	22.7	25.6	26.7
Potash	2.6	5.6	[illegible]	13.4	14.6	24.8	33.2	34.4	26.7	45.5	45.2	40.0	44.7	46.5
Total	9.4	15.7	[illegible]	35.5	43.8	54.5	70.3	74.8	57.1	101.1	105.1	92.3	102.1	111.5
Pakistan														
Nitrogen	3.4	9.9	15.0	20.2	17.6	18.6	25.9	27.6	34.2	38.3	39.7	41.0	47.2	44.6
Phosphate	n.a.	1.4	1.8	2.6	3.0	3.1	6.0	7.8	9.5	9.9	9.4	11.1	13.1	12.2
Potash	n.a.	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.5	0.5	1.1	1.3	1.4
Total	3.4	11.4	16.8	22.8	20.8	21.8	31.9	35.7	44.1	48.8	49.5	53.1	61.6	58.6
Philippines														
Nitrogen	7.2	9.1	12.0	15.2	19.8	18.2	18.0	17.6	25.4	21.2	22.7	19.0	19.6	21.4
Phosphate	3.3	4.0	5.5	5.3	6.7	4.9	4.1	4.1	6.1	4.9	5.4	4.3	4.3	4.9
Potash	2.8	4.9	3.9	5.1	7.3	6.2	5.2	4.6	7.0	6.0	5.6	5.5	4.9	5.7
Total	13.2	17.0	21.4	25.6	33.7	29.3	27.3	26.3	38.5	32.1	33.7	28.8	28.8	32.0
Sri Lanka														
Nitrogen	22.9	25.7	25.4	27.7	25.9	37.6	24.8	31.1	36.9	36.1	42.7	36.4	36.5	37.6
Phosphate	6.8	14.5	9.6	10.9	9.8	12.2	5.8	10.6	11.5	16.1	12.9	12.8	14.1	14.2
Potash	17.1	19.9	14.5	10.1	16.0	18.1	14.1	11.9	14.1	16.0	21.4	19.2	20.7	22.0
Total	40.8	60.1	49.6	48.7	51.7	67.9	44.8	53.6	62.5	68.2	77.0	68.4	71.3	74.0
Thailand														
Nitrogen	1.2	3.9	3.7	4.2	3.9	4.9	8.0	9.2	8.8	8.8	8.6	8.7	9.5	13.2
Phosphate	0.7	2.8	2.7	3.8	3.3	4.3	4.7	5.2	6.0	6.7	5.7	6.8	6.9	7.0
Potash	0.3	0.9	1.2	2.8	2.5	3.1	1.2	1.3	1.7	2.4	2.0	1.9	1.9	3.8
Total	2.2	7.6	7.6	10.8	9.6	12.3	14.0	15.7	16.5	18.0	16.2	17.3	18.3	24.0

Sources: Food and Agriculture Organization of the United Nations, FAO Fertilizer Yearbook, 1978, 1979, 1980, 1981, 1982, 1983, 1984 (Rome: FAO, 1979, 1980, 1981, 1982, 1983, 1984, and 1985).

Notes: Arable land and land under permanent crops includes land under temporary crops (net cultivated area: that is, double-cropped areas are counted once), temporary meadows for mowing or pastures, land under market and kitchen garden, land temporarily fallow or lying idle, and also land under permanent crops. n.a. means data are not available.

Not only is fertilizer consumption in Bangladesh higher than in a majority of the developing countries, but its growth has also been faster. By 1981/82 Bangladesh ranked third among the 40 developing countries that applied less than 5 kilograms of fertilizer per hectare in the early 1960s.[3]

Bangladesh's fertilizer consumption per hectare of gross cultivated area was about 8 percent lower than that of India in 1983/84, only 3 percent lower in 1984/85, and almost 18 percent lower in 1985/86 as a result of a temporary setback in use.[4] But Bangladesh compares favorably with states in East India (Table 2). Among these only West Bengal's consumption was as high. Consumption levels in Bihar, Orissa, Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura were, for the most part, considerably lower.

That fertilizer consumption in Bangladesh was generally higher than in East India is also illustrated by Gunvant Desai in Chapter 1 (Figures 1 and 2), which show levels of fertilizer consumption per hectare of gross cultivated area in the districts of East India and Bangladesh, respectively.

On the other hand, average fertilizer use per hectare of cropped area in Bangladesh in 1983/84 was only 35.6 percent of that of China in the calendar year 1983, and it was lower than all but one of 29 Chinese provinces (Tables 2, 3, and 4). That province was Inner Mongolia, a cold, dry, windswept autonomous region in the northwest, with China's lowest irrigated proportion of cultivated land. It is sparsely populated with predominantly herding peoples. In fact, all of China's provinces in the lowest application intensity category (exceeded in Bangladesh only by Bogra and, narrowly, by Chittagong [Table 4]) are cold, remote, single-cropping regions where cultivation focuses on coarse grains and pulses (Figures 1 and 2). Even those provinces with application intensity comparable to that of Chittagong and Bogra (Shanxi, Shaanxi, and Qinghai) produce predominantly local spring wheat or coarse grains, due to poor land, short growing seasons, or lack of water. The problem in Tianjin Municipal Area is poor land, saline groundwater, and a lack of access to surface irrigation water, which is exhausted during the critical months by neighboring North Chinese provinces.

The principal paddy-cultivating multiple cropping provinces include many of the most intensive users of fertilizer: Fujian,

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[3]Food and Agriculture Organization of the United Nations, FAO Fertilizer Yearbook, various issues (Rome, FAO, various years).

[4]Bangladesh Bureau of Statistics, Statistical Bulletin of Bangladesh, Fertilizer Association of India, Fertilizer Statistics, 1985-86 (New Delhi: FAI, 1986), pp. 1-114.

Table 2--Growth of fertilizer use in Bangladesh compared with China, India, and major states of East India, 1961/62 to 1984/85

Year	Bangla-desh	Major States in East India: West Bengal	Bihar	Orissa	Assam	India	China
	(kilograms of nutrients/hectare of gross cropped area)						
1961/62	2.0	3.8	1.3	0.8	a	2.2	3.1
1962/63	2.2	3.3	1.8	0.9	0.1	2.9	4.5
1963/64	4.4	4.8	2.4	1.1	0.2	3.5	6.4
1964/65	4.1	6.5	3.1	1.3	1.0	4.9	7.5
1965/66	4.9	6.4	3.2	1.3	2.2	5.1	13.6
1966/67	6.1	5.1	3.6	2.5	1.9	7.0	17.1
1967/68	7.6	6.7	3.9	2.8	2.2	9.4	18.8
1968/69	8.2	8.0	6.1	2.9	3.3	11.1	14.5
1969/70	10.0	7.4	9.9	3.1	2.4	12.2	19.3
1970/71	11.4	11.0	9.0	3.3	3.1	13.6	21.4
1971/72	9.9	13.1	10.1	7.1	2.9	16.1	24.9
1972/73	15.1	13.0	11.5	8.1	3.3	17.1	28.4
1973/74	14.9	13.3	9.0	8.6	2.6	16.7	34.4
1974/75	10.8	16.2	10.8	6.9	1.9	15.7	32.7
1975/76	17.0	16.3	12.0	6.1	1.9	16.9	35.9
1976/77	19.6	20.0	15.2	8.6	1.3	20.4	38.9
1977/78	26.8	21.8	17.3	6.1	1.8	24.9	43.4
1978/79	27.6	30.9	17.1	8.7	2.4	29.2	58.9
1979/80	31.6	30.6	16.2	8.1	2.1	30.0	73.2
1980/81	32.3	35.9	18.0	9.2	2.8	31.5	86.7
1981/82	30.9	32.8	18.0	9.9	3.3	34.6	92.0
1982/83	34.6	33.1	18.5	10.8	4.1	36.6	104.3
1983/84	41.1	42.5	26.7	13.0	5.7	44.5	115.3
1984/85	45.9	58.0	39.6	13.7	3.9	50.1	120.6

Sources: India and Bangladesh: Chapter 1, Table 1; 1984/85 data have been added from Bangladesh Bureau of Statistics, Statistical Bulletin of Bangladesh, Vol. 15 (October 1986), pp. 25 and 51; and Fertiliser Association of India, Fertiliser Statistics, 1985-86 (New Delhi: FAI, 1986), pp. I-116. China: Calculated from data found in Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response," in China's Economy Looks Toward the Year 2000, Vol. 1, The Four Modernizations, ed. U.S. Congress Joint Economic Committee (Washington, D.C.: Government Printing Office, 1986), Table 1; Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 137; and Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1986 [Statistical Yearbook of China, 1986] (Beijing: Tongji Chubanshe [Statistical Publishing House], 1986), pp. 149 and 174.

Notes: Chinese data exclude Taiwan and are for calendar years 1961-83. Comparable fiscal year data would generally be somewhat greater than the figures indicated for each year.

[a]Less than 0.05 kilograms.

Table 3--Provincial fertilizer nutrient application per sown hectare in China, 1981-85

Province	1985	1984	1983	1982	1981	Annual Average Growth Rate, 1981-83	Annual Average Growth Increment, 1981-83	Annual Average Growth Increment, 1981-84	Annual Average Growth Increment, 1981-85
	(kilograms/sown hectare)					(percent)	(kilograms/hectare/year)		
Shanghai[a]	181.3	194.6	210.8	221.3	224.2	-3.0	-6.7	-9.8	-10.7
Fujian	210.2	210.3	196.0	184.3	154.4	12.8	20.8	18.6	14.0
Liaoning	191.3	203.9	180.5	167.7	163.3	5.1	8.6	13.5	7.0
Jiangsu	184.5	182.6	174.3	170.0	147.7	8.6	13.3	11.6	9.2
Shandong	171.0	175.9	172.4	158.9	140.8	10.7	15.8	11.7	7.6
Beijing[a]	132.7	154.7	169.2	168.2	156.4	4.0	6.4	-0.6	-5.9
Guangdong	181.1	165.5	166.2	146.7	134.0	11.4	16.1	10.5	11.8
Zhejiang	159.7	153.1	151.2	144.6	134.9	5.9	8.2	6.1	6.2
Hunan	120.0	108.8	135.0	114.6	106.9	12.9	14.5	0.9	3.3
Hebei	127.5	139.2	117.4	102.7	82.7	19.1	17.4	18.8	11.2
Anhui	138.8	127.0	115.3	113.5	91.7	12.1	11.8	11.8	11.8
Henan	122.9	122.6	115.3	95.3	74.7	24.2	20.3	16.0	1[illegible].1
All China[b]	123.6	120.6	115.3	104.6	91.4	12.3	12.0	9.7	8.1
Guangxi	117.3	109.7	112.4	110.2	92.5	10.2	10.0	5.7	6.2
Sichuan	114.4	110.8	111.5	97.7	97.9	6.7	6.8	4.3	4.1
Hubei	125.1	120.3	107.7	93.4	78.9	16.8	14.4	13.8	11.6
Jilin	128.2	122.6	100.3	89.3	76.9	14.2	11.7	15.2	12.8
Yunnan	100.6	96.8	97.3	81.1	64.7	22.6	16.3	10.7	9.0
Guizhou	92.7	93.2	89.6	80.8	79.2	6.4	5.2	4.6	3.4
Jiangxi	99.5	86.9	85.8	86.6	67.8	12.5	9.0	6.4	7.9
Qinghai	59.9	69.1	77.7	83.0	61.7	12.2	8.0	2.5	-0.5
Shaanxi	92.0	88.4	75.4	66.1	55.2	16.9	10.1	11.1	9.2
Shanxi	100.0	99.9	75.3	68.4	66.4	6.5	4.5	11.2	8.4
Tianjin[a]	72.1	72.2	65.8	59.0	62.5	2.6	1.7	3.2	2.4
Tibet	38.1	61.0	61.1	22.9	9.4	154.9	25.9	17.2	7.2
Ningxia	18.8	64.5	60.3	54.6	50.3	9.5	5.0	4.7	4.6
Xinjiang	71.3	67.1	58.9	48.4	40.5	20.6	9.2	8.9	7.7
Gansu	60.2	58.6	51.4	46.3	37.9	16.5	6.8	6.9	5.6
Heilongiang	49.1	54.0	46.7	42.2	40.8	7.0	3.0	4.4	2.1
Inner Mongolia	43.7	35.3	31.1	21.8	17.8	32.2	6.7	5.8	6.5

Sources: Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response," in U.S. Congress Joint Economic Committee, eds., China's Economy Looks Toward the Year 2000, Vol. 1, The Four Modernizations (Washington, D.C.: U.S. Government Printing Office, 1986), pp. 461-462; State Statistical Bureau, PRC, Statistical Yearbook of China, 1985 (Hong Kong and Beijing: Economic Information and Agency, and China Statistical Information and Consultancy Service Centre, 1985), p. 283; Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1986 [Statistical Yearbook of China, 1986] (Beijing: Zhongguo Tongji Chubanshe [Statistical Publishing House of China], 1986), p. 156.

Notes: "Sown" area data are comparable to "total (or "gross") cropped" area in Indian and Bangladeshi statistics.

[a]Shanghai, Beijing, and Tianjin are municipal areas with considerable vegetable acreage.

[b]These data exclude Taiwan Province.

Table 4--Growth of fertilizer nutrient application per sown hectare in Bangladesh districts, 1962-63 to 1984-85

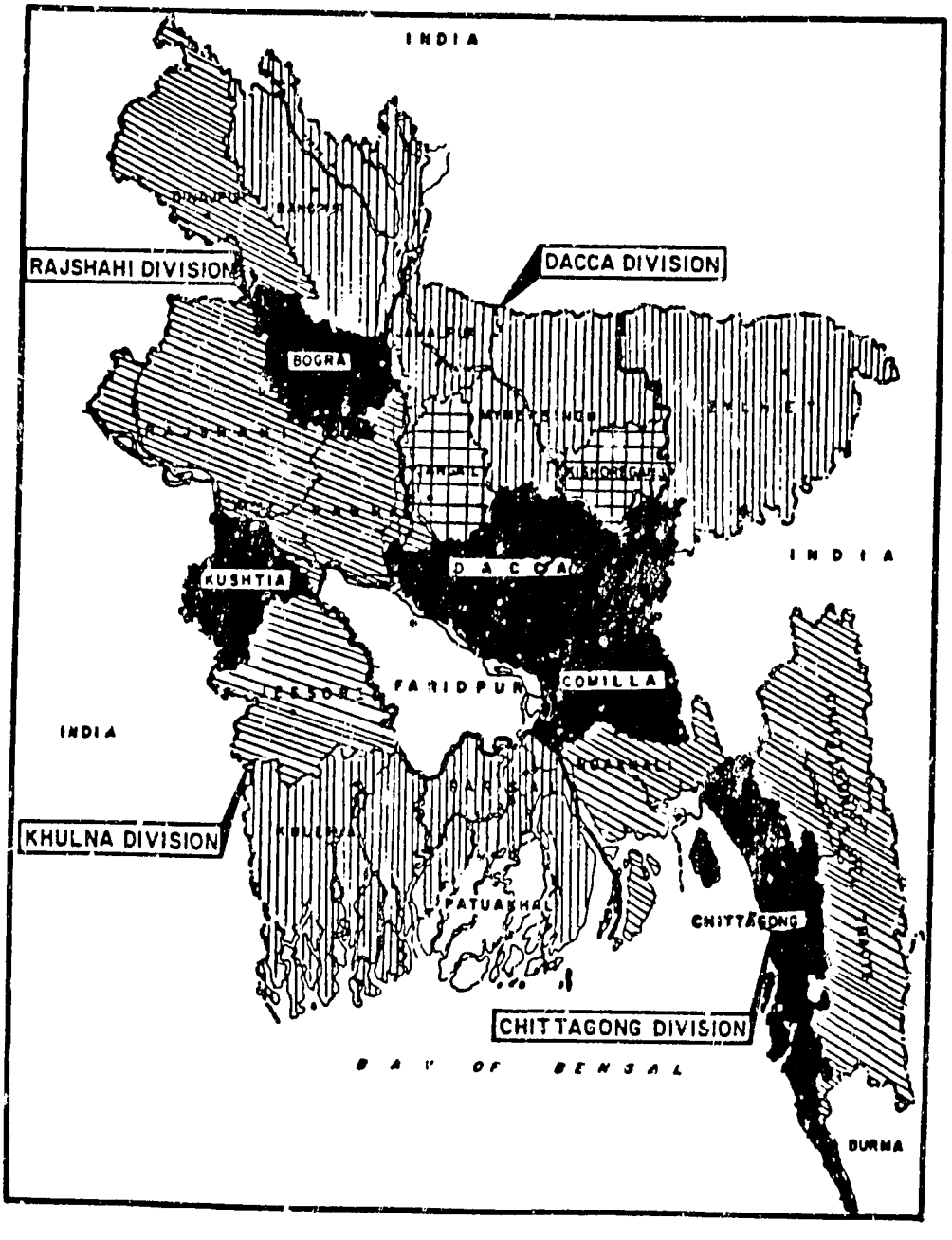
District	Fertilizer Application per Hectare of Total Cropped Area					Annual Rate of Increase			
	1962-63	1970-71	1977-78	1983-84	1984-85	1962-63 to 1970-71	1970-71 to 1977-78	1977-78 to 1983-84	1977-78 to 1984-85
	(kgs of nutrients/total cropped hectare)					(kgs/hectare/year)			
High application districts	5.0	22.9	51.5	69.8	78.06	2.2	4.1	3.0	3.8
Bogra	5.5	20.0	43.3	84.2	78.1	1.8	3.3	6.8	5.0
Chittagong	12.0	47.5	70.5	75.0	84.2	4.4	3.3	0.8	2.0
Dhaka	4.5	22.4	41.7	67.6	75.8	2.2	2.8	4.3	4.9
Kushtia	1.2	9.7	44.8	65.6	78.5	1.1	5.0	3.5	4.8
Comilla	3.1	18.8	57.0	62.6	73.7	2.0	5.5	0.9	2.4
Medium application districts	1.4	8.1	22.7	38.6	45.87	0.8	2.1	2.6	3.3
Rajshahi	1.9	8.0	22.1	46.4	48.9	0.8	2.0	4.1	3.8
Dinajpur	2.2	7.9	25.4	44.2	53.3	0.7	2.5	3.1	4.0
Pabna	0.7	7.7	25.8	43.8	49.6	0.9	2.6	3.0	3.4
Kishoreganj	3.2	14.2	34.5	40.0	47.5	1.4	2.9	0.9	1.9
Mymensingh[a]	0.9	9.0	23.9	37.1	45.0	1.0	2.1	2.2	3.0
Chittagong Hill Tracts	2.1	6.5	12.7	36.6	42.9	0.6	0.9	4.0	4.3
Jessore	0.9	5.8	22.0	36.1	49.5	0.6	2.3	2.4	3.9
Rangpur	1.2	5.8	13.5	30.4	30.3	0.6	1.1	2.8	2.4
Low application districts	0.9	7.2	14.4	16.1	23.1	0.8	1.1	0.3	1.1
Noakhali	2.5	14.7	28.3	22.7	33.4	1.5	2.0	-0.9	0.7
Sylhet	0.8	4.4	12.9	17.1	24.3	0.4	1.2	0.7	1.6
Khulna	1.1	7.2	10.5	16.6	24.1	0.8	0.5	1.0	1.9
Faridpur	0.5	2.8	7.9	14.2	19.1	0.3	0.7	1.0	1.6
Barisal[b]	0.4	9.5	15.0	13.0	14.5	1.1	0.8	-0.4	-0.1
Mean	2.5	12.3	28.4	41.8	48.5	1.2	2.3	2.2	2.9
Coefficient of variation	1.09	0.82	0.59	0.50	0.44	0.77	0.57	0.85	0.50

Source: Calculated from Chapter 4, Table 3 (pounds of fertilizer materials per acre).

[a]Includes Tangail and Jamalpur districts.

[b]Includes Patuakhali district.

Figure 1--Fertilizer nutrient consumption per hectare of total cropped area in various districts of Bangladesh in the early 1980s



5.1 - 10 kgs/ha.

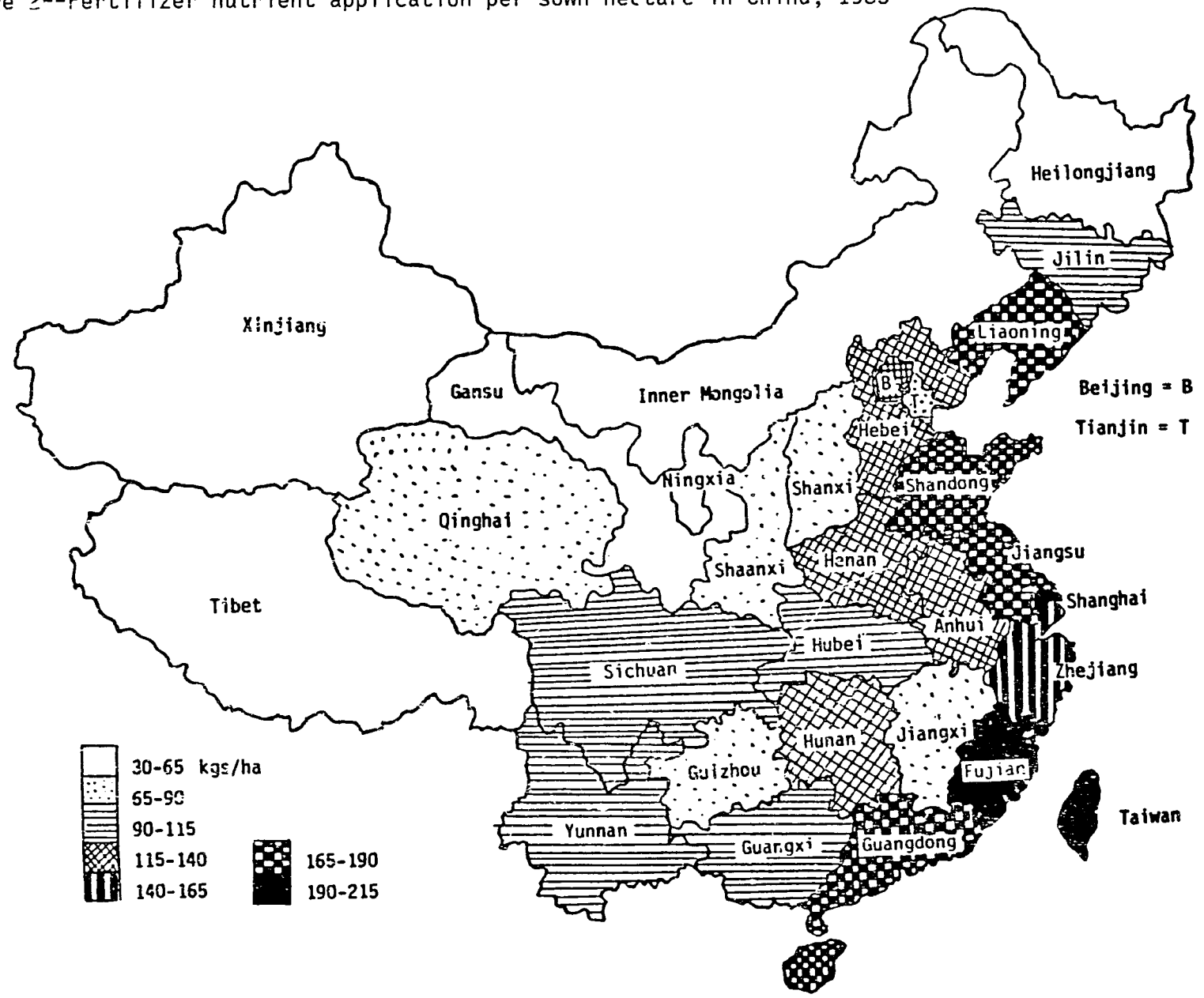
10.1 - 20 kgs/ha.

20.1 - 30 kgs/ha.

30.1 - 50 kgs/ha.

50.1 - 75 kgs/ha.

Figure 2--Fertilizer nutrient application per sown hectare in China, 1983



Taiwan, Zhejiang, Jiangsu, Shandong, and Guangdong. Application in these provinces in 1983/84 was 100-160 percent more intensive than that of Bogra. The other major rice producers (Sichuan, Hubei, Hunan, and Anhui) still used fertilizer 40-80 percent more intensively than even Bogra.

Farm survey data on fertilizer use by crop are available for China only for 1975-78 (Table 5). Although these data must be used with caution, they demonstrate that fertilizer expenditures per hectare were greatest for wheat, rice, and maize in these years, exceeded only by some of the more important nonstaple crops (probably including vegetables and sugarcane, which are excluded from the survey materials). Rough calculations on 1978 data suggest that average use on wheat exceeded 75 kilograms per sown hectare; on paddy, application was close to 90 kilograms (greater for mid-season, and less for early and late rice).[5] Aggregate application intensity in China has doubled since 1978 (Table 2).

The foregoing suggests that quick comparisons with other developing nations in Asia provide no obvious reason for pessimism about the current potential for rapid growth in fertilizer use in Bangladesh. This conclusion is strengthened by examination of other crop-specific fertilizer use data for various Asian countries in Table 6. In comparison with countries that have higher application rates, it is clear that Bangladesh has the potential for considerable fertilizer intensification on rice, wheat, potatoes, sugarcane, and jute. If the Chinese data have any relevance (Table 5), even oilseeds could use more fertilizer in Bangladesh, although the total potential is not apt to be as great. Because pulses in Bangladesh generally either fix their own nitrogen or are otherwise less responsive to nitrogen application, growth in fertilizer use for pulses lies primarily with application of other nutrients and may be limited critically by the low prices and relatively low yield potential for these crops.[6]

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[5]As in Bangladesh, per capita calorie consumption is low and land is sown predominantly with grains, tuber crops, and pulses: 80.3 percent in 1978 declining to 79.2 percent in 1983 (Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggong: Xianggong Jingji Daobao Shechuban [Hong Kong: Economic Reporter Publishing House], 1984), p. 140.

[6]Data for China also show extremely low fertilizer application to field pulses. But scattered Chinese materials indicate that with fertilizer use field pulse yields can grow moderately, even under poor climatological and soil conditions (Bruce Stone, "Edible Beans in China 1929-81," a paper prepared for the Centro Internacional de Agricultura Tropical [CIAT], Cali, June 1983).

Table 5--Relative intensity of chemical fertilizer application expenditures among crops in China, 1975-78

Crop	1975	1976	1977	1978
Wheat	100.0	100.0	100.0	100.0
Rice (average)	126.8	109.6	124.5	116.3
Early rice	103.7	96.5	95.8	98.8
Late rice	52.7	113.3	88.8	71.0
Japonica	224.4	118.9	188.8	178.9
Glutinous rice	10.7	124.9	65.3	97.1
Maize	117.1	134.3	90.3	111.5
Sorghum	40.2	4.9	72.5	59.6
Millet	25.8	11.2	59.2	61.1
Soybeans	5.9	8.4	15.7	20.0
Sweet potatoes	n.a.	n.a.	18.2	19.7
Peanuts	299.5	50.3	41.6	22.6
Rape	87.1	186.5	45.7	74.2
Sesame	17.8	3.7	12.7	5.4
Cotton	153.7	172.0	128.3	n.a.
Tobacco	n.a.	n.a.	124.7	n.a.
Flue-cured tobacco	169.8	152.2	n.a.	n.a.
Bast fibers	142.7	148.0	106.6	n.a.
Jute	113.9	29.4	82.5	n.a.
Hemp	147.6	116.3	110.6	n.a.
Kenaf	184.4	257.3	157.7	n.a.
Ramie	124.9	179.5	67.4	n.a.
Wheat (1975 wheat = 100)	100.0	104.6	128.5	143.7
Average application (in quantity) for all crops(1975 = 100)	100.0	108.4	120.9	164.0

Source: Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response," in China's Economy Looks Toward the Year 2000, Vol. 1, The Four Modernizations, ed. U.S. Congress Joint Economic Committee (Washington, D.C.: Government Printing Office, 1986), p. 465.

Notes: These index numbers (relative to current year wheat expenditures) are derived from survey data listing average expenditures per unit of sown area on fertilizer, broken down for most years as expenditures on "all fertilizer" and "on chemical fertilizer only." Expenditures on wheat rose over the period, although somewhat less than average quantity of chemical fertilizer application per unit of area, both of which are indexed to 1975 at the bottom. These data should be used with caution. The sample is biased toward more productive locations, since average yields among surveyed locations exceeded the national average by 10-30 percent. This is particularly distorting for the poor land crops since diffusion of fertilizer in high-intensity application areas will considerably exceed that on more typical poor lands. The expenditure data are in value terms, so they are imperfect proxies for quantity comparisons. Farm-gate prices of centrally distributed fertilizers remained constant and uniform over the period, but prices of locally produced fertilizers including most ammonium bicarbonate, single superphosphate, and calcium magnesium phosphate vary among locations and over time, and were dominant among applied fertilizers during the period. Per hectare application on mid-season rice, included in the average for rice, exceeds that on wheat.

Table 6--Fertilizer use in crop production in Central and South Asia, and in Southeast and Northeast Asia

Country/ Crop	Area Harvested	Area Fertilized		Nutrient Consumption			Nutrient Application + Harvested Area			Nutrient Application + Fertilized Area			Principal Nutrient Sources
				N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
	(hectares)	(per-cent)	(hectares)	(metric tons)			(kilograms/hectare)						
Central and South Asia													
Burma - 1979													
Wheat	83,000	n.a.	n.a.	400	200	0	5	2	0	n.a.	n.a.	n.a.	Urea, TSP, MP
Maize	80,000	n.a.	n.a.	500	200	10	7	3	0	n.a.	n.a.	n.a.	Urea, TSP, MP
Rice	5,013,000	n.a.	n.a.	56,000	17,300	2,800	11	3	1	n.a.	n.a.	n.a.	Urea, TSP, MP
Sugarcane	50,000	n.a.	n.a.	1,400	300	0	27	6	0	n.a.	n.a.	n.a.	Urea, TSP, MP
Cotton	165,000	n.a.	n.a.	1,100	500	100	7	3	1	n.a.	n.a.	n.a.	Urea, TSP, MP
Jute	52,000	n.a.	n.a.	3,300	0	40	64	0	1	n.a.	n.a.	n.a.	Urea, TSP, MP
Groundnuts	523,000	n.a.	n.a.	1,800	2,100	20	3	4	0	n.a.	n.a.	n.a.	Urea, TSP, MP
Pulses	567,000	n.a.	n.a.	300	200	0	0	0	0	n.a.	n.a.	n.a.	Urea, TSP, MP
Rubber		n.a.	n.a.	200	100	0				n.a.	n.a.	n.a.	Urea, TSP
Bangladesh - 1980[a]													
Wheat	591,000	n.a.	n.a.	21,800	14,200	2,400	37	24	4	46(80)	42(60)	32(35)	Urea, TSP, MP
Rice	10,308,000	n.a.	n.a.	219,000	123,700	9,300	21	12	1	40(54)	28(32)	32(19)	Urea, TSP, MP
Potato	97,000	n.a.	n.a.	3,400	0	1,200	35	0	12	55(65)	0 (0)	68(23)	Urea, TSP, MP
Sugarcane	150,000	n.a.	n.a.	2,400	500	300	16	3	2	38(41)	26 (9)	38 (6)	Urea, TSP, MP
Jute	635,000	n.a.	n.a.	5,900	1,300	1,300	9	2	2	29(32)	31 (7)	34 (5)	Urea, TSP, MP
Oilseeds	283,000	n.a.	n.a.	3,400	1,100	300	12	4	1	43(28)	32(15)	29 (5)	Urea, TSP, MP
Pulses	328,000	n.a.	n.a.	100	300	0	3	1	0	38 (7)	30 (4)	35 (1)	Urea, TSP, MP
India - 1979													
Wheat	22,220,000	90	19,998,000	600,000	240,000	120,000	27	11	5	30	12	6	NPK, urea, DAP, MP
Maize	5,800,000	50	2,900,000	58,000	5,800	0	10	1	0	20	2	0	Urea
Rice	40,200,000	75	30,150,000	754,000	181,000	60,000	19	5	1	25	6	2	Urea, DAP, NPK
Other cereals	37,378,000	60	22,426,800	336,000	45,000	22,000	9	1	1	15	2	1	Urea, SOP
Tuber crops	790,000	95	750,000	60,000	30,000	23,000	76	38	29	80	40	31	Urea, SOP, DAP, MP
Sugarcane	3,119,000	80	2,495,200	200,000	50,000	20,000	64	16	6	80	20	8	Urea, DAP, NPK
Fiber crops	8,275,000	50	4,137,000	166,000	41,000	21,000	20	5	3	40	10	5	NPK, urea, DAP
Fruits and vegetables	5,531,000	50	2,765,500	28,000	14,000	6,000	5	3	1	10	5	2	Urea, PR, MP, DAP
Pakistan - 1978													
Wheat	6,687,000	78	5,215,900	349,000	88,300	0	52	13	0	67	17	0	Urea, DAP, CAN, NPK
Maize	605,000	73	441,600	29,600	6,600	0	49	11	0	67	15	0	Urea, AS, DAP, SOP, NPK
Rice	2,026,000	86	1,742,400	104,500	26,100	0	52	13	0	60	15	0	Urea, DAP, CAN, NPK
Other cereals	1,300,000	1	13,000	300	200	0	0	0	0	25	12	0	Urea, [illegible]K, SOP
Tuber crops	37,000	100	37,000	5,600	1,900	1,900	150	50	50	150	50	50	Urea, NPK, CAN, DAP, SOP
Industrial crops	800,000	95	760,000	76,000	20,500	3,900	95	26	5	100	27	5	Urea, AS, SSP, PR, NPK
Cotton	1,891,000	86	1,626,300	104,100	44,400	0	55	23	0	64	27	0	CAN, urea, DAP
Oilseeds	500,000	10	50,000	1,300	1,300	0	3	3	0	25	25	0	Urea, DAP
Fruits and vegetables	390,000	35	136,500	13,700	1,400	1,400	35	4	4	100	10	10	Urea, NPK, CAN, DAP, SOP
Other crops				13,700	1,400								
Sri Lanka - 1980													
Rice	636,000	n.a.	n.a.	54,500	23,200	19,500	86	36	31	n.a.	n.a.	n.a.	Urea, MP, AS, PR, TSP
Grasses		n.a.	n.a.	1,700	900	900				n.a.	n.a.	n.a.	
Tea	200,000	n.a.	n.a.	25,400	4,600	13,400	115	21	61	n.a.	n.a.	n.a.	Urea, MP, AS, PR
Coconut	465,000	n.a.	n.a.	12,100	7,100	19,400	26	15	42	n.a.	n.a.	n.a.	Urea, MP, AS, PR
Rubber	210,000	n.a.	n.a.	2,400	3,000	1,700	11	14	8	n.a.	n.a.	n.a.	Urea, MP, AS, PR, TSP
Other crops	460,000	n.a.	n.a.	14,500	10,900	12,000	32	24	27	n.a.	n.a.	n.a.	Urea, MP, AS, PR, TSP
Southeast and Northeast Asia													
Indonesia - 1980													
Maize	2,600,000	n.a.	n.a.	40,200	19,200	3,200	15	7	1	n.a.	n.a.	n.a.	Urea, TSP, MP
Rice	8,495,000	n.a.	n.a.	616,000	123,200	104,700	73	15	12	n.a.	n.a.	n.a.	Urea, AS, TSP
Sugarcane	165,000	n.a.	n.a.	16,900	4,900	11,800	102	30	72	n.a.	n.a.	n.a.	AS, NPK
Groundnuts	517,000	n.a.	n.a.	1,700	2,200	0	3	4	0	n.a.	n.a.	n.a.	Urea, TSP, MP
Soybeans	710,000	n.a.	n.a.	1,700	4,400	0	2	6	0	n.a.	n.a.	n.a.	Urea, TSP, MP
Pepper, dry	n.a.	n.a.	n.a.	2,200	1,200	1,200	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK
Tobacco	189,000	n.a.	n.a.	6,400	700	34	4	4	4	n.a.	n.a.	n.a.	AS, NPK
Vegetables	n.a.	n.a.	n.a.	32,700	12,200	6,100	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK
Cloves	n.a.	n.a.	n.a.	2,900	1,500	1,500	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK
Coffee	456,000	n.a.	n.a.	5,800	2,300	2,300	13	5	5	n.a.	n.a.	n.a.	Urea, NPK
Tea	83,000	n.a.	n.a.	8,700	2,900	4,400	105	35	35	n.a.	n.a.	n.a.	Urea, NPK
Coconut	n.a.	n.a.	n.a.	2,800	2,800	2,800	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK
Oil palm	n.a.	n.a.	n.a.	11,700	11,700	23,300	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK
Rubber	n.a.	n.a.	n.a.	25,500	25,500	25,500	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK

Table 6--Continued

Country/ Crop	Area Harvested	Area Fertilized		Nutrient Consumption			Nutrient Application + Harvested Area			Nutrient Application + Fertilized Area			Principal Nutrient Sources
				N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
	(hectares)	(per-cent)	(hectares)	(metric tons)			(kilograms/hectare)						
Malaysia - 1980													
Rice	1,500,000	90	1,350,000	36,500	18,000	18,000	24	12	12	27	13	13	NPK, urea, PR, MP
Tuber crops	14,000	90	12,600	300	300	300	21	21	21	24	24	24	NPK, TSP, AS, MAP
Fruits and vegetables	500,000	50	250,000	4,500	4,500	4,500	9	9	9	18	18	18	NPK
Oil palm	1,500,000	80	1,200,000	54,000	16,300	81,700	36	11	54	45	14	68	Urea, SSP, MP, AS
Rubber	3,600,000	60	2,160,000	39,000	43,800	59,000	11	12	16	18	20	27	AS, PR, MP
Philippines - 1980													
Maize	3,215,500	n.a.	n.a.	7,200	n.a.	n.a.	2	n.a.	n.a.	n.a.	n.a.	n.a.	NPK, NP, urea
Rice	3,543,600	n.a.	n.a.	117,000	n.a.	n.a.	33	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, AS, NP
Sugarcane	528,600	n.a.	n.a.	76,900	n.a.	n.a.	145	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK, AS
Vegetables	n.a.	n.a.	n.a.	3,300	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bananas and pineapples	315,700	n.a.	n.a.	17,500	n.a.	n.a.	55	n.a.	n.a.	n.a.	n.a.	n.a.	Urea, NPK, AS
Other crops	n.a.	n.a.	n.a.	2,900	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	NPK, urea, AS
Thailand - 1978													
Rice	8,288,000	n.a.	n.a.	82,900	95,300	2,700	10	11	0	n.a.	n.a.	n.a.	AS, AC, NPK
Sugarcane	480,000	n.a.	n.a.	37,100	3,300	5,500	77	7	11	n.a.	n.a.	n.a.	AS, NPK
Tobacco	153,000	n.a.	n.a.	4,000	2,500	3,000	26	16	20	n.a.	n.a.	n.a.	NPK
Rubber	n.a.	n.a.	n.a.	5,000	6,000	2,000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	NPK
Other crops	n.a.	n.a.	n.a.	39,000	26,900	23,800	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	NP, AS, NPK
Japan - 1979													
Wheat	149,000	99	147,000	13,300	14,900	18,300	89	100	123	90	101	124	Urea, SSP, MP
Maize	2,000	99	2,000	100	200	100	50	100	50	51	101	51	NPK
Rice	2,497,000	99	2,472,000	229,100	253,900	241,700	92	102	97	93	103	98	NPK
Other cereals	145,000	99	143,500	9,000	11,100	11,100	62	76	77	63	77	77	NPK
Fodder crops	1,002,000	99	992,000	114,200	132,200	102,200	114	132	102	115	133	103	NPK
Edible beans	248,000	99	245,500	9,200	26,000	25,100	37	105	101	37	106	102	NPK
Roots and tubers	189,000	99	187,100	18,500	22,900	26,400	98	121	140	99	122	141	NPK
Industrial crops	258,000	99	255,400	56,500	57,000	52,800	219	221	205	221	223	207	NPK
Fiber crops	126,000	99	124,700	34,900	18,900	22,100	277	150	175	280	152	177	NPK
Forests	48,706	n.a.	n.a.	3,800	n.a.	n.a.	78	n.a.	n.a.	n.a.	n.a.	n.a.	NPK
Fruits and vegetables	1,046,000	99	1,035,500	238,100	238,000	225,700	228	228	216	230	230	218	
Korea, Republic of - 1975													
Cereals	98,000	n.a.	n.a.	10,800	3,900	2,800	110	40	28	n.a.	n.a.	n.a.	n.a.
Barley	995,000	n.a.	n.a.	130,500	78,200	31,800	131	79	32	n.a.	n.a.	n.a.	n.a.
Rice	1,314,000	n.a.	n.a.	171,700	77,400	82,000	131	59	62	n.a.	n.a.	n.a.	n.a.
Feed crops	69,000	n.a.	n.a.	12,400	7,900	4,800	180	115	70	n.a.	n.a.	n.a.	n.a.
Potato	179,000	n.a.	n.a.	15,700	9,500	9,600	87	53	54	n.a.	n.a.	n.a.	n.a.
Industrial crops	144,000	n.a.	n.a.	10,900	6,100	3,400	76	43	24	n.a.	n.a.	n.a.	n.a.
Pulses	420,000	n.a.	n.a.	16,800	10,500	6,700	40	25	16	n.a.	n.a.	n.a.	n.a.
Tobacco	56,000	n.a.	n.a.	5,700	8,500	8,500	101	152	152	n.a.	n.a.	n.a.	n.a.
Vegetables	360,000	n.a.	n.a.	79,000	34,100	21,500	219	95	60	n.a.	n.a.	n.a.	n.a.
Mushrooms	n.a.	n.a.	n.a.	1,000	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Forests	395,000	n.a.	n.a.	2,700	4,000	1,200	7	10	3	n.a.	n.a.	n.a.	n.a.
Fruits	168,000	n.a.	n.a.	15,100	7,900	8,300	90	47	50	n.a.	n.a.	n.a.	n.a.
Mulberry	107,000	n.a.	n.a	18,700	11,100	8,300	175	104	78	n.a.	n.a.	n.a.	n.a.
Other crops	71,000	n.a.	n.a.	4,900	3,500	1,800	69	49	25	n.a.	n.a.	n.a.	n.a.

Source: Adolfo Martinez and R. B. Diamond, Fertilizer Use Statistics in Crop Production (Muscle Shoals, Ala.: International Fertilizer Development Center, 1982), Table 10 and Table 13.

Notes: n.a. means not available.

[a]For Bangladesh, data for percentage of area fertilized with N, P_2O_5, and K_2O were available. The numbers in parentheses after net application rates refer to these percentages.

Key to fertilizer and chemical abbreviations:

AC = ammonium chloride
AS = ammonium sulfate
CAN = calcium ammonium nitrate
DAP = diammonium phosphate
MP = muriate of potash
NPK = N, P_2O_5, and K_2O (compound fertilizer)
PR = phosphate rock
SOP = sulfate of potash
SSP = single superphosphate
TSP = triple superphosphate

Comparison of Bangladesh data with data at the bottom of Table 6, showing fertilizer use by crop in northeast Asian countries, suggests that potential for expansion in fertilizer use is high. But climatic conditions and available seed varieties throughout most of Korea and Japan are so different that this comparison becomes questionable. Furthermore, the price environment is exceedingly favorable in these countries (Table 7).[7]

FARM-GATE FERTILIZER AND FOODGRAIN PRICES IN BANGLADESH COMPARED WITH OTHER DEVELOPING COUNTRIES

The comparative price data in Table 7 for rice (1979 or 1980) and for wheat in 1982 or 1983 show that, if the developed countries of Korea and Japan are excluded, Bangladesh still had among the most favorable fertilizer/foodgrain price environments in the world during that period. Tables 8 and 9 show the historical development of the ratios of nitrogen to procurement prices and nitrogen and phosphate to harvest prices in Bangladesh and in the two principal fertilizer-using countries of the developing world, India and China.

It is important to note that the nitrogen-to-paddy price ratio in Bangladesh has changed considerably since it was 1.6 in 1979/80 (Table 9). Between 1980/81 and 1982/83, the ratio was 2.1-2.2, before declining to 2.0 in 1983/84 and 1.8 during July-September 1984.[8] Even at the peak ratio in 1980/81 the price environment in Bangladesh must be considered among the more favorable in the rice-growing world. Similarly, although the ratio for wheat has been as high as 1.9-2.0 (1980/81-1981/82), this would still place Bangladesh among the more hospitable price environments.

Domestic data on relative phosphate prices among developing countries are less plentiful, and in many cases less critical, since at low levels of application, crop absorption of nitrogen is more likely to be the most binding constraint on yields. Thus in developing countries, less immediate attention is placed on phosphates than

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[7]Agriculture in these developed countries is protected from international competition and receives lucrative price supports--common phenomena that often accompany massive relocation of manpower out of agriculture and rapidly rising incomes and consumer goods prices during periods of rapid industrial development. This thesis has been developed for Japan, Korea, Taiwan, Europe, Australia, and New Zealand in K. Anderson and Yujiro Hayami, The Political Economy of Agricultural Protection (Boston: Allen and Unwin, 1986).

[8]As the notes to Table 8 indicate, these ratios are based on official fertilizer prices. Farm-gate nitrogen prices have been close to official prices, except during the winter of 1981/82 and the fall of 1984 (see Chapter 7).

Table 7--Ratios of farm-gate prices of nitrogen to wheat and to paddy, various countries, 1979-83

Selected Wheat Producers	1982/83 Price Ratio of N:Wheat	Selected Rice Producers	1979/80 Price Ratio of N:Paddy
Mexico	1.3	Japan	0.5
Bangladesh	1.6	Korea, Republic of	0.7
Egypt	1.6	Indonesia	1.6
Portugal	1.6	Bangladesh	1.6
China, market price	1.6[a]	Sri Lanka	1.7
China, surplus-quota price	2.1[a]	China, market price	1.8[a]
Syria	2.1	Nepal	2.2
Canada	2.4	China, surplus-quota price	2.8[a]
Pakistan	2.6	Malaysia	3.1
United States	2.6	Philippines	3.2
Turkey	2.7	Thailand	3.4
Nepal	2.7	Pakistan	3.6
France	3.0	India	1.9-4.7
China, basic quota price	3.1[a]	China, basic quota price	4.2[a]
Brazil	3.1		
India	3.6		
Kenya	4.5		
Australia	5.4		

Sources: Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response," in China's Economy Looks Toward the Year 2000, Vol. 1, The Four Modernizations, ed. U.S. Congress Joint Economic Committee (Washington, D.C.: Government Printing Office, 1986), p. 491. Bangladesh price ratios for these and other years appear in Table 10.

Notes: Fertilizer prices are in terms of nitrogen content. Paddy and wheat prices are in terms of farm-gate prices facing farmers who are selling paddy and wheat.

[a]Chinese farmers may receive surplus quota prices for quantities of grain sold to the government in excess of assigned basic quotas. They are eligible to sell in rural and urban markets when both basic and surplus quota obligations have been met. For these years, market sales totaled a few percent of marketed grain.

Table 8--Ratios of official prices of nitrogen to procurement prices of rice and wheat in Bangladesh, India and China, 1967/68 to 1983/84

Year	Bangladesh		India		China[c]
	Rice[a]	Wheat[b]	Rice[a]	Wheat[b]	Wheat[b]
1967/68	0.78	...	2.19-2.72	1.93-2.82	4.79-4.86
1968/69	0.74	...	2.24-2.79	2.31-2.46	4.79-4.86
1969/70	0.74	...	2.37-3.06	2.70	4.79-4.86
1970/71	0.74	...	2.37-2.99	2.70	3.99-4.86
1971/72	0.58	...	1.32-2.87	2.64	3.04-4.79
1972/73	0.81	...	2.40-2.86	2.75	2.80-4.79
1973/74	1.05	...	2.18	2.78-3.00	e
1974/75	0.91	...	3.94	4.14	e
1975/76	0.91	1.51	3.64	3.83	e
1976/77	1.09	1.76	3.44	3.62	e
1977/78	0.98	1.63	2.93	3.06	e
1978/79	1.12	1.77	2.65	2.98	2.76-3.59
1979/80	1.32	2.27	2.22	2.74	1.99-2.97
1980/81	1.41	2.17	2.77	3.72	2.07-3.11
1981/82	1.41	2.17	2.97	3.93	2.07-3.11
1982/83	1.53	2.38	2.81	3.60	2.07-3.11
1983/84	d	d	2.24-2.37	3.09	2.07-3.11

Sources: The data for India and Bangladesh are from Chapters 2 and 4. The Chinese data are from Bruce Stone, "Relative Foodgrain Prices in the People's Republic of China," in Agricultural Pricing Policy in Developing Countries, ed. John W. Mellor and Raisuddin Ahmed (Baltimore: Johns Hopkins University Press, forthcoming).

Notes: Nitrogen prices are based on urea for India and Bangladesh. For China, the range includes both urea and ammonium sulfate for 1967-72. For 1978-83, only urea prices are adapted since ammonium sulfate use had fallen to less than two percent of produced nitrogen and less than three percent of imported nitrogen. The other major nitrogen fertilizer used in China throughout the period is ammonium bicarbonate, the price of which varies considerably over time and among locations.

[a]Official price of nitrogen/procurement of rice.

[b]Official price of nitrogen/procurement of price of wheat. For China, both basic quota and surplus quota prices are included in the range.

[c]Chinese data are for calendar years 1967 through 1983.

[d]Fertilizer prices were decontrolled throughout Bangladesh from April 1, 1983. But farm-gate prices averaged only a few percent above the official (ex-PDP) prices in that year.

[e]The data are not available. Scattered Chinese price data for 1973-77 suggest that the ratio was higher than in the bracketing years for at least part of the five-year period.

Table 9--Ratios of official prices for nitrogen and phosphate to farmers' harvest prices of paddy and wheat in Bangladesh and China, 1966-84

Year	Nitrogen:Paddy[a]		Nitrogen:Wheat[a]		Phosphate:Paddy[b]		Phosphate:Wheat[b]	
	Bangladesh	China	Bangladesh	China	Bangladesh	China	Bangladesh	China
1966/67	c	6.65-8.01	c	4.86-5.85	c	4.25	c	3.10
1967/68	c	6.55-6.65	c	4.79-4.86	c	3.96-4.25	c	2.90-3.10
1968/69	c	6.55-6.65	c	4.79-4.86	c	3.96-4.25	c	2.90-3.10
1969/70	1.10	6.55-6.65	c	4.79-4.86	1.10	3.96-4.25	c	2.90-3.10
1970/71	1.19	5.46-6.65	c	3.99-4.86	1.19	3.30-4.25	c	2.41-2.90
1971/72	0.86	4.16-6.55	c	3.04-4.79	0.86	3.30-3.96	c	2.41-2.90
1972/73	1.01	3.83-6.55	c	2.80-4.79	0.74	3.05-3.96	c	2.22-2.90
1973/74	1.01	c	c	c	0.67	c	c	c
1974/75	0.90	c	c	c	0.72	c	c	c
1975/76	1.49	c	1.86	c	1.19	c	1.48	c
1976/77	2.00	c	1.60	c	1.60	c	1.28	c
1977/78	1.59	c	1.56	c	1.27	c	1.24	c
1978/79	1.60	3.95-5.14	1.88	2.76-3.59	1.26	3.14-4.08[b]	1.49	2.20-2.86[b]
1979/80	1.60	2.82-4.23	1.86	1.99-2.97	1.24	2.24-3.37[b]	1.44	1.57-2.36[b]
1980/81	2.23	2.82-4.23	1.98	2.07-3.11	1.80	2.24-3.37[b]	1.59	1.65-2.47[b]
1981/82	2.08	2.82-4.23	1.93	2.07-3.11	1.77	2.24-3.37[b]	1.64	1.65-2.47[b]
1982/83	2.15	2.82-4.23	1.61	2.07-3.11	2.03	2.24-3.37[b]	1.36	1.65-2.47[b]
1983/84	1.99	2.82-4.23	c	2.07-3.11	1.88[d]	2.24-3.37[b]	c	1.65-2.47[b]
7/84-9/84	1.81	2.82-4.23	c	2.07-3.11	1.71[d]	2.24-3.37[b]	c	1.65-2.47[b]

Sources: Bangladesh fertilizer and paddy prices are from Chapter 4, Table 18. The data for wheat are from Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983). The 1982/83 harvest wheat prices were estimated using the 1981/82 harvest wheat price and the rate of increase in wholesale wheat prices between 1981/82 and 1982/83. The Chinese data are from Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response," in China's Economy Looks Toward the Year 2000, Vol. 1, The Four Modernizations, ed. U.S. Congress Joint Economic Committee (Washington, D.C.: Government Printing Office, 1986); Bruce Stone, "Relative Foodgrain Prices in the People's Republic of China," a paper prepared for the IFPRI Workshop on Food and Agricultural Price Policy, Elkridge, Maryland, April 29-May 2, 1984; and Bruce Stone, "Fertilizer Marketing and Allocation in China," a paper prepared for the World Bank, Washington, D.C., June 1, 1984.

Notes: The Bangladesh paddy prices are weighted averages of harvest prices during different seasons. For China, the range covers government basic and surplus quota prices. Since 1980, grain produced in China can be sold by farmers at rural and urban markets, once basic and surplus quota obligations are fulfilled. Prices received are substantially higher than government procurement prices, implying ratios for 1980 of: nitrogen:paddy = 1.58; nitrogen:wheat = 1.65; phosphate:paddy = 1.25; phosphate:wheat = 1.31. But the proportion of grain sold at these prices has been no more than a few percent during 1980-82. The proportions may be higher for 1983 and 1984, but the relevant price ratios would be much higher (closer to the lower end of the range indicated in the table).

Data for China are for calendar years, 1966-84.

[a]For Bangladesh, the nitrogen data are based on urea prices. For China, they are based on urea prices for 1978-84, by which time ammonium sulfate application had fallen to around 2 percent of total application of nitrogen. For 1967-72, nitrogen prices based on both urea and ammonium sulfate are used. The other major nitrogen fertilizer used in China throughout the period was ammonium bicarbonate, a lower-quality, more volatile product, the prices of which varied considerably over time and among locations, but were generally higher per unit of nitrogen than were those of urea and ammonium sulfate.

[b]For Bangladesh, the phosphate data are based on triple superphosphate (TSP) prices. For China, data are based on the official price for the major phosphate fertilizer, single superphosphate, although the actual farm-gate price varies among locations. This is a lower-quality product with not only a lower nutrient content, but a lower proportion of nutrients available due to lower solubility. In recent years, increasing quantities of TSP and DAP (diammonium phosphate) have been imported into China, although little is produced. Farm-gate price per unit of phosphate is 40-50 percent higher for these products than for single superphosphate.

[c]The data are not available. Scattered price data for China for 1973-77 suggest that the ratios were higher than those of 1972 and 1978 for at least part of the five-year period.

[d]Fertilizer prices were decontrolled throughout Bangladesh from April 1, 1983. But average farm-gate prices remained within 6 percent of the official (ex-PDP) prices during 1983 and the first nine months of 1984. At about the same time, some fertilizer (totaling 2-3 percent of domestic sales) began to be sold legally at much higher prices where imports had been negotiated outside the State Plan. Early 1980s black market prices in China approach 190 percent of official prices.

on nitrogen, and what small quantities of phosphates are used are apt to be imported and either heavily subsidized to facilitate successful introduction to farmers, or priced in relation to world market prices. World prices, of course, are considerably higher than farm-gate prices for phosphate fertilizers in Bangladesh.[9]

On phosphate-deficient soils, however, or once nitrogen application has reached a reasonably high level as is the case in the higher application areas of Bangladesh and most major growing areas in China, phosphate application can become critical. Table 10 shows that the price environment for phosphates in the form of high-quality, highly soluble triple superphosphate (TSP), is still more favorable than that in China for low-quality, single superphosphate, which exhibits low solubility.[10]

Application, nevertheless, is higher in China, reaching 35.4 kilograms per net cultivated hectare in 1983 (Table 10). In Bangladesh, in 1983/84 phosphate application increased by 72 percent over the previous year and by 63 percent over the previous peak year, 1980/81. Bangladesh uses more phosphate fertilizer per unit of farmland than most developing countries, yet this sharp increase in 1983/84 brought average application in the country to only 20.7 kilograms per net cultivated hectare.[11]

The use of manufactured potash fertilizers in China, however, is at an extremely low level relative to the prodigious use of nitrogen products. It was only 5.9 kilograms per net cultivated hectare

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[9]See Chapter 3. Among 55 countries for which manufactured phosphate fertilizer prices were listed for 1982/83 (excluding basic slag and ground rock phosphate), 8 had lower prices per unit of phosphate than did Bangladesh. Of these, only Egypt and Hungary used more phosphate per hectare than did Bangladesh. The only South, Southeast, or East Asian countries with lower phosphate prices were Pakistan and Sri Lanka, both using less phosphate than Bangladesh (Food and Agriculture Organization of the United Nations, FAO Fertilizer Yearbook, 1983 [Rome: FAO, 1984]).

[10]Chinese studies estimate that only about 15 percent of phosphates applied as single superphosphate are available in the year in which the fertilizer is administered. The proportion for TSP is about 50 percent. In acid soils, however, the slower-releasing single superphosphate may be superior in terms of the cumulative percentage of applied nutrients absorbed by crops over several years.

[11]These data are based on Chapter 1, Table 2, and Bangladesh Bureau of Statistics, Statistical Pocket Book of Bangladesh (Dhaka: BBS, 1984).

Table 10--Application of manufactured fertilizers in China, disaggregated, 1972-85

Year	Nitrogen Nutrients		Phosphate Nutrients		Potash Nutrients	
	(1,000 tons)	(kilograms/ cultivated hectare)	(1,000 tons)	(kilograms/ cultivated hectare)	(1,000 tons)	(kilograms/ cultivated hectare)
1972	3,168	31.4	1,039	10.3	n.a.	n.a.
1973	3,643	36.4	1,468	14.7	n.a.	n.a.
1974	3,490	34.9	1,368	13.7	n.a.	n.a.
1975	4,022	40.3	1,347	13.5	n.a.	n.a.
1976	4,468	45.0	1,360	13.7	n.a.	n.a.
1977	5,065	51.1	1,415	14.3	n.a.	n.a.
1978	7,726	72.7	1,114	11.2	n.a.	n.a.
1979	8,997	90.4	1,758	17.7	108	1.1
1980	10,180	102.9	2,386	24.1	128	1.3
1981	10,363	(104.3)	2,765	27.5	251	2.5
1982	10,433	(105.0)	3,448	34.7	568	(5.7)
1983	11,633	(117.1)	3,514	35.4	584	(5.9)
1984	12,470	126.8	3,920	39.9	1,011	(10.3)
1985	12,049	(121.3)	3,109	31.3	804	(8.1)

Source: Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response," in China's Economy Looks Toward the Year 2000, Vol. 1, The Four Modernizations, ed. U.S. Congress Joint Economic Committee (Washington, D.C.: Government Printing Office, 1986), p. 456; and Bruce Stone, "Systemic and Policy Adjustment in the Administration of Chinese Fertilizer Development," a paper presented to the World Bank, Washington, D.C., June 1986.

Notes: Figures in parentheses were derived assuming no change in official cultivated area for 1980-83. All official cultivated area data may be underestimated (see Bruce Stone, "The Use of Agricultural Statistics," in Chinese Agricultural Economy, ed. Randolph Barker, Radha Sinha, and Beth Rose [Boulder: Westview, 1982]). The 1982-83 data exclude application of compound fertilizer totaling 685,000 tons in 1982, 867,000 tons in 1983, and 1,796,000 tons in 1985. n.a. indicates that the potash application data for 1972-78 are not available. However, production gradually rose to a pre-1981 peak of 20,000 tons in 1978 and imports averaged around 90,000 tons (1972-74).

compared with 4.8 kilograms in Bangladesh.[12] The imbalance between considerable nitrogen application and the modest use of manufactured phosphates and potash is regarded as a serious problem by the Chinese Ministry of Agriculture and related research organizations. The soil nutrient balance remains reasonably hospitable in China only because of the very massive application of organic manures.[13]

Even simple international price comparisons perhaps should not be made without reference to seasonal variation in harvest prices. While many countries exhibit wide fluctuation in prices, some, such as China have permitted relatively little, although this is now in the process of change. Seasonal variation in Bangladesh harvest prices is presented in terms of fertilizer-to-paddy price ratios in Table 11. It is clear that in the 1980s the ratio for Aus has typically been the least favorable to farmers, while that for Aman has usually been more favorable than that for Boro by a very slight margin. On an international scale, none of the price ratios exhibited may be considered particularly intimidating. But as fertilizer prices rise in Bangladesh, the dimensions of seasonal variability and price uncertainty may become matters of increasing concern.

All of the foregoing ignores the issue of the impact of this kind of price relationship on the growth of fertilizer use. Whereas a favorable price environment unquestionably contributes to greater fertilizer purchases, international comparison does not suggest a role of primary significance for pricing relationships in determining long-term development of fertilizer application, at least within the broad range of price ratios exhibited in Table 7. Relative fertilizer prices have been higher in Thailand and the Philippines, where growth in application has been slower than in Bangladesh (Tables 1 and 6). But these two are among the only net agricultural exporters among developing countries, and the relative lack of population pressure has allowed less emphasis on yield-increasing technology in many respects, not only on the fertilizer pricing front (Table 12).

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[12]Ibid. and Table 10.

[13]These were estimated to be 10 million tons of nitrogen, 4.7 million tons of P_2O_5, and 9.7 million tons of K_2O in 1980. Most of the nitrogen, however, evaporates, so that some imbalance toward nitrogen in manufactured fertilizers is efficient. Application of P_2O_5 and K_2O in the form of organic manures would then be around 47 and 97 kilograms per net cultivated hectare (Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response," in United States Congress Joint Economic Committee (eds.), China's Economy Looks Toward the Year 2000, Vol. 1, The Four Modernizations (Washington, D.C.: U.S. Government Printing Office, 1986), p. 480.

Table 11--Ratios of fertilizer nutrient prices to farm-gate harvest prices of paddy in Bangladesh, by season, 1975/76 - 1982/83

Year	N/Aus	N/Aman	N/Boro	P_2O_5/Aus	P_2O_5/Aman	P_2O_5/Boro
1975/76	1.42	1.48	1.52	1.13	1.18	1.21
1976/77	2.25	1.77	1.89	1.80	1.42	1.51
1977/78	1.69	1.55	1.76	1.35	1.24	1.25
1978/79	2.07	1.76	1.39	1.64	1.39	1.10
1979/80	2.40	1.68	1.76	1.86	1.31	1.36
1980/81	2.32	1.96	2.08	1.87	1.58	1.67
1981/82	2.60	2.03	2.11	2.21	1.72	1.79
1982/83	n.a.	2.38	n.a.	n.a.	2.25	n.a.

Sources: Fertilizer prices per unit data of nutrient are from Chapter 4, Table 18. Harvest season paddy prices are from Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983), p. 491. Harvest price data for the 1982/83 Aman season are from BBS, Statistical Pocket Book of Bangladesh, 1983 (Dhaka: BBS, 1984), p. 443.

Notes: Nitrogen (N) price ratios are based on urea prices. Phosphate (P_2O_5) price ratios are based on triple superphosphate (TSP) prices. n.a. indicates not available when the source table was prepared.

In contrast, Malaysia has had faster growth in fertilizer use, despite a less favorable price environment than in Bangladesh.[14] The principal locus of this growth has been on economic crops, but the average intensity of use on paddy is still somewhat greater than that of Bangladesh (Table 6).

Among the other densely populated nations of Asia during the last decade, Indonesia has had a slightly faster rate of application growth with a more favorable price ratio over most of the period, while Sri Lanka has clearly experienced less rapid growth with a somewhat more favorable ratio. Among densely populated Asian countries with less favorable ratios, both India and Pakistan have experienced roughly comparable or more rapid growth.

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[14]Growth in Malaysia since the 1950s has been faster than in Bangladesh, leading to an average application rate roughly twice as great. Growth since 1961-65 has been greater in Malaysia in terms of increments but somewhat lower in percentage terms due to the low base in Bangladesh in the early 1960s.

Table 12--Rice and wheat yields, irrigation and fertilizer use intensity, and population pressure in selected countries, 1982

Country	Total Population/ Hectare of Arable Land[a]	Agricultural Population/ Arable Hectare[a]	Paddy Yields	Wheat Yields	Proportion of Irrigated Land in Arable Land[b]	Fertilizer Nutrients/ Hectare of Arable Land[b]
	(capita/hectare)		(kilograms/ harvested hectare)		(percent)	(kilograms/ net cultivated land)
Bangladesh	10.5	8.7	2,014	1,811	19.7	51.2
Burma	3.9	1.9	3,166	1,306	10.4	16.7
Indonesia	10.7	6.1	3,780	...	27.8	75.0
Korea, Democratic People's Republic	8.6	3.8	6,173	2,647	46.7	338.3
Korea, Republic of	19.4	7.0	6,151	3,348	53.7	281.7
Malaysia	14.5	6.6	2,544	...	9.0	102.1
Pakistan	4.6	2.4	2,612	1,565	72.4	61.6
Philippines	6.7	2.9	2,386	...	11.6	28.8
Sri Lanka	14.7	7.7	2,890	...	n.a.	71.3
Thailand	2.9	2.1	1,893	...	17.6	18.3
India	4.3	2.7	1,851	1,691	23.9	34.6
Japan	27.8	2.7	5,688	3,256	66.9	412.1
China	10.1	8.0	4,878	2,449	44.2	151.3
Mexico	3.4	1.2	3,544	4,409	22.2	77.8
Egypt	19.1	9.5	5,666	3,496	100.0	334.6
Turkey	1.9	1.0	4,525	1,942	7.7	53.5
Syria	1.8	0.9	5,000	1,273	9.6	27.0
Brazil	2.0	0.7	1,615	654	2.7	36.5

Source: Chinese data (excluding Taiwan) are from State Statistical Bureau of China, Statistical Yearbook of China, 1983 (Hong Kong: Economic Information Agency, 1983), pp. 109, 171, and 197-199); the remaining data are from Food and Agriculture Organization of the United Nations, FAO Production Yearbook, 1983 (Rome: FAO, 1984).

Notes: The ellipses indicate the country grows little or no wheat.

[a]Only net cultivated land (double-cropped land only counted once) and temporary fallow are included. This may be misleading for some countries. Malaysia and Sri Lanka have a high proportion of farmland under permanent crops (receiving considerable fertilizer) compared to other Asian countries. The ratios of total population to arable land plus land under permanent crops are 3.4 and 7.1 for these two countries. Those of the agricultural population are 1.5 and 3.7. Those of most other listed countries are within 5 or 10 percent of the ratios based on arable land alone. Indonesia's population density is far greater on Java, where most Indonesian fertilizer is used. However, the ratios for Indonesia as a whole comparing population and agricultural population to arable land plus land under permanent crops are 7.8 and 4.5.

[b]Net cultivated land and land under permanent crops are included.

As indicated above, the most rapid long-term growth of fertilizer application among developing countries has been recorded by China, which has had an extremely unfavorable price environment for most of the last 35 years. Nevertheless, fertilizer consumption has grown even faster since 1979 with the establishment of a more favorable price environment and rural organizational reforms to improve incentives for farmers. With average fertilizer application per unit of sown area in China standing at more than three times that of Bangladesh, only the highest paddy prices available for a small proportion of production of a minority of Chinese farmers now bears a similar relationship to fertilizer prices as exhibited throughout Bangladesh, although average agricultural (including paddy) prices for Chinese farmers relative to fertilizer prices, are still considerably less attractive than in Bangladesh.[15]

Before turning from broad international comparisons, it may be useful to note the rates of growth experienced by various wheat growing developing countries and various Asian rice growing developing countries. Table 13 shows rates of growth in a number of countries during the decade from the late 1960s to the late 1970s, based on five-year averages. Growth of Bangladesh wheat production, area, and yield stands out immediately. Although the extremely high figures in each category would not have been possible had the base figures in the 1960s been higher, the performance for wheat was clearly outstanding. It was related to irrigation and the introduction of high-yielding varieties, as well as to fertilizer application.

Conversely, growth in paddy production in Bangladesh has been slower than in all other developing countries of Asia. Growth in yields has been slower than in all other Asian countries except Sri Lanka and Thailand, which considerably exceeded Bangladesh in growth of sown area. The constraints limiting Bangladesh to this relatively poor performance for rice require more detailed examination.[16]

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[15]The higher prices for agricultural products since 1979 have proved an onerous burden for the Chinese government, absorbing one-quarter of budgetary expenditures. Consequently, procurement prices were cut back in 1985 to a 70/30 weighted average of the surplus and basic quota prices, with any excess over these quotas purchased at basic quota prices. This means that the 1985 nitrogen to paddy price ratio is 3.2 and that for wheat, 2.4, for all quota sales. Any further sales to the government face ratios of 4.2 for paddy and 3.1 for wheat (Stone, "Chinese Fertilizer Application in the 1980s and 1990s").

[16]See Chapter 4.

Table 13--Yield, production, and area growth rates for wheat and paddy, selected countries, 1966/70 - 1976/80

Country	Wheat					Rice				
	Production	Sown Area	Yield	Proportion of Production due to: Sown Area Growth	Proportion of Production due to: Yield Growth	Production	Sown Area	Yield	Proportion of Production due to: Sown Area Growth	Proportion of Production due to: Yield Growth
	(percent)									
Bangladesh	20.0	10.6	9.4	53.0	47.0	1.6	0.3	1.3	18.8	81.2
Burma	2.7	-1.3	4.0	-48.1	148.1	3.2	0.2	3.0	6.3	93.7
China	6.7	1.5	5.5	17.9	82.1	3.3	1.2	2.1	36.4	63.6
Indonesia	...	...	...	...	...	4.7	1.0	3.7	21.3	78.7
Korea, Democratic People's Republic	4.0	1.7	2.3	42.5	57.5	8.1	6.1	2.0	75.3	24.7
Korea, Republic of	11.8	-12.7	0.9	107.6	-7.6	3.7	0.2	3.5	5.4	94.6
Malaysia	...	...	...	...	...	2.7	0.4	2.3	14.8	85.2
Pakistan	5.1	1.2	3.9	23.5	76.5	4 9	2.5	2.4	51.0	49.0
Philippines	...	...	...	...	...	4.3	1.0	3.3	23.3	76.7
Sri Lanka	...	...	...	...	...	3.2	3.3	-0.1	103.1	-3.1
Thailand	...	...	...	...	...	2.2	2.4	-0.2	109.1	-9.1
India	7.4	4.0	3.4	54.1	45.9	2.5	0.8	1.7	32.0	68.0
Japan	-7.4	-9.1	1.7	122.9	-22.9	-1.6	-2.1	0.5	131.3	33.1
Mexico	2.3	-0.8	3.1	-34.8	134.8				...	...
Egypt	2.7	2.4	0.3	88.9	11.1	...	...	...	...	...
Turkey	5.3	1.0	4.3	18.9	81.1	...	...	...	...	...
Syria	7.9	3.2	4.7	40.5	59.5	...	...	...	...	
Brazil	9.9	11.0	-1.1	111.1	-11.1	...	...	...	...	

Sources: Food and Agriculture Organization of the United Nations, "FAO Production Yearbook Tapes, 1975, 1979, 1981, and 1983" (Rome, 1975, 1979, 1981, and 1983).

The data for China are from Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), pp. 138 and 141.

Note: The ellipses indicate that the country grows little or none of the crop. Although several of the countries showing ellipses actually grow nontrivial quantities of rice, the comparison is not of primary importance.

Even if comparisons with Bangladesh are confined to developing countries in Asia (where farmers are fairly skilled, but their incomes are still low), considerable social and environmental differences may severely limit comparability.[17] Perhaps the most meaningful comparisons would be with Thailand, because of similarities in cropping, risk, and other environmental conditions, with West Bengal because of similarities in society and rural population density and, to some extent, the environment, and with Guangdong Province in China because of similarities in cropping patterns, the density of rural population per unit of sown area, and environmental conditions, including weather risk.[18] But even so, there is no clear relationship exhibited between the pricing environment and long-term fertilizer development. Prices in slower growing Thailand are indeed less favorable, but so are prices in West Bengal, where the growth path of fertilizer application has been similar to that of Bangladesh (Tables 2, 3, and 7; Figure 2).

This chapter has provided general international comparisons among Asian developing countries (with some occasional data for developed countries and less-developed wheat producers outside of Asia) with respect to levels and growth of fertilizer use per unit of net and gross cropped area and with respect to farm-gate price ratios

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[17]Price data are insufficient for meaningful comparisons with Burma, Laos, Kampuchea, or Vietnam. Fertilizer use intensity in Vietnam is less than 60 percent of that of Bangladesh. Fertilizer use in the other three countries is lower still (Food and Agriculture Organization of the United Nations, FAO Fertilizer Yearbook, 1983 [Rome: FAO, 1984]).

[18]Guangdong is a subtropical, monsoon-oriented South Chinese coastal province producing 19.6 million tons of grain, soybeans, and sweet and white potatoes (evaluated at one-fifth natural weight) in 1983. Of this total 91.4 percent was paddy. The principal growing region in Guangdong is the Pearl River Valley and delta, which have rich soil resources but low-lying farmlands subject to serious flooding. Other parts of Guangdong face drought in the winter or cold dry winds, which can reduce yields. The average cropping intensity in Guangdong is 2.26. Fifty-two million people, mostly farmers, live in Guangdong, operating about 7 million acres of farmland. Thus the population density is somewhat greater per unit of net cultivated land than in Bangladesh and somewhat less dense per unit of sown area (Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1984; Zhongguo Nongyebu [China, Ministry of Agriculture], Zhongguo Nongye Nianjian, 1980 and 1983 [Agricultural Yearbook of China, 1983] (Beijing: Nongye Chubanshe [Agricultural Publishing House], 1981 and 1984).

of fertilizer nutrients to crop output. It has also focused more specifically on densely populated subtropical rice producers and on a few areas with somewhat greater claim to similarity with Bangladesh (West Bengal, Guangdong Province, and Thailand).

Although all of these comparisons are flawed in some way, the mass of material does not provide evidence that the level or rate of growth of fertilizer use is heavily determined by farm-gate fertilizer to farm output price ratios. This does not mean that levels or changes in price ratios have no effect on levels or rate of growth of fertilizer use, only that it does not appear to be a major determining factor. Chapter 4 will show this conclusion is borne out specifically for Bangladesh using cross-section and time-series data. That chapter concludes that relative prices do have some long-term impact but other demand-related variables are far more important. It may not be useful to press the international comparison further because all countries ultimately are different, and too much concentration on these differences not only renders the whole exercise more arbitrary but diminishes the usefulness of engaging in international comparisons. Before closing the chapter, however, it may be interesting to examine the experience of one developing country that has had rapid long-term growth in fertilizer use for the purpose of appreciating difficulties that Bangladesh may be moving toward, as fertilizer application increases, as well as of identifying activities important to rapid growth that have been neglected in Bangladesh.

SOURCES OF RAPID GROWTH IN FERTILIZER USE IN THE PEOPLE'S REPUBLIC OF CHINA

It will be clear from other chapters in this collection that impressive growth in fertilizer use in Bangladesh, compared with most developing countries, is due to a number of factors: the early establishment and continued activities of the East Pakistan (Bangladesh) Agricultural Development Corporation, which provided all basic nutrients, in the form of high-quality fertilizers, to broad areas throughout Bangladesh at very attractive prices; the establishment of domestic urea production capacity and international assistance to provide grants and credits for importing large quantities of fertilizer; the introduction of high-yielding rice and wheat varieties in the late 1960s and throughout the 1970s and 1980s; irrigation development during the past two decades and some efforts at flood control; and one of the densest farm extension networks among developing countries, which served to introduce farmers to fertilizer use. It may now be useful to see what was particularly instrumental

in generating the even faster long-term growth experienced by the People's Republic of China.[19]

Helped by Soviet assistance in the 1950s, China made an early commitment to construction of capacity for domestic production of chemical fertilizers. Although construction of new plants continued into the early 1960s, growth in production from the mid-1960s through the mid-1970s was dominated by the development of small-scale, locally financed chemical fertilizer plants. Although this development was inefficient relative to large plant construction under several engineering and standard economic criteria, it utilized local low-opportunity-cost resources, channeled local initiative, and developed a close interface between producers, distributors, and users. The small nitrogen plants often used local low-grade coal or coal dust, but occasionally resorted to high grade coal or natural gas. Small phosphate plants used low-grade phosphate ore to produce crude single superphosphate. By 1978, 70 percent of China's nitrogen fertilizer and 90 percent of its phosphate fertilizer were produced in the small plant sector.

In the early 1970s, China made a massive commitment to import the equipment for 13 large-scale synthetic ammonia/urea complexes, which formed the backbone of tremendous growth in production of chemical fertilizers in China in the late 1970s and early 1980s.[20] This major commitment to domestic production capacity, supplemented by small plants built on local initiative, provided consistent supply pressure on managers to find ways to move fertilizers out of inventory at highly remunerative fertilizer prices. This contrasts with import-generated growth, which often falls prey to budget cuts or foreign exchange and trade difficulties, resulting in relatively modest or at best strong but sporadic pressure to reduce inventories, followed by supply cutbacks in succeeding years.

Whereas the small plants were locally managed and boosted fertilizer use in disaggregated localities, the production from the carefully controlled larger plant sector was allocated directly to

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[19]Quantitative evidence and arguments are developed more fully in two other papers: Stone, "Chinese Fertilizer Application in the 1980s and 1990s;" and Bruce Stone, "An Examination of the Prospects for Demand for Chemical Fertilizers in the People's Republic of China," a paper prepared for the World Bank, Washington, D.C., January 3, 1984.

[20]Nitrogen production rose from 3.7 million tons of nutrients in 1975 to 12.2 million tons in 1984 (Stone, "Chinese Fertilizer Application in the 1980s and 1990s," p. 470).

high yield and market surplus areas to assure adequate supplies where marketing ratios and (until very recently) response ratios were high. Proliferation of these poorer quality and relatively more expensive fertilizers at dispersed locations required farmers to learn to use and handle these products without state assistance since availability of higher quality, cheaper fertilizers was low (outside the high yield and other market-oriented areas). Since the small plants were locally run, considerable local cooperation was achieved to make the sector a success. As some of those localities have gained access to higher quality supplies, their ability, developed over more than a decade, to use fertilizers frugally and fairly efficiently has resulted in high marginal response despite poorer land and infrastructure.

Like Bangladesh, China has had a public mechanism for broadly distributing fertilizer supplies, providing at least small amounts of fertilizer in most locations to establish early contact. In the 1950s, the distributing organizations were the State Supply and Marketing Cooperatives (SMCs), which eventually came under full state control and were responsible for purchasing produce and providing basic agricultural tools and simple consumer goods. Later these responsibilities were split: procurement was taken over by specialized organizations, SMCs handled consumer goods, and the Agricultural Means of Production Corporation was established to distribute inputs for farm production processes. Yet the expedient of providing a large share of available fertilizer in exchange for procurement continued under AMPC auspices, guaranteeing that market surplus areas would receive adequate fertilizer to continue to increase production and marketings. Other yield-increasing inputs and services were also concentrated in these areas, which tended to have superior soil resources and water control, leading quickly to high rates of application.

This orientation has contributed to formation of a dual structure in Chinese agriculture, which can be criticized on equity grounds but was initially efficient in an output-maximizing sense, since both average and marginal response ratios were highest in these more favored areas. But as China's need to increase domestic procurement of output intensified, effective price ratios for these favored areas were allowed to decline in order that they would continue to increase application despite declining marginal response rates at very high levels of use. Now the practice of providing fertilizer in exchange for procurement at reduced price ratios is no longer efficient even in an overall production sense because marginal response ratios on high-yield land have declined compared to the

marginal rates on low- and medium-yield lands, which receive little fertilizer.[21]

However, sophisticated institutions have developed in the high-application provinces, which have facilitated both the proliferation of efficient farmers' practices to maximize response to applied fertilizers and the substantial improvement of product quality, bagging, and application procedures related to small plant fertilizers. It is no accident that the most sophisticated research and extension institutions related to soil fertility are concentrated in Shanghai, 210.8 kilograms of nutrients per hectare; Fujian, 196.0 kilograms per hectare; Jiangsu, 174.3 kilograms per hectare; and Zheijiang, 151.2 kilograms per hectare.[22] These provinces were ranked 1, 2, 4, and 8 out of 29 in fertilizer application intensity in 1983, and 4, 1, 3, and 7 in 1985 (Table 3). All are multiple cropping, paddy-producing provinces that also grow high-yielding wheat. All are densely populated provinces. The same four provinces are the national leaders in terms of efficiency of the small plant sector, with Zhejiang and Shanghai being the front runners. The most famous soil science institute in the country is in Jiangsu. The most innovative soil and fertilizer institute is in Fujian, where an applicator was developed for deep placement of pelletized small plant nitrogen fertilizer. This applicator was used throughout Fujian by the late 1970s, when introduction to other provinces became quite active. Jiangsu has developed fertilizer application procedures without equipment, which substantially reduce evaporation and denitrification losses on paddy. Each of these provinces is pressing hard with applicators and improved application methods.

The measured rate of uptake of nitrogen from low-quality volatile ammonium bicarbonate under normal broadcast conditions has ranged in various Chinese studies from 24 to 30 percent, with application to calcareous paddy soils at the low end of the range. Yet ammonium sulfate and urea do no better on calcareous paddy soils, although on more acid soils, recovery by rice plants could be as high as 40 percent for urea and almost 60 percent for ammonium sulfate. On nonpaddy soils, uptake for broadcast urea and ammonium sulfate is generally estimated at around 50 percent. These are important statistics because they are relatively similar to those found for Bangladesh.

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[21]In some high application areas, the marginal response has declined to one-tenth or one-fifteenth of medium- and low-yield (low-application) land, and in some localities there is virtually no marginal response.

[22]For comparison with Bangladesh districts and the other Chinese provinces, see Tables 3 and 4. The figures quoted are averages for the province. High application land in these provinces may receive up to 600 kilograms per hectare.

By contrast, deep placement of low-quality ammonium bicarbonate can improve recovery to between 37 and 52 percent, with some further improvement if granulized. For deep-placed urea, the lower bound appears to be similar, but the upper bound for granulized urea could exceed 80 percent under good conditions. Top dressing in the middle stages of rice growth showed more than 60 percent recovery, although less was retained in the soil for potential later uptake. Jiangsu's application technique of removing paddy water during fertilizer application, followed by rapid incorporation, has had equally good results in reducing nitrogen losses but requires a high degree of water control. Fortunately, each of these provinces has done considerable leveling of land and includes areas of relatively good water management. Elsewhere in China water management and fertilizer application efficiency tend to be well below these levels, although they have improved somewhat since the 1950s and 1960s. The important point is that the high-application provinces are putting considerable effort into improving efficiency of application and have enjoyed some degree of success. The remainder of China is slowly benefiting from their experience.[23]

Thus, Chinese efforts not only succeeded in distributing fertilizer supplies fairly broadly throughout China during a period of rapidly growing domestic production, but also succeeded in increasing efficiency of fertilizer use, especially during the 1970s and 1980s. While this latter development may help to explain the high current levels of use in the four East and Southeast China provinces, despite a less attractive price environment, and is an indication of their orientation in attempting to further raise application levels, it cannot explain considerably higher growth throughout China than in Bangladesh and faster growth during the 1950s and 1960s. Faster growth in the 1950s was closely related to development of the public distribution system, which began even earlier in China than in Bangladesh. However, growth throughout China for the entire three-decade period is apt to be associated with organic manure use.

Over thousands of years, Chinese farmers developed the peasant technology of recycling organic materials to high levels of pre-

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[23]The previous three paragraphs are based on an examination of Chinese soil studies in journals, as well as visits to relevant institutions throughout China. The material is discussed in Stone, "Chinese Fertilizer Application in the 1980s and 1990s;" Bruce Stone, "Fertilizer Marketing and Allocation in China," a paper prepared for the World Bank, International Food Policy Research Institute, Washington, D.C., 1984; and Bruce Stone, "Chinese Experience and Research on Fertilizer Use Efficiency," Proceedings of the International Seminar on Fertilizer Use Efficiency (Lahore: Fauji Fertilizer Co., 1986).

industrial sophistication. They probably have no peers among the developing world in organic manipulation of soil quality. Organic manures used in China include human, large animal, and swine wastes, compost, crop residues, ashes, oilseed cakes, urban waste, and mud from rivers and ponds. In addition, green manure crops, in particular azolla, alfalfa, lupine, vetch, sesbania, and beans, are grown whenever possible. In recent years, green manure acreage has expanded rapidly to 10 million hectares, or roughly one-fifteenth of sown area, because the Chinese are worried about the growing imbalance between chemical and organic fertilizers, despite application of some 25 million tons of nutrients in organic form.[24]

How has organic manure use in China facilitated rapid growth in chemical fertilizer application? It has allowed China great success with a very simple approach to the development of fertilizer use: adding more nitrogen. China's balance between nitrogen, phosphate, and potash is far more skewed toward nitrogen than that of Bangladesh.[25] Most applied phosphates and potash are furnished organically. Because the Chinese have traditionally applied these materials, their use is reasonably sophisticated. During the past 35 years and, throughout China, most components required for proper nutrient balance have been supplied over broad areas by organic manures.

As long as the bulk of applied nutrients were supplied from organic sources,[26] the system was essentially nitrogen-starved because much of the nitrogen evaporates from human and animal wastes, which constitute the principal nutrient sources. Until the Chinese applied extremely large amounts of urea and ammonium bicarbonate, lack of nitrogen was the major constraint in the system, and chemical fertilizer application achieved consistently high marginal response rates over time despite rapid growth in application. Now that chemical fertilizers dominate nutrient application in high-yield areas, the nutrient balance is becoming an important constraint, and

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[24]Ibid. Various estimates of organic manure are provided. About 60 percent of 1983 nutrient application was organic manure. The remainder consisted of 16.6 million tons of chemical fertilizers. All tables and figures for China in the preceding part of this section refer to chemical fertilizers only.

[25]The 1983/84 aggregate NPK application ratio for Bangladesh was 1:0.48:0.11 (Table 1) as opposed to 1:0.30:0.05 in China (Table 10), ignoring some application of compound fertilizers. Although the proportion of potash improved slightly, that of phosphate remained roughly the same through 1985. In 1978, it was even more skewed toward nitrogen: 1:0.14:0.01.

[26]The proportion probably exceeded 90 percent into the 1970s.

Chinese farmers must learn how to use these manufactured products with greater sophistication.

Until recently, organic manure application postponed the day when micronutrient difficulties would become a limiting factor. Now deficiencies of zinc and boron are constraining response to nitrogen in many Chinese high-yield areas. And problems with manganese and molybdenum have occasionally appeared. China, unlike Bangladesh, has avoided sulfur deficiencies inasmuch as the principal phosphate fertilizer applied is domestically produced single superphosphate. In addition, the leading nitrogen fertilizer used in China until the late 1960s was ammonium sulfate. In Bangladesh, sulfur has not been regularly applied with nitrogen and phosphate because urea and TSP contain no sulfur. In addition, TSP may also provide so many phosphate ions around the root zones of crops that it may exacerbate certain micronutrient deficiencies by binding with ions of these elements. It is interesting to note that Bangladesh is running into serious micronutrient problems in addition to sulfur deficiencies at much lower levels of nitrogen application than did China, probably because the high organic application rates in China took care of these minor requirements until the recent period.[27]

As China's experience demonstrates, unsophisticated use of fertilizer, even at high prices, can be profitable for farmers until high rates of nitrogen application are achieved (Tables 7-9). At high rates, marginal response to nitrogen will decline rapidly so that either prices must be cut to maintain profitability for expanded use or efficiency must be improved. Appropriate balance, timing, and application methods for particular crops on particular soils, coordinated with all other cultural practices, become important. In China, this basic information is provided by a wide network of extension personnel, demonstration farms, and model farmer programs, backed up a system of agricultural colleges and national agricultural research. The basic network also exists in Bangladesh, but there are great differences between providing basic information and developing sophistication about these complicated processes among broad groups of farmers. And most of China, like most of Bangladesh, is handicapped by the slow pace of progress in building quality institutions. It was relatively easy to develop production and broad distribution of fertilizers to achieve a rapid growth rate, but this expansion is now limited by the lack of quality and sometimes quantity in areas such as research, extension, and soil survey work.

Of course, China's success can also be discussed in terms of efforts to shift agriculture's entire production function upward, which is of particular importance because fertilizer application growth has been deliberately concentrated in technical transformation

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[27]See Chapter 5 and Stone, "Chinese Fertilizer Application in the 1980s and 1990s."

areas. As in Bangladesh, the principal components of this transformation have been better water control, fertilizer, and high-yielding seed varieties.

A much larger proportion of Chinese land was irrigated in the 1950s than was the case in Bangladesh. Growth proceeded rapidly in the 1950s, followed by a large decline and recovery by the mid-1960s. There was rapid growth during the 1965-78 period, but expansion has stagnated since 1978 (Table 14). Growth of power irrigation was rapid from the late 1950s through 1979, then stalled, although electricity consumed in rural areas has continued to grow even during the recent period. It is interesting to note that chemical fertilizer application doubled between 1978 and 1985 despite the lack of growth in either irrigated area or power-irrigated area. This must not be interpreted to mean that irrigation has had nothing to do with fertilizer application expansion in China. Irrigated area was roughly 45 percent of cultivated area from 1978-85. Fertilizer application was growing partly on the basis of unrealized potential created by previous irrigation expansion. The full effect of irrigation development on growth in use of fertilizers has been realized with long lags.

As the result of a push to develop seed improvement systems in the 1950s, 80 percent of rice area was covered with new varieties, but these were not the dwarf rice varieties that are common today. That development took place in the 1960s and 1970s, as in Bangladesh, but it began earlier and developed more thoroughly in China. The first semidwarf variety was developed in 1959, and similar varieties spread rapidly in the early 1960s to most areas in the south. Radiation breeding gained acceptance in the 1960s, but conventional breeding has been the most common method. Important breeding objectives have been the development of semidwarfs and varieties with varying maturity dates and resistance to pests.[28] Seed improvement has been facilitated by good irrigation coverage on paddy, amounting to about 80 percent of sown area.

China not only bred its own rice varieties with conventional techniques, but it developed the original technique of rice hybridization. Although this difficult process began in 1964 and did not reach fruition on farmers' fields until 1978, China is today the only country with an important proportion of rice acreage in hybrid varieties (about 20 percent). Shifting to higher-yielding hybrid

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[28]International Rice Research Institute and Chinese Academy of Sciences, Rice Improvement in China and Other Asian Countries (Los Baños: IRRI, 1980); International Rice Research Institute, Rice Research and Production in China: An IRRI Team's View (Los Baños: IRRI, 1978); and Anthony M. Tang and Bruce Stone, Food Production in the People's Republic of China, Research Report 15 (Washington, D.C.: IFPRI, 1980).

Table 14--Effectively irrigated area, fertilizer nutrient application, small hydropower stations, and electrical use in rural areas in China, 1952-85

Year	Irrigated Area: Total	Irrigated Area: Power-Irrigated Area	Proportion of Power-Irrigated Area to Effectively Irrigated Area	Consumption of Chemical Fertilizers[a]	Small Hydropower Stations: Total	Small Hydropower Stations: Generating Capacity	Electricity Consumed in Rural Areas[b]
	(1,000 hectares)		(percent)	(1,000 metric tons)	(units)	(1,000 kilowatt hours)	(100 million kilowatt hours)
1952	19,959	317	1.6	78	98	8	0.5
1957	27,339	1,202	4.4	373	544	20	1.4
1962	30,545	6,065	19.9	630	7,436	252	16.1
1965	33,055	8,093	24.5	1,942			37.1
1978	44,965	24,895	55.4	8,840	82,387	2,284	253.1
1979	45,003	25,321	56.3	10,863	83,224	2,763	282.7
1980	44,888	25,315	56.4	12,694	80,319	3,041	320.8
1981	44,574	25,231	56.6	13,349	74,017	3,360	369.9
1982	44,177	25,145	56.9	15,134	66,256	3,530	396.9
1983	44,644	25,265	56.6	16,598	62,328	3,463	428.1
1984	44,453	25,062	56.4	17,398	60,062	3,615	464.0
1985	44,036	24,629	55.9	17,758	55,754	3,802	508.9

Sources: Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 175; Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1986 (Beijing: Zhongguo Tongji Chubanshe [Statistical Publishing House of China], 1986), p. 149.

[a]Figures of and prior to 1965 refer to sales of chemical fertilizer nutrients; those since 1978 refer to application of nutrients.

[b]Includes electricity provided by state power grid as well as by rural power stations, excluding electricity consumed by state-owned units located in rural areas.

varieties (HYVs) contributed equally to production as has growth of yields on conventional HYV dwarf varieties in recent years.[29]

China also has one of the fastest systems in the world for development, local adaptation, field testing, and popularization of a new variety, once the basic research breakthrough has been made.[30] As part of this process, the high qualitative development of seed stations and seed supply companies has been particularly important, as has been a closely linked network of agricultural technical stations and demonstration and breeding stations for seed strain improvement (Table 15).

China has also developed HYVs of wheat. The biggest breakthroughs began about 1973 with Chinese varieties crossed with Mexican varieties from the International Center for Wheat and Maize Improvement (CIMMYT). Descendant semidwarf wheat is sown on almost all irrigated wheat lands in China. Wheat production grew from 18.1 million tons in 1952 to 53.8 million tons in 1978 and reached a peak of 87.8 million tons in 1984. Wheat sown area increased during the entire period from 24.8 million hectares to 29.6 million hectares, but most of the increase occurred between 1952 and 1957. Yields increased from 0.73 tons per hectare in 1952, to 1.84 tons per hectare in 1978, to 2.97 tons per hectare in 1984.[31] The success

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[29]Ibid., and Bruce Stone, "Trends in Chinese Hybrid Rice Production," International Food Policy Research Institute, Washington, D.C., April 1984 (mimeographed). Chinese paddy production has increased from 137 million tons in 1978 to a peak of 178 million tons in 1987. Most of the growth since 1952, and all of the growth since 1957, has been due to yield increases: 2.41 tons per hectare in 1952, 2.70 tons per hectare in 1957, 2.94 tons per hectare in 1965, 3.945 tons per hectare in 1978, 5.10 tons per hectare in 1983, 5.37 tons per hectare in 1984, and 5.25 tons per hectare in 1985 (Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1956, pp. 180 and 185).

[30]This process has often occurred in three to four years in China: Thomas B. Wiens, "The Evaluation of Technology and Policy Capabilities," in Chinese Economy Post-Mao, ed. U.S. Congress Joint Economic Committee (Washington, D.C.: Government Printing Office, 1978); Bruce Stone, "China's 1985 Foodgrain Production Target," in Anthony M. Tang and Bruce Stone, Food Production in the People's Republic of China, Research Report 15 (Washington, D.C.: International Food Policy Research Institute, 1980); and Bruce Stone, et al., "Agro-ecological Zones for Wheat Production in China: A Compendium of Basic Research Materials," International Food Policy Research Institute, Washington, D.C., July 1985 (mimeographed).

[31]Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1984, pp. 137, 143, and 153; Zhongguo Guojia Tongjiju, Zhongguo Tongjiju Nianjian, 1986, pp. 174, 180, and 185.

Table 15--Numbers of agricultural service institutions in China, various years, 1949-1984

Year	Agricultural Technical Stations	Seed Stations and Seed Companies	Demonstration and Breeding Stations for Seed Strain Improvement	Meteorological Observations	Weather Stations
1949	n.a.	n.a.	n.a.	5	96
1950	10	n.a.	n.a.	n.a.	n.a.
1952	232	n.a.	n.a.	34	283
1957	13,669	1,390	1,899	110	1,537
1962	n.a.	n.a.	n.a.	227	2,134
1965	n.a.	n.a.	n.a.	221	2,162
1978	n.a.	n.a.	n.a.	294	2,446
1979	17,622	2,369	2,418	294	2,445
1980	15,114	2,436	2,404	294	2,374
1981	15,415	2,370	2,392	293	2,361
1982	17,300	2,787	2,421	296	2,352
1983	14,694	2,548	2,271	296	2,355
1984	14,035	2,545	2,414	294	2,279

Source: Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 189; State Statistical Bureau, PRC, Statistical Yearbook of China 1985 (Hong Kong and Beijing: Economic Information and Agency and China Statistical Information and Consulting Service Center, 1985), p. 301.

Note: n.a. indicates not available.

story for wheat was closely related to surface irrigation development in the 1950s and early 1960s, followed by tubewell and reservoir development in the late 1960s and 1970s. A major boost from varietal improvement in the late 1970s and, of course, fertilizer application, all contributed to wheat's success (Table 5).[32]

Fertilizer, irrigation, and extensive dissemination and development of HYVs have only been a part of the technical transformation effort, although they are the best-known elements outside of China. China's Ministry of Water Control and Electric Power has traditionally been most concerned with flooding, not irrigation. Drought was traditionally a common occurrence on the North China Plain, which became China's fastest growing region in the 1970s due to tubewell development.[33] But flooding has been the bane of China's most productive growing areas for centuries. These are located primarily in central China in the Yangzi River region and in the Pearl River Delta in the South. In addition, the North China water table is very close to the surface and is prone to waterlogging during peak precipitation months of July and August. This can bring about severe salinization difficulties, as can overirrigation. Rapid but ill-designed irrigation of the North China Plain with Yellow River water in the late 1950s and early 1960s resulted in a loss of at least 1.3 million hectares of farmland to soil salinity.[34] Thus both year-to-year yield risk and risk of long term deterioration have been important problems for Chinese agriculture.

Table 16 presents time series of Chinese sown area affected by various natural disasters, especially droughts and floods. The table shows that disasters still are a regular feature of the Chinese agricultural environment. It is always difficult to evaluate the validity of intertemporal comparisons based on such materials, but it is clear that while disaster-affected areas have increased since the 1950s, the "severely affected" proportion of the total (those experiencing at least 30 percent yield loss) has generally declined. In particular, the severely affected flood areas have declined as a proportion of the total. Although a stubborn opponent, flooding has

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[32]Stone, "China's 1985 Foodgrain Production Target"; and Stone et al., "Agroecological Zones for Wheat Production in China."

[33]John Lossing Buck, Land Utilization in China, Statistics (Nanking: University of Nanking Press, 1937); Stone, "China's 1985 Foodgrain Production Target: Issues and Prospects."

[34]Bruce Stone, "The Chiang Jiang Diversion Project: An Overview of Economic and Environmental Issues," in Long-Distance Water Transfer: A Chinese Case Study and International Experiences, ed. Asit K. Biswas, Zuo Dakang, James E. Nickum, and Liu Changming, Water Resources Series Vol. 3 (Dublin: Tycooly International Publishing Company, 1983).

[illegible] area affected by natural disasters, 1949-84

Year	Total: Total Disaster Affected Crop Area[a]	Total: Severely Affected Area[b]	Total: Severely Affected Proportion of Total	Flooding: Disaster Affected Crop Area[a]	Flooding: Severely Affected Area[b]	Flooding: Severely Affected Proportion of Total	Droughts: Disaster Affected Crop Area[a]	Droughts: Severely Affected Area[b]	Droughts: Severely Affected Proportion of Total
	(million hectares)		(percent)	(million hectares)		(percent)	(million hectares)		(percent)
1949	n.a.	8.53	n.a.	n.a.	8.53	n.a.	n.a.	n.a.	n.a.
1950	10.01	5.12	51.1	6.56	4.71	71.8	2.40	0.41	17.1
1951	12.56	3.78	30.1	4.17	1.48	35.5	7.83	2.30	29.1
1952	8.19	4.43	54.1	2.79	1.84	65.9	4.24	2.59	61.1
1953	23.42	7.08	30.2	7.41	3.20	43.2	8.62	0.68	7.9
1954	21.45	12.59	58.7	16.13	11.31	70.1	2.99	0.26	8.7
1955	19.99	7.87	39.4	5.25	3.07	58.5	13.43	4.14	30.8
1956	22.19	15.23	68.6	14.38	10.99	76.4	3.13	2.06	65.8
1957	29.15	14.98	51.4	8.08	6.03	74.6	17.21	7.40	43.0
1958	30.96	7.82	25.3	4.28	1.44	33.6	22.36	5.03	22.5
1959	44.63	13.73	30.8	4.81	1.82	37.8	33.81	11.17	33.0
1960	65.46	24.98	38.2	10.16	4.93	49.0	38.13	16.18	42.4
1961	61.75	28.83	46.7	8.87	5.40	60.9	37.85	18.65	49.3
1962	37.18	16.67	44.8	9.81	6.32	64.4	20.81	8.69	41.8
1963	32.18	20.02	62.2	14.07	10.48	74.5	16.87	9.02	53.5
1964	21.64	12.64	58.4	14.93	10.04	67.2	4.22	1.42	33.6
1965	20.80	11.22	53.9	5.59	2.81	50.3	13.63	8.11	59.5
1966	24.21	9.76	40.3	2.51	.95	37.8	20.02	8.11	40.5
1970	9.97	3.30	33.1	3.13	1.23	39.3	5.72	1.93	33.7
1971	31.05	7.45	24.0	3.99	1.48	37.1	25.05	5.32	21.2
1972	40.46	17.18	42.5	4.08	1.26	30.9	30.70	13.61	44.3
1973	36.49	7.62	20.9	6.24	2.58	41.3	27.20	3.93	14.4
1974	38.65	6.53	16.9	6.40	2.30	35.9	25.55	2.74	10.7
1975	35.38	10.24	28.9	6.82	3.47	50.9	24.83	5.32	21.4
1976	42.50	11.44	26.9	4.20	1.33	31.7	27.49	7.85	28.6
1977	52.02	15.16	29.1	9.10	4.99	54.8	29.85	7.01	23.5
1978	50.79	21.80	42.9	2.85	0.92	32.3	40.17	17.97	44.7
1979	39.37	15.12	38.4	6.76	2.87	42.5	24.65	9.32	37.8
1980	44.53	22.32	50.1	9.15	5.03	54.9	26.11	12.49	47.8
1981	39.79	18.74	47.1	8.62	3.97	46.1	25.69	12.13	47.2
1982	33.13	16.12	48.7	8.36	4.46	53.3	20.70	9.97	48.2
1983	34.71	16.21	46.7	12.16	5.75	47.3	16.09	7.59	4[illegible]
1984	31.89	15.26	47.9	n.a.	5.40	50.5	15.82	7.02	44.[illegible]

Source: Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 190; State Statistical Bureau, PRC, Statistical Yearbook of China 1985 (Hong Kong and Beijing: Information and Economic Agency and China Statistical Information and Consultancy Service Centre, 1985), p. 302.

Note: n.a. indicates not available.

[a]Natural disasters include floods, drought, frost, freezing, typhoons, and hailstorms.

[b]Severely affected areas are those where crop production is reduced by at least 30 percent relative to normal years due to natural disaster.

been brought somewhat under control in China. Droughts, if anything, have appeared to increase, but this may be due to acreage expansion onto marginal lands, and the high "severely affected" proportion may be related to overexpansion of wheat onto relatively unsuitable areas.

It is worth noting that the major rice-growing provinces, such as Jiangsu, Zhejiang, Hunan, Sichuan, and Guangdong, while not exempt from flooding, exhibited a low proportion of severely affected areas in 1983 (Table 17). In general, it is now drought (especially in the northern part of China) that is typically the greatest scourge, while in the first 30 years of the 20th century it was primarily flooding that caused massive disasters.[35] This is due to increased population and agricultural production in dry areas, as well as the relative success of flood control efforts. On some lands, including the Pearl River Delta in Guangdong and the lower Yangtze valley, flooding at certain times of the year is difficult to control, but the situation has unquestionably improved. In Tables 18-21 indicators of infrastructural efforts for protection against droughts, floods, and salinization are quantified. These efforts have been supplemented by a local meteorological network that attempts to warn farmers of coming weather conditions (Table 15). In many areas provisions have been made to utilize this information for amelioration of adverse effects on yields.

Numerous efforts have been made to mitigate risks farmers face through infrastructural and institutional development in China, and to shift upward the "normal year" production function through technical transformation of agriculture. But what has insured Chinese farmers against financial risk (since the yield risk reduction efforts, however sedulously pursued, could never be completely successful)? Until 1985, the Chinese government maintained an official position of standing ready to purchase all marketed agricultural output at prices that tended to grow or remain stable for some time. But the government's promise to be a guaranteed buyer has sometimes not been honored. Moreover, the prices offered have typically been quite unattractive. Although agricultural output prices have been raised periodically, while those of agricultural inputs have occasionally declined, the original prices were so low and the rate of increase of purchased inputs so rapid (especially since the mid-1960s) that a serious burden was placed on farmers' finances. By far the largest cash cost of production has been for chemical and organic fertilizers (Table 22). Against this cost, agricultural credit provision has been meager. Loans for all

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[35]Buck, Land Utilization in China, Statistics; Stone, "China's 1985 Foodgrain Production Target."

Table 17--Proportion of Chinese provincial sown area affected by natural disasters, 1983

Province	Total Sown Area[a] (1982)	Total Natural Disaster-Affected Proportion[b] (1983)	Total Severely Affected Proportion of Sown Area[c] (1983)	Severely Affected Proportion of Disaster Area[d] (1983)	Flood-Affected Proportion of Sown Area (1983)	Severely Flood-Affected Proportion of Sown Area[c] (1983)	Drought-Affected Proportion of Sown Area (1983)	Severely Drought-Affected Proportion of Sown Area[c] (1983)
	(1,000 hectares)				(percent)			
All China	144,685	24.0	11.2	46.7	8.4	4.0	11.1	5.2
Beijing	642	25.2	13.9	54.9	...	...	20.2	10.9
Tianjin	610	43.9	24.7	56.3	...	...	38.2	22.1
Hebei	8,598	33.4	20.4	61.3	1.4	0.8	27.5	17.8
Shanxi	4,116	42.4	21.0	49.5	6.2	1.5	27.2	13.7
Inner Mongolia	4,633	37.9	21.8	57.6	4.5	2.9	27.1	16.5
Liaoning	3,797	26.4	10.7	40.5	5.1	2.0	15.5	5.3
Jilin	4,065	16.2	6.0	36.9	6.0	3.8	2.1	0.1
Heilongjing	8,483	23.0	7.9	34.5	16.8	4.9	1.8	0.7
Shanghai	759	10.7	1.4	13.6	0.1	...	...	...
Jiangsu	8,624	23.0	7.3	31.6	10.8	3.8	8.4	2.6
Zhejiang	4,627	20.9	9.8	47.1	12.0	6.7	6.0	2.3
Anhui	8,009	22.5	11.1	49.6	15.0	9.6	5.7	0.9
Fujian	2,469	27.5	7.4	27.0	9.0	4.1	14.5	1.6
Jiangxi	5,531	24.5	14.8	60.5	13.3	8.0	3.7	3.6
Shandong	10,315	31.3	14.3	45.6	0.6	0.1	27.1	12.5
Henan	11,070	17.2	7.9	46.0	7.1	4.3	8.1	2.9
Hubei	7,463	29.7	15.8	53.1	19.4	10.7	5.5	2.5
Hunan	7,967	25.1	12.9	51.3	10.1	5.9	9.0	4.7
Guangdong	6,401	20.0	6.7	33.5	9.3	3.6	6.3	1.3
Guangxi	4,809	16.3	6.0	36.5	3.5	1.8	10.4	3.1
Sichuan	12,129	11.8	3.7	31.2	5.4	0.7	4.4	1.9
Guizhou	2,933	28.4	11.1	39.3	12.2	3.6	7.9	3.5
Yunnan	3,970	27.5	13.3	48.3	5.2	2.0	15.4	8.3
Xizang	218	72.4	27.5	38.0	0.5	...	60.5	24.3
Shaanxi	4,735	32.6	19.6	60.0	17.4	10.4	10.8	7.6
Gansu	3,413	17.5	7.9	45.5	3.7	0.8	3.0	1.8
Qinghai	506	21.9	9.7	44.1	1.6	1.0	...	...
Ningxia	806	14.4	7.7	53.4	0.2	...	8.8	5.3
Xinjiang	2,996	5.0	3.2	65.1	0.2	0.1	2.0	1.4

Sources: Calculated from Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 191; and 1982 sown area data from Zhongguo Nongyebu [Chinese Ministry of Agriculture], Zhongguo Nongye Nianjian, 1983 (Agricultural Yearbook of China, 1983] (Beijing: Nongye Chubanshe [Agricultural Publishing House], 1984).

[a]1983 sown area data are not yet available. 1982 data have been substituted.

[b]Natural disasters include flood, drought, freezing, typhoons, and hailstorms.

[c]Severely affected areas are those where crop production is reduced by at least 30 percent relative to normal years due to the natural disaster.

[d]The third column divided by the second.

Table 18--Soil and water conservation, prevention of waterlogging, and improvement of saline land in China, 1982-85

Area/Conservation Measure	1982	1983	1984	1985
Total area prone to waterlogging (1,000 hectares)	23,777	24,066	24,235	24,207
Area with waterlogging prevention measures (1,000 hectares)	18,092	18,867	18,399	18,584
Proportion with prevention measures (percent)	76.1	78.4	75.9	76.8
Total area subject to water loss and soil erosion (1,000 square kilometers)	120.9	120.3	121.0	129.2
Area with soil and water conservation measures (1,000 square kilometers)	41.4	42.4	44.6	46.4
Proportion with conservation measures (percent)	34.2	35.2	36.9	35.9
Total area of saline cultivated land (1,000 hectares)	7,243	7,357	7,333	7,693
Saline area improved (1,000 hectares)	4,265	4,391	4,474	4,569
Proportion of saline area improved (percent)	58.9	59.7	61.0	59.4
Total length of dykes and embankments (1,000 kilometers)	17.1	17.5	17.9	17.7
Land protected by dykes and embankments (1,000 hectares)	33,620	33,882	35,459	31,060

Source: Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 179; and Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1986 [Statistical Yearbook of China, 1986] (Beijing: Zhongguo Tongji Chubanshe [Statistical Publishing House of China], 1986), p. 150.

Table 19--Mini-reservoirs and power-pumped wells in China, 1978-83

Item	1978	1982	1983
Mini-reservoirs (1,000)	4,530	6,321	6,192
Capacity (100 million cubic meters)	283	268.5	263.6
Power-pumped wells (1,000)	2,553	2,621	2,672
Wells equipped with pumps (1,000)	2,029	2,095	n.a.

Source: Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 179.

Note: n.a. indicates not available.

Table 20--Effectively irrigated area in China under irrigation systems with capacity of at least 1,000 hectares, 1982-85

Irrigating Capacity	Number of Irrigation Systems at Year End				Effectively Irrigated Area			
	1982	1983	1984	1985	1982	1983	1984	1985
					(1,000 hectares)			
Total	5,252	5,288	5,319	5,281	20,578	20,808	20,775	20,777
33,000 hectares and over	66	65	71	71	5,788	5,725	5,994	5,996
7,000 - 33,000 hectares	565[a]	604	546	524	6,800[a]	6,978	6,600	6,462
1,000 - 7,000 hectares	4,621	4,619	4,702	4,686	7,990	8,105	8,181	8,319

Source: Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 [Statistical Yearbook of China, 1984] (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 179; and State Statistical Bureau of China, Statistical Yearbook of China, 1983 (Hong Kong: Economic Information and Agency, 1983), p. 200; State Statistical Bureau, PRC, Statistical Yearbook of China, 1985 (Hong Kong and Beijing: Economic Information and Agency and China Statistical Information and Consulting Service Centre, 1985), p. 284; Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1986 [Statistical Yearbook of China, 1986] (Beijing: Zhongguo Tongji Chubanshe [Statistical Publishing House of China], 1986), p. 150.

[a]For 1982, these data may be disaggregated to 72 larger systems (23-33,000 hectares) irrigating a total of 1.825 million hectares, and 493 smaller systems (7-23,000 hectares) irrigating a total of 4.975 million hectares.

Table 21--Area irrigated by reservoirs in China, 1982-85

Item	Large (More Than 100 Million Cubic Meters)	Medium (10-100 Million Cubic Meters)	Small (0.10-10 Million Cubic Meters)
Number of reservoirs			
1982	331	2,353	84,216
1983	335	2,367	83,865
1984	338	2,387	82,273
1985	340	2,401	80,478
Capacity (100 million cubic meters)			
1982	2,994.00	632.00	562.0
1983	3,006.50	640.40	561.3
1984	3,068.20	658.40	565.7
1985	3,075.65	661.52	564.2
Effectively irrigated area (1,000 hectares)			
1982	6,217.0	4,317.0	5,407.0
1983	6,081.0	4,251.0	5,339.0
1984	6,278.0	4,232.0	5,321.0
1985	6,406.9	4,205.7	5,147.3

Source: Zhongguo Guojia Tongjiju [State Statistical Bureau of China], Zhongguo Tongji Nianjian, 1984 (Xianggang: Xianggang Jingji Daobao Shechuban [Hong Kong Economic Reporter Publishing House], 1984), p. 179; State Statistical Bureau of China, Statistical Yearbook of China, 1983 (Hong Kong: Economic Information Agency, 1983), p. 200; State Statistical Bureau, PRC, Statistical Yearbook of China, 1985 (Hong Kong and Beijing: Economic Information and Agency and China Statistical Information and Consulting Service Centre, 1985), p. 284; Zhongguo Guojia Tongjiju, Zhongguo Tongji Nianjian, 1986 [Statistical Yearbook of China, 1986] (Beijing: Zhongguo Tongji Chubanshe [Statistical Publishing House of China], 1986), p. 180.

Table 22--Shares of various cash costs for crop production in China

Cost	Paddy	Wheat	Sweet Potatoes	Peanuts	Rape-seed	Jute
			(percent of total)			
Direct production fees						
Seeds	13.3	16.4	29.0	40.7	3.1	7.6
Natural and chemical fertilizers						
Total	43.1	47.0	35.8	32.1	62.6	59.9
Chemical fertilizer	20.8	20.1	5.3	7.6	23.6	14.7
Pesticides	6.8	1.8	0.3	1.2	2.5	2.0
Animals (oxen)	8.5	11.3	11.2	9.0	9.9	7.1
Machine operation	4.0	4.1	1.5	0.9	2.4	0.9
Irrigation and drainage	5.3	2.4	1.5	0.7	1.5	2.8
Other	3.5	1.9	2.6	1.2	1.6	3.6
Indirect fees						
Combined agricultural	14.3	12.6	15.8	12.0	14.2	12.7
Administrative	1.7	1.9	2.2	2.3	2.1	3.2
Total	∿100	∿100	∿100	∿100	∿100	∿100

Source: Calculated from farm survey data results appearing in Nongye Jishu Jingji Shouce Bienweihui [Agricultural Technical and Economic Handbook Editorial Committee], Nongye Jishu Jingji Shouce [Agricultural Technical and Economic Handbook] (Beijing: Nongye Chubanshe [Agricultural Publishing House], 1983), pp. 640-666.

Note: The data for sweet potatoes are average proportions for three years only (1977, 1978, and 1979).

agricultural purposes as of 1982 covered less than 15 percent of the cost of chemical fertilizer purchases.[36]

Although relative prices in China have improved significantly for farmers since 1979, they are not as favorable as those of Bangladesh, and in 1985 they became less favorable still. Farmers were able to bear costs and expand chemical fertilizer use and output partly because they were organized in production teams, which spread risk among groups of roughly 30 families. But many areas that had increased production successfully by the mid-1970s had no greater per capita income than a decade before, due to rising input costs and labor application.[37] Two further observations are worthy of notice: in 1982, the value of loans granted by rural credit cooperatives were more than five times the total value of those of central budgetary sources;[38] the establishment of the production responsibility system since 1979, which accomplished the break-up of commune organization and thus involves greater incentive and risk for individual farmers, has resulted in increased use of farmers' own savings for chemical fertilizer purchase.[39]

The conclusion that emerges from the entire international comparison and China's experience in particular is that a variety of considerations and complex interactions appear more important than relative prices in determining long-term growth of fertilizer use in developing countries. In China's case, a high and rapidly rising agronomic potential for fertilizer use, coupled with aggressive state marketing of major farm products and the expedient of supplying fertilizer in exchange far in advance of harvest sales, as well as a variety of means of reducing individual risk, overcame the disincentive effects of high relative prices so that there was little difficulty in converting agronomic potential into rapid growth in

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[36]Fertilizer application was about 34 million tons of urea equivalent (15.134 million tons of nutrients); the urea price was the most attractive among major fertilizer prices (450 yuan per ton for a total of 15,300 million yuan). The net increase in agricultural loans for all purposes was 2,270 million yuan, or about 15 percent of fertilizer costs. The situation was much more drastic during the pre-1976 period, when the net increase in loans averaged less than 20 percent of the 1982 total (State Statistical Bureau of China, Statistical Yearbook of China, 1983, p. 451).

[37]Stone, "China's 1985 Foodgrain Production Target: Issues and Prospects."

[38]State Statistical Bureau, Statistical Yearbook of China, 1983, p. 450.

[39]Stone, "Chinese Fertilizer Application in the 1980s and 1990s."

effective demand for fertilizers until the mid-1970s. Reacceleration of growth since that time has had as much to do with provision of higher-quality, less volatile fertilizers as it has with the adjustment in relative prices.

3. STRUCTURE, DYNAMICS, AND RELATED POLICY ISSUES OF FERTILIZER SUBSIDY IN BANGLADESH

Raisuddin Ahmed

This chapter analyzes the structure and dynamics of fertilizer subsidy in Bangladesh and a number of related policy issues. Those aspects of the study that concern fertilizer demand, supply, and marketing are covered in other chapters.

Fertilizer subsidy entered the public budget in the wake of the grow-more-food campaign launched in Bangladesh in the late 1950s and early 1960s. With the increased consumption of fertilizers, the budgetary burden from fertilizer subsidy has also grown over time. Although few would dispute the logic of using subsidy as an instrument for introducing a new, modern input to agriculture, questions relating to efficient use of this input, the opportunity cost of resources spent on fertilizer subsidy, and the likely consequences of subsidy withdrawal on small and subsistence farms and on food production in general have emerged as serious policy issues in Bangladesh.[1]

Domestic consumption of fertilizers exceeded a million metric tons in 1983-84, involving a subsidy transfer of 1,426 million taka (Tk) (see Table 1).[2] Fertilizer subsidy as a proportion of the total public development budget for agriculture has declined over time, but the absolute amount of subsidy is still quite high.

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[1]A good review of the controversies over fertilizer subsidy issues, particularly the conditions under which subsidy arguments are valid or inappropriate, is presented in Haim Shalit and Hans P. Binswanger, Fertilizer Subsidies: A Review of Policy Issues with Special Emphasis on Western Africa, World Bank Discussion Paper, (Washington, D.C.: World Bank, November 1984).

[2]Estimates of subsidy vary rather widely among various sources of published information. The main reason for this variation is that the subsidy estimates are generally revised several times after the initial calculation is made for inclusion in the annual development program (ADP). These revisions become necessary because of deviations of actual from planned targets of distribution, procurement, and distribution costs, and various other financial adjustments.

Before any conclusions can be arrived at on subsidy policy, it is necessary to reexamine the definitions, size, structure, and dynamic factors underlying fertilizer subsidy. Specifically, the following areas of investigation are presented in this paper: What are the current methods and magnitudes of fertilizer subsidy? What is the appropriate method to follow in estimating the amount of subsidy and in fixing fertilizer prices? What is the structure of the subsidy? How large are the subsidies by type of fertilizer and by sources of supply (imports obtained through cash purchase, barter, grants, and credit, as well as domestic production)? What are the dynamic elements that influence the extent of subsidy (such as quantity, domestic and world prices, exchange rate, management of procurement, stock, and distribution)? Finally, some approaches to and implications of rationalizing fertilizer subsidy policy are examined.

Table 1--Fertilizer subsidy and its share of the agricultural development budget, 1977-78 to 1983-84

Financial Years	Subsidy	Agricultural Development Budget[a]	Subsidy as Percent of Agricultural Development Budget
	(million Tk)		(percent)
1977-78	944	3,480	27.1
1978-79	1,286	4,688	27.4
1979-80	1,342	6,658	20.2
1980-81	1,172	7,548	15.5
1981-82	1,084	8,820	12.3
1982-83	850	9,505	8.9
1983-84	1,426	10,511	13.6
1984-85[b]	913	...	...

Source: Bangladesh Ministry of Agriculture, Sub-sector Review, Fertilizers (Dhaka: PETA/AST, 1984).

[a]The agriculture sector includes agriculture (crops, livestock, fisheries, and forestry), rural development, and water resources development.

[b]First estimate.

METHODS OF ESTIMATING SUBSIDY

In public parlance the difference between the cost (acquisition and distribution costs) and the sale proceeds is interpreted as subsidy. If the sale price is higher than the average cost, it is a negative subsidy for farmers. Generally the sale price is lower than the average cost, representing a positive subsidy to farmers. However, the cost estimates made for the purpose of budgetary provision could be quite different from the economic prices reflecting the real opportunity costs of fertilizers and associated factors. Thus a distinction must be made between two types of subsidy--budgetary and economic--to prevent confusion about who is subsidizing whom or about the extent of explicit and implicit subsidy. Such an understanding will also provide a basis for arriving at correct criteria for pricing fertilizers. In this chapter a third type of subsidy is also included: the cash-flow budgetary impact of fertilizer subsidy. Because most imported fertilizers in Bangladesh are received as grants and on credit, the actual effects on cash flow could be quite different from what is reported as budgetary transfer from the Treasury. Rationales and underlying assumptions for each of the three subsidy concepts will be covered.

Subsidy under Current Procedure

The Bangladesh Agricultural Development Corporation (BADC), under the Ministry of Agriculture, has been the public agency responsible for procurement and distribution of fertilizers. BADC prepares an annual plan for procurement and distribution of fertilizers, with a four-to-six-month lead time, in the financial year preceding the one for which the plan is meant. Formulation of this plan is done in consultation with the Ministries of Agriculture and Planning.

The estimate of subsidy requirement is based on distribution targets by type of fertilizer; projected opening stocks, domestic procurement, import requirements, and closing stocks; prospective sources of foreign exchange financing; projected prices for domestic and imported fertilizers; projected distribution costs; and sales prices from BADC godowns.

Subsidy estimates are made for the quantity to be sold to farmers during a particular financial year (July-June). Procurement of this quantity of fertilizer is, however, made partly in the previous year and partly in the same year. Therefore, the configuration of the time of procurement and the time of distribution is an important element in influencing the size of the subsidy under a changing price regime.

In the past, BADC estimated the subsidy by adopting an average cost (by type of fertilizer and sources of supply) based on the procurement prices and distribution cost pertaining to the same year in which the fertilizers were distributed. Starting in the fiscal year 1983-84, however, BADC improved this method by basing the procurement cost on the price of the opening stock, as well as the price of all stocks procured during the year in which the fertilizers were distributed. Purchases made in cash, credit, barter, or grant are valued at full prices. Even if a quantity of fertilizer is obtained under a grant, it is valued at the donor's invoice price. Nor are restrictions on tendering reflected in costing fertilizers. Currently, estimates based on such financial costing are termed "full-economic" subsidies. The actual claims on subsidy in 1983-84 and the estimated subsidy for 1984-85[3] following the current procedure are presented in Tables 2 and 3.

A comparison of the two tables shows that the 1984-85 estimate does not include minor fertilizers (like $ZnSo_4$ and zinc) included under the "other" category in 1983-84. This category accounts for a very small proportion of total subsidy and costs. Therefore, its inclusion is not vital. The important point to note is the declining overall average cost (from Tk 5,090.50 to Tk 4,959.64 per ton) and rate of subsidy between the two years. Primarily because of the drop in distribution cost, from Tk 881 per ton in 1983-84 to Tk 750 per ton in 1984, overall procurement cost does not appear to have changed. Composition of fertilizer changed, however, as diammonium phosphate (DAP) was eliminated and the proportion of triple superphosphate powder, TSP(P), was lowered. This change in composition, particularly the elimination of high-priced DAP, has enabled BADC to maintain a stable overall procurement cost, even though prices of some individual fertilizers have increased moderately.

The summary tables of BADC's subsidy estimates presented in Tables 2 and 3 do not reveal various elements of costs. Such information, as well as procedures followed in making these estimates, are available from BADC.

Time configurations for procurement and distribution must be consistent. It was mentioned previously that under a changing price regime a difference in this configuration will affect the subsidy estimates. Under a rising procurement price, procurement cost for the particular financial year when the fertilizers are distributed would tend to inflate the subsidy estimate.

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[3]This was a preliminary estimate because the financial year was not yet over at the time of this exercise.

Table 2--Fertilizer subsidy, 1983-84

Category	Urea	TSP(P)	TSP(G)	DAP	MP	Others	Total
Quantity distributed (1,000 metric tons)	708.07	55.47	205.26	93.83	63.22	3.21	1,129.06
Average cost[a] (Tk/ton)	4,480.55	6,025.24	6,025.24	7,497.95	4,353.29	7,798.72	5,090.50
Total cost (million Tk)	3,172.54	334.20	1,236.76	703.74	275.22	25.01	5,747.48
Sale price (Tk/ton)	3,966.40	2,948.00	3,752.00	3,966.40	2,948.00	6,325.98	3,826.99
Total receipt (million Tk)	2,808.49	163.52	770.15	372.17	186.38	20.29	4,320.90
Subsidy (Tk/ton)	514.15	3,077.24	2,273.24	3,531.55	1,405.29	1,472.74	1,263.50
Total subsidy (million Tk)	364.05	170.69	466.61	331.37	88.85	4.72	1,426.60
Rate of subsidy (percent)	11.48	51.08	37.72	47.09	32.29	18.89	24.81

Source: Bangladesh Agricultural Development Corporation.

Notes: TSP(P) is triple superphosphate powder, TSP(G) is triple superphosphate in granular form, DAP is diammonium phosphate, and MP is muriate of potash.

[a]Average cost includes distribution cost at the rate of Tk 881 per ton across the board.

Table 3--Estimated subsidy requirement for fertilizers, 1984-85

Category	Urea	TSP(P)	TSP(G)	MP	Total
Quantity distributed (1,000 metric tons)	800	20	340	60	1,220
Average cost[a] (Tk/ton)	4,529.08	5,977.69	5,977.69	4,592.05	4,959.64
Total cost (million Tk)	3,623.26	119.55	2,032.42	275.52	6,050.76
Sale price (Tk/ton)	4,360.00	3,240.00	4,130.00	3,240.00	4,222.46
Total receipt (million Tk)	3,488.00	64.80	1,404.20	194.40	5,151.40
Subsidy (Tk/ton)	169.08	2,737.69	1,847.69	1,352.05	737.18
Total subsidy (million Tk)	135.26	54.75	628.22	81.12	899.36
Rate of subsidy (percent)	3.73	45.80	30.91	29.44	14.86

Source: Bangladesh Agricultural Development Corporation.

Notes: TSP(P) is triple superphosphate powder, TSP(G) is triple superphosphate in granular form, and MP is muriate of potash.

[a]Average cost includes distribution cost at the rate of Tk 750 per ton across the board.

Even though BADC has recently amended this time configuration in arriving at relevant procurement costs for a particular year, the procedure has further room for improvement. Specifically, BADC should consider the opening stock and total procurement in that year minus the closing stock in making the estimate for average procurement cost. Although it would be difficult to exactly trace the consignments that comprise opening stocks, current procurement, and closing stocks, it is possible to make a close approximation of these stocks, their sources, and cost prices.

BADC always maintains month-by-month and consignment-by-consignment records, which are also published in BADC's monthly Fertilizer Newsletter. To provide an example and to present a detailed structure of procurement cost and subsidy, the 1983-84 financial year is analyzed here. Size and cost of monthly consignments of fertilizer from January 1983 to March 1984 were found to be roughly consistent with quantities distributed in 1983-84. Within this range, some periods showed different figures for certain types of fertilizer. Procurement made during April-June 1984 was assumed to be carried over as opening stock in the following year, 1984-85.

The estimates of cost and subsidy worked out for 1983-84 are presented in Tables 4 and 5. In Table 4 the average procurement cost is presented for various fertilizers distributed in 1983-84 but procured during the period from January 1983 through March 1984 (see the notes to the table). In Table 5 the magnitude of the subsidy has been reestimated for comparison with the figure in Table 2.

It can be seen that the total subsidy, as reworked, comes to about Tk 1,466 million, compared to BADC's estimate of Tk 1,427 million, a difference of Tk 39 million in absolute terms but only 2.7 percent of the BADC estimate in relative terms. It was not expected that the BADC estimate would differ much from the present one under the relatively stable price conditions that prevailed during 1983 and 1984. Nevertheless, the difference could be substantial in a time of changing prices. Thus to avoid overcharging or undercharging farmers or the government, it is important to identify the correct procurement price to be used to estimate the subsidy for a particular year.

It can be seen that the budgetary subsidy was about 25 percent of cost in 1983-84. There were tremendous variations in the subsidy rates among various types of fertilizer and among various sources of supply with a given type. Thus, the subsidy rate was 11.4 percent on urea, 40.6 percent on TSP, 49.5 percent on DAP, and 33.6 percent on muriate of potash (MP). Urea from Ghorasal and Fenchuganj earned a rate of profit of 7.8 percent for BADC, whereas Ashuganj urea was subsidized at 16.3 percent. Subsidy on imported urea ranged from about 32 to 42 percent.

Table 4--Average procurement cost of fertilizers distributed in 1983-84

Fertilizer	Source	Quantity	Procurement Price Ex-factory/ c.i.f.	Total Cost	c.i.f. and Ex-factory Price
		(1,000 metric tons)	(Tk/ton)	(million Tk)	(US$/ton)[b]
Urea	Local[a]	279.642	2,800.00	783.00	112.00
	Local[a]	356.045	3,860.00	1,374.33	154.00
	Import Saudi	7.900	4,920.00	38.87	205.00
	Import USAID	24.237	5,193.17	125.87	210.25
	Import Saudi	14.051	4,940.00	69.41	205.00
	Import USAID	26.195	5,985.69	156.80	242.34
All Urea		708.070	3,598.91	2,548.28	...
TSP	Local	74.631	5,735.00	428.01	229.40
	Import Danish grant	10.065	5,887.92	59.26	239.96
	Import Dutch grant	52.458	4,519.42	237.08	200.65
	Import Japan	8.805	6,793.94	59.82	283.08
	Import NORAD	17.443	4,908.38	85.62	198.72
	Import U.K.	5.000	4,933.48	24.67	199.74
	Import ADB	8.580	4,639.72	39.81	188.74
	Import IFAD	8.400	4,739.03	39.81	192.78
	Import Dutch	30.100	4,574.37	137.69	182.34
	Import Danish	45.248	5,101.31	230.82	203.30
All TSP		260.730	5,149.35	1,342.59	...
DAP	Import USAID	1.923	5,449.20	10.48	227.05
	Import USAID	15.488	7,678.80	118.93	319.75
	Import USAID	24.990	7,563.63	189.02	306.22
	Import Bulgaria barter	24.553	6,637.30	162.97	270.00
	Import Czech barter	20.997	6,637.30	139.36	270.00
	Import NORAD	5.880	5,737.40	33.74	228.65
All DAP		93.831	6,975.31	654.50	...
MP	Import CIDA	13.222	3,651.84	48.28	152.18
	Import CIDA	50.000	3,532.40	176.62	141.30
All MP		63.222	3,557.31	224.90	...

Source: Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, various issues, January 1983 - June 1984.

Notes: Acronyms included refer to the U.S. Agency for International Development (USAID), the Norwegian Agency for Development (NORAD), the Asian Development Bank (ADB), the International Fund for Agricultural Development (IFAD), the Canadian International Development Agency (CIDA), and the United Kingdom (U.K.).

TSP is triple superphosphate, DAP is diammonium phosphate, and MP is muriate of potash.

Procurement costs are based on consignments received from March 1983 through March 1984 for urea; January 1983 through March 1984 for TSP; April 1983 through March 1984 for DAP; and March 1983 through March 1984 for MP.

[a]The Ghorasal and Fenchuganj urea price is Tk 2,800 per ton. The Ashuganj urea price is Tk 3,860 per ton.

[b]U.S. $1 = Tk 25 for local fertilizers. For import the exchange rate is as reported.

Table 5--Estimated full budget subsidy on fertilizers distributed, 1983-84

Fertilizer	Source	Quantity	Average Cost[a]	Sale Price	Total Cost	Total Receipt	Total Subsidy	Rate of Subsidy
		(1,000 metric tons)	(Tk/ton)			(million Tk)		(percent)
Urea	Domestic	279.642	3,681.00	3,966.40	1,029.36	1,109.17	-79.81	-7.8
	Domestic	356.045	4,741.00	3,966.40	1,688.00	1,412.22	275.78	16.3
	All domestic	635.687	4,274.70	3,966.40	2,717.36	2,521.39	195.97	7.2
	Import Saudi	7.900	5,801.00	3,966.40	45.83	31.33	14.50	31.6
	Import USAID	24.237	6,074.17	3,966.40	147.22	96.13	51.09	34.7
	Import Saudi	14.051	5,821.00	3,966.40	81.79	55.73	26.06	31.9
	Import USAID	26.195	6,866.69	3,966.40	179.87	103.90	75.97	42.2
	All import	72.383	6,282.00	3,966.40	454.71	287.09	167.62	36.9
	All urea	708.070	4,479.88	3,966.40	3,172.07	2,808.48	363.59	11.4
TSP	Domestic[b]	74.631[b] (55.467P)	6,616.00	2,948.00P 3,752.00G	493.76	235.42	258.34	52.3
	Import Danish	10.065	6,768.92	3,752.00	68.13	37.76	30.37	44.6
	Import Dutch	52.458	5,400.42	3,752.00	283.30	196.82	86.48	30.5
	Import Japan	8.805	7,674.94	3,752.00	67.58	33.04	34.54	51.1
	Import NORAD	17.443	5,789.38	3,752.00	100.98	65.45	35.53	35.2
	Import U.K.	5.000	5,814.48	3,752.00	29.07	18.76	10.31	35.5
	Import ADB	8.580	5,520.72	3,752.00	47.37	32.19	15.18	32.0
	Import IFAD	8.400	5,620.03	3,752.00	47.21	31.52	15.69	33.2
	Import Dutch	30.100	5,455.37	3,752.00	164.21	112.94	51.27	31.2
	Import Danish	45.248	5,982.39	3,752.00	270.69	169.77	100.92	37.3
	All import	186.099	5,795.52	3,752.00	1,078.54	698.25	380.29	35.3
	All TSP	260.730	6,030.38	3,580.98	1,572.30	933.67	638.63	40.6
DAP	Import USAID	1.923	6,330.20	3,966.40	12.17	7.63	4.54	37.3
	Import USAID	15.488	8,559.80		132.57	61.4	71.14	53.7
	Import USAID	24.990	8,444.63	3,966.40	211.03	99.1	111.91	53.0
	Import Bulgaria barter	24.553	7,518.30	3,966.40	184.60	97.3	87.21	47.2
	Import Czech barter	20.997	7,518.30	3,966.40	157.86	83.28	74.58	47.2
	Import NORAD	5.880	6,618.40		38.92	23.3	15.60	40.1
	All import	93.831	7,856.15	3,966.40	737.15	372.1	364.98	49.5
MP	Import CIDA	13.222	4,532.84	2,948.00	59.93	38.98	20.95	35.0
	Import CIDA	50.000	4,413.40	2,948.00	220.67	147.40	73.27	33.2
	All import	63.222	4,438.33	2,948.00	280.60	186.38	94.22	33.6
Others	Minor elements	3.207	7,779.72	6,325.98	24.95	20.29	4.66	18.7
All fertilizers		1,129.060	5,125.56	3,827.06	5,787.07	4,320.99	1,466.08	25.3

Source: Compiled from information from Bangladesh Agricultural Development Corporation.

Notes: Acronyms included refer to the United States Agency for International Development (USAID), the Norwegian Agency for Development (NORAD), the Canadian International Development Agency (CIDA), and the International Fund for Agricultural Development (IFAD).

TSP(P) is triple superphosphate powder, TSP(G) is triple superphosphate in granular form, DAP is diammonium phosphate, and MP is muriate of potash.

[a]Average cost consists of procurement cost as in Table 4 plus distribution cost at the rate of Tk 881 per ton.

[b]Local TSP consists of 55,467 tons of powdered and 19,164 tons of granular TSP. Powdered TSP is sold at a lower price.

Unlike domestic urea, domestic TSP was heavily subsidized at 52.3 percent, compared to rates ranging from 30 to 50 percent for imported TSP. This is partially attributable to the poor quality of domestic TSP (powdered, rather than granular), which caused it to sell for a lower price.

It is most revealing that the prices of the same variety of imported fertilizer differed so widely among sources of supply. Discussions with BADC and the Bangladesh Chemical Industries Corporation indicated that the price differences were not caused by quality differences because nutrient content, acid, and particle size were similar and consistent with the standard specifications of the government. Rather price differences were caused primarily by conditions related to aid.

For accounting purposes, if fertilizer imported with credit from the Asian Development Bank or the International Fund for Agricultural Development were valued on the principle that the benefits of concessional credits were meant for the farming sector, the cost and hence the amount of subsidy would be smaller.

Farmers mostly use cash for purchases, although at a subsidized rate. The present value of credits is certain to be lower than the price charged to farmers. The terms of credit generally involve a nominal 0.75 percent interest rate, 10 years grace period, and repayment within 40 years in equal installments. The market rate of interest is 10 to 16 percent in Bangladesh. Assuming an average interest rate of 12 percent and other terms of credit, the present value of U.S. $100 million is roughly equal to only U.S. $10.12 million.

This implies that a ton of fertilizer that is presently valued at Tk 5,986 for sale to farmers could have been priced at Tk 600 per ton if all benefits of credit were passed on to farmers. But such a presumption would also mean that all "grant fertilizers" should be sold at a zero price. The basic consideration for valuation of such concessional imports should be sought in the logic of economics. This will be discussed further under economic subsidy.

Cash-Flow Budgetary Impact of Fertilizer Subsidy

The budgetary subsidy for 1983-84 shown previously is based on the valuation of all imported fertilizers at donor's invoice, even though a substantial quantity was received under grant and credit. In 1983-84, about 60 percent of the total procurement was obtained from domestic sources, the rest being imported. Of the total import value, 70.7 percent was accounted for through grants, 4.8 percent through credit, 17.0 percent through barter agreements, and 7.5 percent through cash foreign exchange imports.

For fertilizers imported under grant and credit arrangements, no immediate cash disbursement for procurement is required, except in the case of the Saudi grant. The Saudi grant requires the shipping cost to be borne by Bangladesh.

The cash flow impact on procurement and distribution of fertilizers in 1983-86 is shown in Table 6. In its fertilizer transactions that year the government gained a net surplus of about Tk 218 million.[4] This resource generation has made it easy for the government to maintain a high level of subsidy on fertilizer and has generated pressure to pass down a part of the grant to farmers. How the government allocates these resources for economic development will of course determine whether the present practice is efficient or not. Presently, the funds are being used to finance the Annual Public Sector Development Program (ADP) which, incidentally, is also a source of financing for the subsidy.

Economic Subsidy

It is important to determine a reference price, in relation to which prices of domestic and imported fertilizer can be evaluated, in order to indicate the extent of implicit and explicit subsidy and to identify who is subsidizing whom. This reference price shall be called the economic price of fertilizer.

The difference between the economic and budgetary subsidy is a reflection of the difference in valuation of fertilizers and the associated factors underlying the distribution of fertilizers. Instead of financial cost, the principle of opportunity cost is applicable for economic subsidy. Thus, for domestic fertilizers the appropriate price that should be charged to domestic users is the price the fertilizer industry could get if they were allowed to sell elsewhere--in other words the export or f.o.b. price.

This criterion is based primarily on a desire for efficiency, rather than any other national objective.[5] If the cost of production of domestic fertilizers is higher than the economic price, it is not the farmers who receive the subsidy, but the fertilizer industry. Likewise, if the domestic cost of production is lower than the economic price, the industry gains the profit. If this profit is

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[4]Excluding credit purchases, this amount came to Tk 142 million

[5]The government considers generation of revenue another policy objective in its dealings with fertilizer. But government revenue is meant for public expenditure, which has an efficiency consideration in its use.

Table 6--Cash flow impact on procurement and distribution of fertilizers, 1983-84

Fertilizer	Source	Quantity Procured	Total Procurement Cost	Quantity Distributed	Distribution Cost	Total Revenue	Net Cash Flow[a]
		(1,000 metric tons)	(million Tk)	(1,000 metric tons)		(million Tk)	
Urea	Local	261.339	731.75	...	...	1,109.17	...
	Local	378.973	1,462.84	...	...	1,412.22	...
	All local	640.312	2,194.59	...	...	2,521.39	...
	Import USAID	24.237	...	...	...	...	...
	Import Saudi	14.051	10.60	...	...	...	...
	Import USAID	26.195	...	...	...	...	...
	Cash import	29.042	133.36	...	...	...	...
	All urea	733.837	2,338.15	708.07	637.26	2,808.48	156.73
TSP	Local	74.458	427.02	74.63	...	...	...
	Import NORAD	17.443	...	...	...	...	...
	Import U.K.	5.000	...	...	...	...	...
	Import ADB	8.580	...	...	...	...	...
	Import IFAD	8.400	...	...	...	...	...
	Import Dutch	15.100	...	...	...	...	...
	Import Danish	45.248	...	...	...	...	...
	Import KFW	9.036	...	...	...	...	...
	All import	108.807	...	186.10	...	...	...
	All TSP	183.265	427.02	260.73	234.66	933.67	-271.94
DAP	Import USAID	24.990	...	...	...	...	...
	Import Bulgaria barter	24.553	162.97	...	...	...	...
	Import Czech barter	20.997	139.36	...	...	...	...
	Import NORAD	5.880	...	...	...	...	...
	All DAP	76.420	302.33	93.83	84.45	372.17	14.71
MP	Import CIDA	60.000	...	63.22	56.90	186.38	-129.48
All fertilizers[b]		1,053.522	3,067.90	1,125.85	1,013.27	4,300.07	-218.9

Sources: Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, various issues, January 1983 - June 1984; and personal contacts with External Division, Bangladesh Ministry of Finance, Dhaka.

Notes: Acronyms included refer to the U.S. Agency for International Development (USAID), the Norwegian Agency for Development (NORAD), the Canadian International Development Agency (CIDA), the Asian Development Bank (ADB), the International Fund for Agricultural Development (IFAD), and the German Credit Institute for Reconstruction (KFW).

TSP is triple superphosphate, DAP is diammonium phosphate, and MP is muriate of potash.

[a]Net cash flow = (total procurement cost + distribution cost) - total receipt.

[b]Minor fertilizers are excluded.

high, government can obtain some or all of it by taxation. If farmers pay a price lower than the economic price, then they receive a subsidy equivalent to the difference between the farm-level price and the economic price.

Cost of Production

Ascertaining the cost of production of domestic fertilizers is not necessary for economic pricing. But cost of production of fertilizers produced under public corporations must be regularly computed in order to monitor the efficiency of such corporations.

The cost of production of domestically produced fertilizers is shown in Table 7. These cost statistics were provided by the Bangladesh Chemical Industries Corporation, and there was no scope for detailed examination of the cost data. To scrutinize it appropriately, a full-time team would have had to work for a much longer time than the present team could afford. Therefore, only a limited significance should be attached to these cost data. A few observations, however, are relevant to the present study.

In the case of urea (from Fenchuganj, Ghorasal, and Ashuganj), the Ashuganj factory produces urea at a cost equivalent to world prices at f.o.b. level. The cost of production in the other two factories is so low that the costing practice could be questioned. Of course, cost of production could be genuinely different among factories due to differences in the technique of production, as must also be true in the present case. But the interest and depreciation charges are so different among factories that the question of proper capital costing, particularly in the cases of Fenchuganj and Ghorasal, cannot be put aside.

Raw materials (natural gas for urea) constitute the second largest item of cost in Ashuganj and the largest in the two other urea factories. As all costs are financial outlays for factories, indirect subsidy to industry through underpricing of raw materials and capital cost cannot be assessed from the cost of production data in the table. A study by the Planning Commission indicates that the underpricing of natural gas to fertilizer factories could be on the order of 63 percent.[6] Moreover, capacity utilization is very uneven, and adjustment for this will increase cost.

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[6]A. Rab, Possibilities of Increasing Domestic Financial Resource Mobilization for the Second Five-year Plan (Dhaka: Bangladesh Planning Commission, 1981).

Table 7--Production cost, ratio of production cost to f.o.b. price, and rates of capacity utilization and depreciation at four fertilizer factories, 1983-84

Category	Fenchuganj Urea		Ghorasal Urea		Ashuganj Urea		Chittagong TSP	
	Cost	Share	Cost	Share	Cost	Share	Cost	Share
	(Tk/ton)	(percent)	(Tk/ton)	(percent)	(Tk/ton)	(percent)	(Tk/ton)	(percent)
Cost of raw materials	1,122	40.2	898	50.5	768	20.1	4,539	71.2
Management charges	323	11.6	139	7.8	96	2.5	286	4.5
Interest charges	321	11.5	43	2.4	1,525	39.9	211	3.3
Depreciation	322	11.5	166	9.3	1,167	30.5	236	3.7
Labor	300	10.8	95	5.3	37	0.0	147	2.3
Energy	...	...	152	8.5	22	0.0	588	9.2
Other overhead	402	14.4	285	16.0	206	5.4	371	5.8
Total cost	2,790	100.0	1,778	100.0	3,821	100.0	6,378	100.0
Ratio of cost of production to f.o.b price of fertilizer	0.71		0.5		0.98		1.41	
Capacity utilization (percent)	83.0		75.0		71.0		53.0	
Rate of depreciation (percent)	7.0		8.0		6.0		8.0	

Source: Bangladesh Chemical Industries Corporation.

Note: TSP is triple superphosphate.

Domestic TSP production is clearly an extremely expensive venture. The cost of production is 1.41 times higher than the f.o.b. price of TSP. The data indicate that if a rigorous analysis of the cost of production of domestic fertilizers were undertaken, it might show the cost of producing urea at Ashuganj was higher than f.o.b. world prices. The situation of Fenchuganj is not so obvious, but Ghorasal may turn out to be the only factory with a clear competitive edge.

Pricing domestic fertilizers on the basis of a cost of production that does not properly include all costs may appear to be a convenient and temporary device for showing low rates of subsidy on fertilizers. The practice masks either the indirect subsidy to industry or the part of subsidy to farmers that is currently borne by industry. If pressures develop on industries to include real costs of natural gas and capital in the cost of production--and emergence of such pressures seems to be a reality--the estimates of subsidy would rise dramatically. Then the question would arise whether such escalated cost should be charged to farmers. If it is done so, farmers in effect would be bearing the cost of inefficient industries.

Economic Approach to Calculating Subsidy

In this approach, fertilizers are valued at their world (border) prices, following the principle of economic pricing. Some implications of this approach for estimation of subsidy are shown in Figure 1. These illustrations are based on linear cost and revenue assumptions. In the diagrams, Q_D^* and Q_M^* are the quantities procured and distributed from domestic sources and import.

SP = sale price to farmers,

EP = economic price (f.o.b. price plus distribution cost for import),

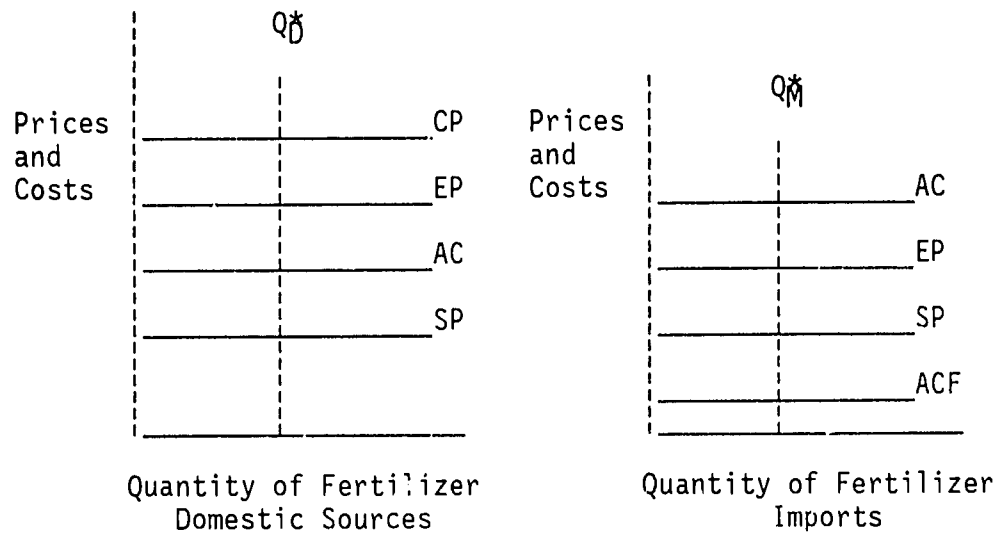
AC = average cost of procurement and distribution to BADC,

ACF = average cost in terms of actual cash flow cost, and

CP = cost of production of domestic fertilizers plus distribution cost. All are on a per ton basis.

It is assumed that the quantity procured is also distributed. The diagram for domestic fertilizer reflects closely the situation of Ashuganj urea and Chittagong TSP if the cost of production is adjusted for natural gas and capital cost underpricing. In this case the total economic subsidy is Q_D^* (EP-SP), that is, quantity times the difference between the economic and sales price. Of this amount of

Figure 1--Model for estimating economic subsidy



economic subsidy, Q_D^* (AC-SP) is the budgetary subsidy coming from the government treasury and Q_D^* (EP-AC) is the part being subsidized by industry, even though industry has a hidden subsidy equivalent to Q_D^* (CP-EP).

In the case of imported fertilizers, the diagram reflects the imports under tied aid. The total economic subsidy is measured by Q_M^* (EP-SP), which is smaller than the total budgetary subsidy of Q_M^* (AC-SP). The difference between the two, Q_M^* (AC-EP), is the part of budgetary subsidy that is attributed to overpricing of tied aid, but under current practice it is considered a subsidy to farmers. (See the supplementary tables in Appendix 1, Tables 26-32, for price differences.) Q_M^* (SP-ACF) is the net resource generated by the government from fertilizers received under grant and credit arrangements.

On the basis of economic prices, the economic subsidy for fertilizers distributed in 1983-84 is calculated and shown in Table 8. In doing this, the exchange rate used is the official exchange rate, and the distribution cost is Tk 900 per ton. For a number of reasons no attempt has been made to use a shadow price for the exchange rate. For one thing, considerable controversy seems to exist around the question of an appropriate rate of exchange. More substantively, the partial approach taken here (partial in the sense that we are dealing with only one commodity--fertilizer) dictates that the exchange rate controversy be left to macroeconomic management, and it does not dilute the effort here to address some other basic issues on fertilizer subsidy.

Table 8--Full economic subsidy on fertilizers, 1983-84

Fertilizer	Source	Quantity	Average Cost[a]	Sale Price	Total Cost	Total Receipt	Total Subsidy	Rate of Subsidy
		(1,000 metric tons)	(Tk/ton)			(million Tk)		(percent)
Urea	Domestic	279.642	4,740.00	3,966.40	1,325.50	1,109.17	216.33	16.3
	Domestic	356.045	4,740.00	3,966.40	1,687.70	1,412.22	275.48	16.3
	All domestic	635.687	4,740.00	...	3,013.20	2,521.39	491.81	16.3
	Import Saudi	7.900	5,525.00	3,966.40	43.65	31.33	12.32	28.2
	Import USAID	24.237	5,525.00	3,966.40	133.91	96.13	37.78	28.2
	Import Saudi	14.051	5,525.00	3,966.40	77.63	55.73	21.90	28.2
	Import USAID	26.195	5,525.00	3,966.40	144.73	103.90	40.83	28.2
	All import	72.383	5,525.00	3,966.40	399.92	287.09	112.83	28.2
	All urea	708.070	4,820.30	3,966.40	3,413.12	2,808.48	604.64	17.7
TSP	Domestic	74.631 (55.467P)	4,532.00	2,448.00P 3,752.00G	338.23	235.42	102.81	30.4
	Import Danish	10.065	5,275.00	3,752.00G	55.09	37.76	15.33	28.9
	Import Dutch	52.458	5,275.00	3,752.00G	276.72	196.82	77.90	28.9
	Import Japan	8.805	5,275.00	3,752.00G	46.45	33.04	13.41	28.9
	Import NORAD	17.443	5,275.00	3,752.00G	92.01	65.45	26.56	28.9
	Import U.K.	5.000	5,275.00	3,752.00G	26.34	18.76	7.58	28.9
	Import ADB	8.580	5,275.00	3,752.00G	45.26	32.19	13.07	28.9
	Import IFAD	8.400	5,275.00	3,752.00G	44.31	31.52	12.79	28.9
	Import Dutch	30.100	5,275.00	3,752.00G	158.78	112.94	45.84	28.9
	Import Danish	45.248	5,275.00	3,752.00G	238.68	169.77	68.91	28.9
	All import	186.099	5,275.00	3,752.00	981.67	698.25	283.42	28.9
	All TSP	260.730	...	...	1,319.90	933.67	386.23	29.3
DAP	Import USAID	1.923	6,575.00	3,966.4	12.64	7.63	5.01	39.7
	Import USAID	15.488	6,575.00	3,966.4	101.83	61.43	40.40	39.7
	Import USAID	24.990	6,575.00	3,966.4	164.31	99.12	65.19	39.7
	Import Bulgaria barter	24.553	6,575.00	3,966.4	161.44	97.39	64.05	39.7
	Import Czech barter	20.997	6,575.00	3,966.4	138.06	83.28	54.78	39.7
	Import NORAD	5.880	6,575.00	3,966.4	38.66	23.32	15.34	39.7
	All import	93.831	6,575.00	...	616.94	372.17	244.77	39.7
MP	Import CIDA	13.222	3,900.00	2,948.0	51.57	38.98	12.59	24.4
	Import CIDA	50.000	3,900.00	2,948.0	195.00	147.40	47.60	24.4
All fertilizers		1,125.853	5,006.36	3,819.95	5,596.53	4,300.70	1,295.83	23.1

Sources: Average costs are based on f.o.b. prices taken from the Bangladesh Chemical Industries Corporation; the c&f prices are from World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, 1982 and 1983).

Notes: TSP is triple superphosphate, DAP is diammonium phosphate, and MP is muriate of potash. P indicates TSP in powder form, G in granular form.

Nevertheless, it should be emphasized that the exchange rate has powerful implications for tradable products produced and used in agriculture. The limited open market exchange rate in 1983-84 was about Tk 28 per U.S. dollar compared with an official rate of Tk 25 per U.S. dollar.

The distribution cost has quite a number of elements where hidden subsidy may exist. No attempt has been made to identify or correct this mostly nontradable component of cost, even though it has elements with import content. However, the distribution cost has been adjusted slightly upwards from Tk 881 to Tk 900 to accommodate an apparent storage cost element.

The important point to note in Table 8 is that the economic subsidy (Tk 1,296 million) is smaller than the budgetary subsidy shown in Table 3 (Tk 1,427 million) or in Table 5 (Tk 1,466 million). This implies that farmers received 131-170 million taka less than the subsidy the accounts show they received in 1983-84.

The estimate of economic subsidy in Table 8 is based on the f.o.b. price of domestic urea, at U.S. $153.60 per ton. This is an average of the export price BCIC received for export of about 127,000 tons during 1982-84. The f.o.b. price of domestic TSP was assumed to be U.S. $145.25 per ton. This price is slightly higher than the ex-Gulf and ex-West European f.o.b. prices. For imported fertilizers, the c.i.f. price for urea was assumed to be $185; for TSP, $175; for DAP, $227; and for MP, $120.[7] The government imported some urea in 1984 on cash foreign exchange financing. The c.i.f. price of this urea was U.S. $183.

The c.i.f. and f.o.b. prices are adjusted with appropriate distribution costs to arrive at border prices. This approach, of adopting border prices as opportunity costs of resources, has been questioned by some. Others have wrongly interpreted it as a free-market proposition. Because fertilizer is an input that increases agricultural production, its price cannot be fixed arbitrarily, without consideration of its role in production growth and efficient use of resources.

It has often been argued that the opportunity cost of fertilizer under grant is lower than its world price. These arguments imply that donors have no other option than to supply fertilizers on grant--as if such grants are not actively sought by the recipient government. This position appears untenable. Fertilizer aid is

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[7]These prices are consistent with the world market price quoted and published in World Bank, Commodity Trade and Price Trends, (Washington, D.C.: World Bank, 1983) and with recent unpublished data from the same source.

simply a mechanism of resource transfer and balance-of-payments support to Bangladesh. Given the dimensions of Bangladesh's food problems, fertilizer response functions, and price environment, the country would probably import fertilizers, even if other imports had to be reduced, if fertilizer aid were not forthcoming.

Moreover, even if donors dump fertilizers in Bangladesh, the government should approach the use of these resources in a manner that does not lead to an expansion of the use of fertilizer beyond the point of economic return, because of the implications for painful adjustment when the "free good" is no longer available. After all, the government of Bangladesh considers foreign aid to be a transitory phenomenon; the explicit objective of the government has been to eliminate dependence on foreign aid in the long run.

It has also been argued that the market clearing price of fertilizer is its economic price. The market clearing price is, of course, equivalent to the world price, if no intervention in the market is entertained. Market clearing prices could fall at <u>any</u> level with intervention, depending on the mechanism involved and the extent of its operation.

The fact that the government is exporting domestic urea while importing urea at higher prices using cash foreign exchange appears inconsistent with the anxiety of donors and the government to reduce subsidies to farmers through an improved pricing policy for fertilizers. If this practice is due to temporary storage problems, it is a planning and coordination issue that perhaps can be solved. But if it is due to the Chemical Industries Corporation's incentives or eagerness to earn foreign exchange under the current policy of encouragement to foreign exchange earners, it should be corrected through appropriate pricing mechanisms.

The importance of approaching the question of fertilizer subsidy on the basis of economic prices of fertilizers is once again vindicated by this state of affairs. Domestic factories need to be made more efficient by correctly analyzing the cost of producing fertilizer. Likewise, appropriate prices need to be adopted that will be accepted as just by both factories and farmers.

One serious handicap in following the economic pricing principle for fertilizer is the wide fluctuation in world prices for most fertilizers. Fertilizer prices in the world market, as published by the World Bank, are presented in Table 9. It may be seen that even without the exceptional oil crisis years of 1972 through 1975, fertilizer prices fluctuated rather widely from year to year. In the case of urea, annual fluctuation excluding the crisis years ranged from 2 to 40 percent. Figures for TSP, the main imported fertilizer in Bangladesh, are similar. Moreover, exceptional years have proved to be not that unusual--they have occurred in the past and there is no guarantee that a repetition of such events is unlikely.

Table 9--International prices of fertilizers, 1965-84

Year	Urea[a]	Fluctuation[b]	TSP[c]	Fluctuation	DAP[c]	Fluctuation
	(U.S. $ per ton)	(percent)	(U.S. $ per ton)	(percent)	(U.S. $ per ton)	(percent)
1965	95.8	...	n.a.	...	n.a.	...
1966	89.3	- 6.8	n.a.	...	n.a.	...
1967	79.3	-11.2	47.0	...	68.5	...
1968	65.5	-17.4	38.0	-19.1	65.5	- 4.4
1969	56.0	-14.5	39.0	+ 2.6	58.0	-11.5
1970	48.3	-13.8	43.0	+10.3	54.0	- 6.9
1971	46.0	- 4.8	43.0	0.0	61.8	+14.4
1972	59.3	+28.9	68.0	+58.1	91.0	+47.2
1973	94.8	+59.9	100.0	+47.0	118.8	+30.5
1974	315.8	+233.1	304.0	+204.0	332.6	+180.0
1975	198.0	-37.3	202.0	-33.6	243.0	-26.9
1976	112.0	-43.4	91.0	-55.0	120.0	-50.6
1977	127.4	+13.8	97.0	+ 6.6	133.0	+10.8
1978	144.8	+13.7	98.0	+ 1.0	139.8	+ 5.1
1979	172.9	+19.4	146.0	+49.0	193.3	+38.3
1980	222.1	+27.9	180.0	+23.3	222.2	+15.0
1981	216.0	- 2.3	161.0	-10.6	195.0	-12.2
1982	158.8	-26.5	138.4	-14.0	182.8	- 6.3
1983	135.4	-14.7	134.7	- 2.7	183.5	- 0.0
1984[d]	160.1	+18.2	129.8	- 3.6	193.8	+ 5.6

Source: International Bank for Reconstruction and Development/World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, 1983); and recent information from the same source.

Notes: TSP is triple superphosphate and DAP is diammonium phosphate. n.a. indicates data were not available. The ellipses (...) indicate a nil or negligible amount.

[a]Urea is f.o.b., ex-Europe, bagged.

[b]Fluctuation is the percent change from the previous year.

[c]TSP and DAP are f.o.b., U.S. Gulf ports.

[d]1984 figures are for January - June.

Domestic sale prices of fertilizer, if allowed to fluctuate with world prices, may create severe instability in agriculture. Fertilizer cost constitutes about 30 percent of the farmers' cash cost of production for foodgrains. Fluctuations in fertilizer prices of as much as 45 percent may thus critically exacerbate the problems of households facing short-term cash constraints.

This may lead to a reduction in the level of fertilizer use in a way that simply cannot be measured by the usual estimates of fertilizer demand elasticities. The usual demand elasticities are estimated from data exhibiting price ranges that fall significantly short of the international fertilizer price fluctuations. The increased fluctuations in prices may in turn induce a change in farmer behavior with respect to risk, adding a new force that could adversely influence the demand for fertilizers.

The economic principle may therefore be adopted only with the additional provision that domestic prices can be stabilized with a normal rate of increase in nominal prices commensurate with the general inflation rate or the inflation rate for prices of producers' goods.

Such a mechanism would require the organization of a fund for cushioning the price against severe fluctuation. Prices would be fixed at some trend of f.o.b. and c.i.f. prices, and if actual procurement prices went below this trend price the fund would be conserving resources, but when actual procurement prices went above it the fund would be giving out money. In exceptional years, like the oil crisis period, the fund may not be able to bear such a burden, and government may have to provide a subsidy. In the absence of such a mechanism, even if the fertilizer subsidy were completely removed now, the probability of its subsequent reintroduction would be high.

Approaches to Price Cushioning Under World Pricing Regimes

Two pricing mechanisms are considered here, both with an associated requirement for a stabilization fund. The basic idea is to evolve some sort of an average price for fixing a sale price of fertilizers following world pricing principles.

The first mechanism assumes that the sale price for the next year would be fixed at the simple three-year average of world fertilizer prices for the current, last, and previous years. To evaluate how such a mechanism could work in reality and what would be the probable size of a stabilization fund under such a practice, a simulation exercise was run for the period from the financial year 1977-78 through 1983-84. The results are shown in Table 10. It is obvious from the results that using the last three years' simple average to fix the current year's sale price would result in

Table 10--Simulated yearly surplus or deficit on fertilizer account, 1977-78 to 1983-84, under a simple average and a moving average pricing mechanism

Year/Pricing Mechanism	Surplus (+) or Deficit (-)			
	Urea[a]	TSP[b]	MP[c]	All Fertilizers
	(million Tk)			
Simple average				
1977-78	+ 22.55	+ 85.65	- 1.36	+106.84
1978-79	-207.99	- 53.85	-13.49	-275.33
1979-80	-601.58	-274.21	-40.17	-915.96
1980-81	-712.32	-267.02	-49.41	-1,028.75
1981-82	-458.28	-194.55	-33.48	-735.72
1982-83	- 76.11	-157.36	-18.40	-251.87
1983-84	-279.05	-252.44	-27.56	-559.05
Total				-3,659.84
Moving average				
1977-78	- 0.48	+ 24.77	+ 9.52	+ 33.81
1978-79	-168.46	-122.35	-18.94	-309.75
1979-80	-170.66	-115.82	+13.83	-272.65
1980-81	+ 20.16	+ 37.01	- 0.45	+ 56.72
1981-82	+192.55	+ 92.52	+14.98	+300.05
1982-83	+318.27	+ 48.27	+16.45	+382.99
1983-84	- 37.54	+ 15.95	+ 0.32	- 21.27
Total				+169.90

Note: TSP is triple superphosphate and MP is muriate of potash.

[a]For urea, the world price (f.o.b.) plus distribution cost was used.

[b]For TSP, the world price (c&f) plus distribution cost was used.

[c]For MP, the world price (c&f) plus distribution cost was used.

sustained deficits in the stabilization fund. The method fails to accommodate any inflationary trend in world prices and thus produces a continual deficit, year after year. Such a pricing route could not be followed in practice.

The second mechanism, simulated for the same time period, relates to a three-year moving average. For example, the 1977-78 year's sale price, under this approach, would be the moving average of world prices for 1974-75, 1975-76, and 1976-77 projected for 1977-78. (See Appendix 2 for the exact method.) The need for a projected price arises from two factors: first, the construction of a three-year moving average automatically involves a lag of one year, and, second, the next year's sale price has to be fixed in the current financial year. The projection is made on the basis of the average growth rate in moving average prices for the three years.

The simulation results indicating yearly surpluses and deficits under this pricing approach are also shown in Table 10. The results indicate that this approach generates surpluses in some years and deficits in others. Over the period of seven years simulated for this example, surpluses were generated in four years and deficits in three years. During this entire period the exercise showed a net surplus of about Tk 170 million or an average of less than Tk 25 million annually.

The size of the fund required would be indicated by the sizes of annual deficits and surpluses, as well as successive repetitions of deficits and surpluses. On this basis, such a mechanism could become a practical possibility for a sum roughly equivalent to Tk 500-600 million, which would be used to create a stabilization fund. Regular replenishment is not likely to be required, inasmuch as supplementary funds, necessitated by increasing volumes of distributed fertilizers, are not likely to be large.

As the numbers in Table 10 indicate, the size of the fund does not increase proportionally with increases in volume. The size of the required revolving fund is more a function of price fluctuations and the incidence of successive years in which price increases are accelerating. Any small increase over time from an increasing volume of fertilizer distribution could be managed through marginal changes in allocation or by reevaluating the pricing principle.

This amount, Tk 500-600 million, is only 35-45 percent of the estimated fertilizer subsidy to be incurred in 1984-85. This approach, therefore, appears to be a feasible option, provided the stabilization fund is managed efficiently. To ensure proper management and accountability, a stabilization fund should always be controlled by the government, preferably the Ministry of Finance. Banking principles have to be strictly followed and pricing analysis has to be conducted very carefully. Lapses on one of these fronts

could allow the fertilizer subsidy to reappear or could cause the imposition of entirely unwarranted burdens on farmers through higher-than-necessary prices for fertilizers.

Dynamics of Fertilizer Subsidy

One way to eliminate subsidies would be to leave the entire business to the private sector. Such a step may be bad for growth in food and agricultural production (at least if the government were to withdraw suddenly). So long as the government remains in the business, however, it has to be flexible with regard to pricing. Factors influencing fertilizer subsidy must be noticed as soon as changes occur.

First, the quantity and composition of fertilizers to be distributed in any year must be carefully planned. More thought should go into the selection of distribution targets. (See the technical papers by Samad and Quasem in this report.) Once target distribution has been set it should not be abandoned in mid-course. If the sale target is exceeded in a certain month, any panicky move to increase imports is going to be expensive, raising the budgetary subsidy.[8]

Second, any foreign purchase or request for concessional aids for fertilizer should be planned to avail of the best market situation. The foreign price of fertilizer affects domestic cost price and subsidy, given the inflexibility of the sales price. It has been shown that foreign prices fluctuate rather violently, and donors incorporate this price change in their invoice.

Third, fluctuation in exchange rates and world prices together may have a multiplicative effect on fluctuations in domestic prices. Foreign exchange to a government agency like BADC is generally provided at the official rate at any given time, but the official exchange rate is occasionally devalued (see Table 11). These devaluations, which are made according to macroeconomic considerations, are considered given. Nevertheless, the implications of exchange rate management are important for prices and fertilizer subsidy.

Fourth, price changes must be more gradual and regular. Fixation of sales price has generally been done once a year at the time of budget preparation (although mid-year price changes took place in a number of years). The official price changes are presented in Tables 12 and 13. It would appear from the tables that the

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[8]This does not mean that there should be no flexibility for handling emergencies.

Table 11--Average exchange rates, 1971-72 to 1982-83

Averages	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
	(taka per U.S. $)											
Monthly averages[a]												
July	b	7.7641	7.4617	7.9429	13.7314	14.9104	15.4954	14.7873	14.6134	14.7174	18.2498	22.1397
August	...	7.7419	7.6575	8.0851	14.1884	14.9698	15.3466	14.5067	15.2398	15.3008	18.5420	22.3419
September	...	7.7705	7.8347	8.1899	14.3786	15.4060	15.3193	14.8023	15.7860	15.1027	18.9374	22.7745
October	...	7.9164	7.8121	8.1337	14.5924	16.3132	15.0788	14.8744	16.1913	15.6365	19.1705	22.9284
November	...	8.0645	7.9363	8.1476	14.6310	15.5268	15.0578	15.5763	16.2735	16.2532	18.8739	23.8690
December	7.5090	8.0886	8.1793	8.1459	14.8397	15.1741	14.9034	15.3888	15.7798	16.5906	19.5321	24.1007
January	7.3747	8.0508	8.5286	8.0291	14.7931	15.5495	14.3185	15.4032	15.3406	16.1987	20.3203	24.5000
February	7.2841	7.8185	8.3375	7.9241	14.8014	15.6104	14.8010	15.5180	15.1585	16.8981	20.7867	24.5000
March	7.2368	7.6575	8.1093	7.8460	15.4208	15.5449	15.0481	15.2761	15.7394	16.6974	21.2765	24.5000
April	7.2673	7.6390	7.9429	8.0027	15.3611	15.5296	15.4348	15.2718	15.6715	17.2153	21.6819	24.5000
May	7.2618	7.4942	7.8574	12.9203	15.5446	15.5368	15.4138	15.6332	15.0836	17.6162	21.2319	24.5000
June	7.3632	7.3632	7.9363	13.1433	15.9422	15.5287	15.2414	15.6361	14.8539	17.9089	21.8762	24.5000
Quarterly averages[c]												
July-September	b	7.7588	7.6513	8.0726	14.0995	15.0954	15.3871	14.6988	15.2134	15.0403	18.5764	22.4187
October-December	b	8.0232	7.9759	8.1424	14.6877	15.6714	15.0133	15.2798	16.0815	16.1601	19.1922	23.6330
January-March	7.2985	7.8423	8.3251	7.9331	15.0051	15.5683	14.7225	15.3991	15.4128	16.5981	20.7945	24.5000
April-June	7.2974	7.4988	7.9122	11.3554	15.6160	15.5317	15.3633	15.5137	15.2030	17.5801	21.5967	24.5000
Fiscal year averages[d]	...	7.7808	7.9661	8.8759	14.8521	15.4667	15.1215	15.2228	15.4777	16.3447	20.0400	23.7620

Source: International Monetary Fund.

Note: The rates shown are period averages of the market rate, which are cross rates based on a fixed relationship to the Pound Sterling since January 1972.

[a]Monthly averages are averages of daily exchange rates.

[b]For July-December 1971 the trade conversion rate was Rupees 4.762 per U.S. $1.00.

[c]Quarterly averages are unweighted averages of monthly exchange rates shown.

[d]Fiscal year averages are unweighted averages of quarterly exchange rates shown. The average for 1983-84 was 25.0000.

Table 12--Official subsidized retail fertilizer prices, 1973-84

Year	Month	Official Prices for Urea	TSP(G)	MP	DAP
		(taka/maund)			
1973	July-December[a]	30	20	15	...
1974	January-March	30	20	15	...
	April-December[b]	50	40	30	...
1975	January-December	50	40	30	...
1976	January-June	50	40	30	...
	July-December[c]	60	48	40	...
1977	January-December	60	48	40	...
1978	January-June	60	48	40	...
	July-December[d]	70	55	45	70
1979	January-July	70	55	45	70
	August-December[e]	90	70	55	90
1980	January-October	90	70	55	90
	November-December[f]	110	90	70	110
1981	January-November	110	90	70	110
	December[g]	132	115	90	132
1982	January-June	132	115	90	132
	July-December	148	140	110	148
1983	January-March[h]	148	140	110	148
1984	July-December[i]	163	154	121	163

Source: Bangladesh Agricultural Development Corporation.

Notes: Prices to be charged by fertilizer retailers were not to exceed these prices.

TSP(G) is triple superphosphate in granular form, MP is muriate of potash, and DAP is diammonium phosphate.

[a]Effective July 10, 1973

[b]Effective April 1, 1974

[c]Effective July 1, 1976

[d]Effective July 1, 1978 DAP prices became effective on October 16, 1978.

[e]Effective August 27, 1979

[f]Effective November 2, 1980

[g]Effective December 7, 1981

[h]Effective April 1, 1983, there was no official regulated fertilizer price.

[i]Effective July 7, 1984

Table 13--Growth in official subsidized fertilizer prices, 1973-84

Period	Number of Months[a]	Growth in Prices[b] Over Previous Level		
		Urea	TSP(G)	MP
			(percent)	
July 1973 to March 1974	9	...	...	...
April 1974 to June 1976	27	67	100	100
July 1976 to June 1978	24	20	20	33
July 1978 to July 1979	13	17	15	13
August 1979 to October 1980	15	29	27	22
November 1980 to November 1981	13	22	29	27
December 1981 to June 1982	7	20	28	29
July 1981 to July 1982	12	12	22	22
July 1982 to July 1984	24	10	10	10

Source: Mohinder S. Mudahar, Fertilizer Price Deregulation and Public Policy: The Case of Bangladesh (Muscle Shoals, Ala.: International Fertilizer Development Center, 1984).

Note: Ellipses (...) indicate a nil or negligible amount.

[a]Number of months during each period when prices remained unchanged.

[b]Official price levels during July 1973 to March 1974 were, in terms of taka/maund, 30 for urea, 20 for granular triple superphosphate, TSP(G), and 15 for muriate of potash, MP.

sales prices remain constant for quite a long period and then suddenly go up. Farmers are used to a stable price that lasts a long time and they resent a sudden large increase.

Every price change involves an assessment of stock; and if they wish, storekeepers may make a lot of money at the expense of the budgetary subsidy simply by showing that some stock actually sold at the later price was sold at the earlier price. To prevent this, BADC arranges some stock inspection and verification by supervisory officers at the time of a price change. This procedure makes frequent price changes impractical.

But sales prices at least have to keep up with the relevant inflation index, so the pricing mechanism should allow nominal sales prices to move up dependent upon rice prices, for example, or some other index of prices.

Fifth, BADC's distribution cost should be evaluated regularly. Estimates of the distribution cost and its components are discussed in the following section.

Cost of Internal Distribution

The structure of the distribution cost of fertilizers can be gleaned from the data in Table 14. It should be noted that dealers' commission is included as an item of distribution cost, reflecting that the government sets the farm price and dealers are expected to accommodate their cost and profit within the margin of the dealers' commission.[9]

The dealer's commission is a decision variable and as such has been shown separately. The real distribution cost items indicate that the total distribution cost, excluding the dealer's commission, is only about 9.4 percent of the full value of fertilizers at primary distribution points in 1984-85. The figure including the dealer's commission is 14.8 percent. This estimate was about 13.2 percent in 1981-82. Distribution cost has been reduced by about 19 percent in nominal terms between 1980-81 and 1983-84. In real terms the reduction in distribution cost would be still larger.

This downward trend in distribution cost can primarily be attributed to the shifting cost to dealers (or to farmers) through the introduction of a new marketing system (see the technical paper by Quasem). However, part of the reduction is also due to an improvement in BADC's performance, which may have been indirectly caused by the pressure for such improvement from the new system.

Scope for further reduction in distribution may exist in items like movement and handling, overhead, and pay and allowances (staff strength remains the same even though thana sales centers have been closed). On the other hand, the depreciation of public godowns is not included in the cost.

BADC has conducted a commendable exercise to find out the least costly modes of transportation of fertilizers, and it has been restructuring its tendering procedures for internal movement on the basis of these low-cost solutions. Overhead used to be charged at a flat rate of 2.5 percent of the total value of fertilizers; this flat rate has also been brought down. Therefore, further scope for reduction of the distribution cost may not be substantial.

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[9]It is somewhat odd that commission is still included in the distribution cost since in 1984-85 the government deregulated retail prices of fertilizers, implying that dealers can sell at any price they can get.

Table 14--Internal distribution cost of fertilizers, 1980-81 to 1983-84

Cost	1980-81		1981-82		1982-83		1983-84[a]	
	Cost	Share	Cost	Share	Cost	Share	Cost	Share
	(Tk/ ton)	(per- cent)	(Tk/ ton)	(per- cent)	(Tk/ ton)	(per- cent)	(Tk/ ton)	(per- cent)
Movement and handling	280	47.5	428	63.4	361	52.9	286	60.1
Staff pay and allowances	44	7.5	43	6.4	56	8.2	48	[illegible].0
Establishment cost and repair-maintenance	13	2.2	16	2.4	12	1.8	11	2.3
Overhead	85	14.4	104	15.4	92	13.5	75	15.8
Godown rent	18	3.1	12	1.8	16	2.3	3	0.6
Physical verification, bagging, and dunnage	6	1.0	7	1.0	1	0.1	1	0.2
Stock loss	49	8.3	19	2.8	19	2.8	11	2.3
Publicity, promotion, and training	1	0.1	1	0.1	2	0.3	3	0.6
Interest on working capital	87	14.8	26	3.9	101	14.8	16	3.3
Marine insurance	6	1.0	19	2.8	23	3.4	22	4.6
Subtotal	589	(100.0)	675	(100.0)	683	(100.0)	476	(100.0)
Dealers' commission	180		241		275		275	
Total	769		916		958		751	

Source: Bangladesh Agricultural Development Corporation.

Note: The quantity distributed in 1,000 metric tons was 875.2 tons in 1980-81; 829.3 tons in 1981-82; 968.4 tons in 1982-83; and 1,220.0 tons in 1983-84.

[a]The 1983-84 figures were estimated.

Conclusion

The selection of an appropriate methodology for estimating the fertilizer subsidy to farmers does not appear to be straightforward. The method based on economic pricing (world prices) requires a price stabilization mechanism, which, based on experience in other commodities, could be administratively cumbersome.

On the other hand, the modified current approach, based on cost of production for domestic fertilizers and world prices for imports, could result in a greater burden on farmers in future years, if a stricter procedure is imposed on industries for estimating the cost of production, particularly with the requirement that such cost estimates should include a realistic provision for capital replacement and opportunity cost of raw materials.

Moreover, the advantage of the modified current method over the economic pricing method is not that great. In 1983-84, the modified current method yielded a subsidy rate of roughly 21 percent compared to 23 percent using the economic pricing approach.

The potential difficulties in managing a stabilization fund are likely to be less onerous than those experienced in other commodity price stabilization schemes. In fact, this proposed fund is nothing more than a variable subsidy and tax mechanism.

Most commodity stabilization programs have failed in the past in Bangladesh because the control of funds as well as the pricing and costing authority were left with the same organization. If the Ministry of Finance keeps control over the fertilizer stabilization fund and participates in strictly enforcing the pricing principle, the chances of failure may be small. Under this condition, the economic pricing principle, as delineated above, may be considered the best option.

PRICE SCENARIOS FOR 1985-86 AND 1986-87 WITH A ZERO SUBSIDY

In this section, a number of alternative scenarios will be presented in order to pinpoint the best method for changing subsidy policy. Six items appear to be relevant for developing these scenarios: the methods or approaches for estimating subsidy, the distribution targets in 1985-86 and 1986-87, the domestic production and import projections, the profile of base year prices (1984-85), the rate of increase in acquisition costs, and the sale prices at BADC godowns in future years.

In estimating subsidy, two approaches are selected--the modified current approach and the economic subsidy. The former is the existing method of calculation of budgetary subsidy, with the modification that all imports are assumed to be valued at prevailing

world market prices, rather than donor's invoices. This assumption is made because future sources of aid and aid-related prices are not known, and the passing over of the cost of tied aid to farmers may not be desirable. The latter approach, economic subsidy on fertilizers, has already been defined.

The figures shown in Table 15 have been adopted on the basis of targets for distribution, domestic production estimates, and implied import requirements. Distribution targets are the results of the Agriculture Ministry's exercise for the Third Plan. Import requirements are worked out as residuals of distribution targets and domestic production. Domestic production is unreliable, so trend or planned growth in plant output has not been assumed. Instead, best historical production performance for each fertilizer factory has been adopted with marginal adjustments.

Table 15--Distribution targets and supply of fertilizers, 1985-86 and 1986-87

Distribution/ Source of Supply	1985-86	1986-87
	(1,000 metric tons)	
Target distribution		
Urea	833	904
TSP	433	479
MP	71	75
Total demand	1,337	1,458
Domestic supply		
Urea from Ghorasal and Fenchuganj	370	370
Urea from Ashuganj	400	400
TSP	85	85
Total	855	855
Imported		
Urea	63	134
TSP	348	394
MP	71	75
Total	482	603
Total supply (domestic and imported)	1,337	1,458

Note: TSP is triple superphosphate and MP is muriate of potash.

Base year and projected cost prices used in the scenario analysis are shown in Table 16. It is assumed that imported urea will increase in price by 10 percent per year. By the end of September 1984, upward pressure on the world urea price had developed, though TSP and MP had not yet shown any upward trend. Other prices are assumed to increase at 7 percent per year. Distribution cost is also assumed to increase at a 7 percent rate.

Subsidy Scenario under the Modified Current Approach

The results of this exercise are shown in Tables 17 and 18. In Table 17 budgetary implications for a policy of no change in fertilizer sales prices during 1985-86 and 1986-87 are shown. Because of the assumption that fertilizers under grant and tied aid would be valued at market prices, the size of the subsidy is not that large compared to what it could have been otherwise, particularly in 1985-86.

The interesting result is in Table 18. If the subsidy is to be completely eliminated by 1985-86, there will have to be a one-time increase in the sales price of urea, TSP, and MP of 3.25, 39.70, and 23.86 percent, respectively, taking effect on July 1, 1985.

Thereafter, the sales prices would have to be raised every year to keep up with the rise in procurement prices of fertilizer. If fertilizer prices in the world and domestic markets do not rise or rise at a slower rate than assumed, the required increase in sales prices would accordingly be smaller.

The second part of Table 18 shows that the same objective, elimination of subsidy, can be achieved by a cross subsidy of TSP financed by an implied tax on urea. This would imply price increases for urea of 12.2 percent, for TSP of 20 percent, and for MP of 23.86 percent. Thereafter, sale and procurement prices of fertilizers would have to keep pace with inflation.

Subsidy Scenario under the Economic Pricing Approach

The economic subsidy scenarios for the years 1985-86 and 1986-87 are presented in Tables 19 and 20. The higher figures for subsidy in 1986-87 in Table 19 are based on the assumption that sales prices of fertilizers will remain the same, but procurement and distribution costs will rise.

The absolute magnitude of overall gross subsidies under the economic pricing approach are, of course, substantially larger than the figures under budgetary subsidy. But the uniform pricing of cost distributes the rate of subsidy relatively evenly across types of fertilizer. As a result, the increases in sales prices in 1985-86 that would be required to eliminate economic subsidy are 18.0 percent

Table 16--Procurement and distribution costs projected for 1985-86 and 1986-87

Approach/Fertilizer	Base Year	1985-86	1986-87
		(Tk/ton)	
Modified current approach			
Procurement cost			
Urea, domestic[a]	2,800	2,996	3,206
Urea, other domestic	3,860	4,130	4,419
Urea, imported	4,625	5,088	5,596
TSP, domestic	5,735	6,136	6,566
TSP, imported	4,375	4,681	5,009
MP, imported	3,000	3,210	3,435
Distribution cost	750	803	859
Economic subsidy approach			
Procurement cost			
Urea, domestic	3,840	4,224	4,646
Urea, imported	4,625	5,088	5,596
TSP, domestic	3,632	3,886	4,158
TSP, imported	4,375	4,681	5,009
MP, imported	3,000	3,210	3,435
Distribution cost	800	856	916

Source: Base year figures are from previous tables, derived from data provided by the Bangladesh Agricultural Development Corporation.

Notes: With the modified current approach, domestic urea prices increase at an annual rate of 7 percent, imported urea prices increase at an annnual rate of 10 percent, and imported triple superphosphate (TSP) and muriate of potash (MP) prices increase at an annual rate of 7 percent.

With the economic subsidy approach, urea prices increase at a 10 percent rate, and TSP and MP prices increase at a 7 percent rate.

[a]This is urea from Ghorasal and Fenchuganj.

Table 17--Budgetary subsidy on fertilizers, scenarios for 1985-86 and 1986-87, using 1984-85 sales prices

Fertilizer	Source	Average Costs	Average Sales Price	Total Cost	Total Receipt	Total Subsidy	Rate of Subsidy
		(Tk/ton)		(million Tk)			(percent)
			1985-86 Scenario				
Urea	Domestic	3,799	4,360	1,405.63	1,613.20	-207.57	-14.8
	Domestic	4,933	4,360	1,973.20	1,744.00	229.20	11.6
	Imported	5,891	4,360	371.13	274.68	96.45	26.0
TSP	Domestic	6,939[a]	4,130	589.82	351.05	238.77	40.5
	Imported	5,484	4,130	1,908.43	1,437.24	471.13	24.7
MP	Imported	4,013	3,240	284.92	230.04	54.88	19.3
All fertilizers	...	...	...	6,533.33	5,650.21	882.86	13.51
			1986-87 Scenario				
Urea	Domestic	4,065	4,360	1,504.05	1,613.20	-109.15	-7.3
	Domestic	5,278	4,360	2,111.20	1,744.00	367.20	17.4
	Import	6,455	4,360	864.97	584.24	280.73	32.5
TSP	Domestic	7,425	4,130	631.13	351.05	280.08	44.4
	Imported	5,868	4,130	2,311.99	1,627.22	684.77	29.6
MP	Imported	4,294	3,240	322.05	243.00	79.05	24.5
All fertilizers	...	...	...	7,745.39	6,162.71	1,582.68	20.4

Source: Calculated from basic data provided by the Bangladesh Agricultural Development Corporation.

Notes: TSP is triple superphosphate and MP is muriate of potash.

for urea, 30.3 percent for TSP, and 25.5 percent for MP. (Remember that the corresponding figures for the elimination of the budgetary subsidy were price increases of 3.25 percent for urea, 39.7 percent for TSP, and 23.86 percent for MP.)

A slight cross subsidy of urea for TSP, financed via higher urea prices, makes the required price increase for both urea and TSP almost the same--22.1 percent for urea and 22.0 percent for TSP--in order to eliminate economic subsidy. Under the economic subsidy approach, cross subsidy does not appear to be very important.

For 1986-87, the price increases are required only to sustain the zero subsidy status by keeping up with increases in the procurement and distribution cost of fertilizers. These price increases are based on the assumed inflation rate. If the rate of inflation were different than expected, sales prices would have to be adjusted accordingly.

Table 18--Estimated sale price of fertilizers in 1985-86 and 1986-87 for a zero budgetary subsidy and with a cross-subsidy of TSP from urea

Type of Fertilizer	Base Year Price	1985-86 Estimated Price	Increase	1986-87 Estimated Price	Increase from 1985-86
	(Tk/ton)		(percent)	(Tk/ton)	(percent)
			Zero Budgetary Subsidy		
Urea	4,360	4,501.75	3.3	4,956.00	10.1
TSP	4,130	5,769.63	39.7	6,144.30	6.5
MP	3,240	4,013.00	23.9	4,294.00	7.0
			Zero Budgetary Subsidy with Cross-Subsidy		
Urea	4,360	4,892.27	12.2	5,392.56	10.2
TSP	4,130	4,956.00	20.0	5,320.32	7.4
MP	3,240	4,013.00	23.9	4,294.00	7.0

Source: Calculated from basic data provided by the Bangladesh Agricultural Development Corporation.

Notes: TSP is triple superphosphate and MP is muriate of potash.

Table 19--Scenarios for 1985-86 and 1986-87 of economic subsidy on fertilizers, using 1984-85 sales prices

Fertilizer	Source	Average Costs	Average Sales Price	Total Cost	Total Receipt	Total Subsidy	Rate of Subsidy
		(Tk/ton)		(million TK)			(percent)
			1985-86 Scenario				
Urea	Domestic	5,080	4,360	3,911.60	3,357.20	554.40	14.2
	Import	5,944	4,360	374.47	274.68	99.79	26.6
TSP	Domestic	4,742	4,130	403.07	351.05	52.02	12.9
	Import	5,537	4,130	1,926.88	1,437.24	489.64	25.4
MP	Import	4,066	3,240	288.69	230.04	58.65	20.3
All fertilizers		...	...	6,904.71	5,650.21	1,254.50	18.2
			1986-87 Scenario				
Urea	Domestic	5,562	4,360	4,282.74	3,357.20	925.54	21.6
	Import	6,512	4,360	872.61	584.24	288.37	33.0
TSP	Domestic	5,074	4,130	431.29	351.05	80.24	18.4
	Import	5,925	4,130	2,334.45	1,627.22	707.23	30.3
MP	Import	4,351	3,240	326.33	243.00	83.33	25.5
All fertilizers		...	...	8,247.42	6,162.71	2,084.71	25.3

Source: Calculated from basic data provided by the Bangladesh Agricultural Development Corporation.

Notes: TSP is triple superphosphate and MP is muriate of potash.

Table 20--Estimated sale price of fertilizers in 1985-86 and 1986-87 for a zero economic subsidy and with a cross-subsidy of TSP from urea

Type of Fertilizer	Base Year Price	1985-86 Estimated Price	Increase	1986-87 Estimated Price	Increase from 1985-86
	(Tk/ton)		(percent)	(Tk/ton)	(percent)
		Zero Economic Subsidy			
Urea	4,360	5,145.34	18.0	5,702.82	10.8
TSP	4,130	5,380.95	30.3	5,773.99	7.3
MP	3,240	4,066.00	25.5	4,351.00	7.0
		Zero Economic Subsidy with Cross-Subsidy			
Urea	4,360	5,323.30	22.1	5,895.82	10.8
TSP	4,130	5,038.60	22.0	5,406.42	7.3
MP	3,240	4,066.00	25.5	4,351.00	7.0

Source: Calculated from basic data provided by the Bangladesh Agricultural Development Corporation.

Notes: TSP is triple superphosphate and MP is muriate of potash.

Phasing of Subsidy Withdrawal

To ensure a smooth transition from the present situation to one with little or no subsidy, the phasing of the increases in sales prices has to be worked out carefully. The basic consideration should be the effect of price changes on farm-level incentives for use of fertilizer. Farm-level incentives are, in turn, dependent on product, as well as fertilizer, prices. Therefore, an assessment of the likely behavior of the following three factors should provide some direction in determining the least disruptive pattern of phasing for the increase in fertilizer prices.

Paddy Price. Although consumers are naturally bitter about high rice prices, the current product price environment is one of the best in Bangladesh from the producers' point of view. This will be clearly shown later in this paper, when rice price trends are analyzed relative to fertilizer prices. The average rice price is close to the world price, when valued at the official exchange rate. Rarely has such a situation prevailed for foodgrain prices in the history of

Bangladesh. The product price conditions thus appear to be congenial for a moderately abrupt increase in fertilizer prices with minimal effects on farm-level incentives.

Expected World Prices of Fertilizers. Although it is somewhat hazardous to guess what world fertilizer prices will be during the next five years, indications are that they will rise in real terms, at least for nitrogenous fertilizers. Table 21 and Figures 2 and 3 show the price outlook for fertilizers in the world market. In the table and figures, a rising trend is seen in the real prices of both urea and TSP from 1985 through 1990.[10]

Several adverse economic factors contributed to the temporary reduction in international fertilizer prices from 1981 through 1983. The general economic slowdown was accompanied by a steep decline in agricultural product prices. High interest rates in the major industrial countries made fertilizers more expensive to farmers. Because of budgetary pressures, some of the major fertilizer importers among developing countries had to reduce fertilizer subsidies. Finally, the substantial appreciation of the U.S. dollar vis-à-vis other major currencies during this period brought down dollar-denominated prices of fertilizers in the international market. The price setback made fertilizer production unprofitable for many producers, leading to cutbacks and plant closures.

All of these factors are gradually changing and by 1984, the price of urea had already shown some upward movement. It seems that the working group's projection is becoming a reality. On the basis of this projection, urea prices are expected to rise by 24.4 percent in real terms between 1985 and 1990, and TSP prices are projected to increase by 12.4 percent during the same period. Prices in nominal terms will rise still faster.

This price increase can primarily be attributed to long-term rises in the prices of natural gas and rock phosphate. The U.S. Department of Energy projects that natural gas prices to the indus-

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[10]It is necessary to mention here that projection of prices in international commodity markets, particularly for fertilizers, has seldom been accurate. Therefore, this observation that fertilizer prices on the market will increase in coming years is extremely speculative. A further fall in real prices cannot altogether be ruled out. If prices on the world market in fact fall in the coming years, then elimination of subsidy may result automatically without much of an increase in the farm-level price of fertilizer.

Table 21--World fertilizer prices, 1955-81 (actual) and 1982-95 (projected)

Year	Phosphate Rock[a] Current	Phosphate Rock[a] Constant	Urea[b] Current	Urea[b] Constant	TSP[c] Current	TSP[c] Constant	DAP[c] Current	DAP[c] Constant	Potash[d] Current	Potash[d] Constant
					(U.S. $)					
					Actual					
1955	14.5	56.2	...	...	...	...	...	...	32.5	126.0
1956	14.5	54.9	...	...	...	...	...	...	32.5	123.1
1957	14.0	50.5	...	...	...	...	...	...	32.0	155.5
1958	14.0	47.9	...	...	...	...	...	...	31.0	106.2
1959	13.0	46.8	...	...	...	...	...	...	30.0	107.9
1960	13.0	45.6	...	...	...	...	...	...	28.5	100.0
1961	13.0	45.6	...	...	...	...	...	...	30.0	105.3
1962	11.5	40.8	...	...	...	...	...	...	30.0	106.4
1963	11.5	40.4	72.3	253.7	...	...	...	...	30.0	105.3
1964	12.5	43.3	90.5	313.1	...	...	...	...	32.5	112.5
1965	14.0	47.5	95.8	324.7	...	...	...	...	29.5	100.0
1966	13.0	43.0	89.3	295.7	...	...	...	...	27.5	91.1
1967	12.0	39.2	79.3	259.2	45.0	147.1	68.5	223.9	25.5	83.3
1968	11.5	40.1	65.5	228.2	37.5	130.7	65.5	228.2	24.0	83.6
1969	11.3	39.1	56.0	193.8	39.3	136.0	58.0	200.7	22.0	76.1
1970	11.0	34.5	48.3	151.4	42.5	133.2	54.0	169.3	31.5	98.7
1971	11.3	32.7	46.0	132.9	43.3	125.1	61.8	178.6	32.5	93.9
1972	11.5	30.3	59.3	156.1	67.5	177.6	91.0	239.5	33.5	88.2
1973	13.8	30.4	94.8	208.8	99.5	219.2	118.8	261.7	42.5	93.6
1974	54.5	97.0	315.8	561.9	303.6	540.2	332.6	591.8	60.5	107.7
1975	67.0	104.0	198.0	307.5	202.5	314.4	243.0	377.3	81.3	126.2
1976	36.0	55.0	112.0	171.0	90.9	138.8	120.0	183.2	55.0	84.0
1977	30.5	42.9	127.4	179.2	97.9	137.7	133.0	187.1	51.0	71.7
1978	29.0	34.4	144.8	172.0	98.0	116.4	139.8	166.0	56.4	67.0
1979	33.0	35.1	172.9	183.7	142.2	151.1	193.3	205.4	76.7	81.5
1980	46.7	45.1	222.1	214.4	180.3	174.0	222.2	214.5	115.7	111.7
1981	49.5	49.5	216.0	216.0	161.3	161.3	195.0	195.0	112.4	112.4
					Projected					
1982	43.0	41.3	185.0	177.9	160.0	153.8	200.0	192.3	90.0	86.5
1983	48.5	44.0	210.0	190.6	180.0	163.3	230.0	208.7	105.0	95.3
1985	59.6	47.0	270.0	212.9	220.0	173.5	300.0	236.6	130.0	102.5
1990	84.9	50.0	449.7	265.0	330.9	195.0	543.0	320.0	186.7	110.0
1995	113.6	50.0	624.5	275.0	442.8	195.0	735.8	324.0	249.8	110.0

Sources: British Sulphur Corporation (actual); World Bank, Economic Analysis Projections Department (projected).

Notes: Ellipses indicate that these figures are not available. All prices are per product ton.

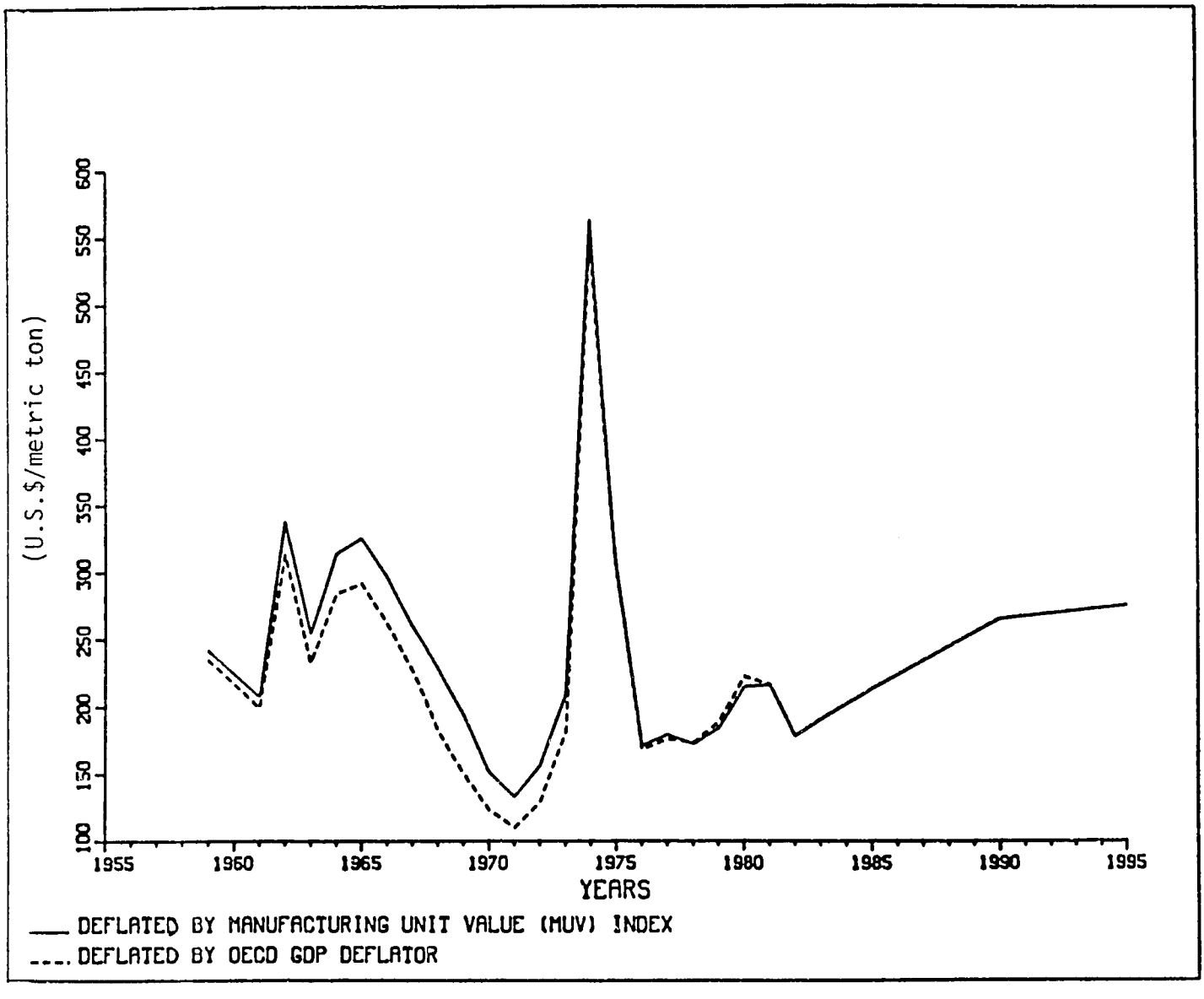
[a]Price of 75 percent BPL rock, FAS Casablanca through 1975; that of 72 percent BPL rock during 1976-80; and that of 70 percent BPL rock from 1981 onward.

[b]Bagged, f.o.b. Northwest Europe.

[c]Bulk, f.o.b. Florida.

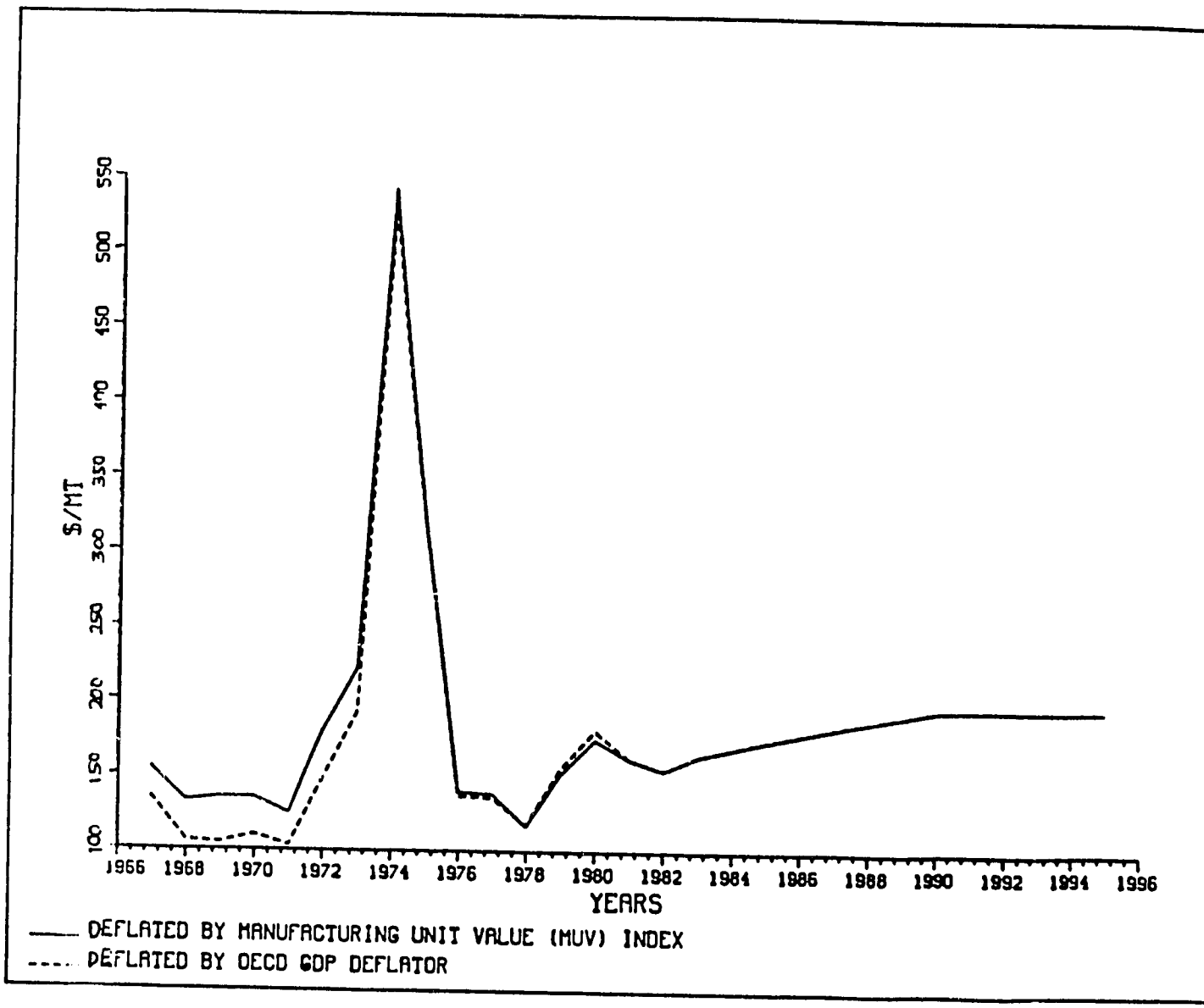
[d]Bulk, f.o.b. Vancouver.

Figure 2--Urea prices in 1981 constant U.S.$ (1958-81 actual and 1982-95 projected)



Sources: British Sulphur Corporation (actual); World Bank, Economic Analysis and Projections Department (projected).

Figure 3--TSP prices, 1981 constant U.S. $ (1967-81 actual and 1982-95 projected)



Sources: British Sulphur Corporation (actual); World Bank, Economic Analysis and Projections Department (projected).

trial sector in terms of 1981 constant dollars will increase from U.S. $2.30 to U.S. $8.00 per million Btus from 1981 to 1990.[11]

Although the balance between world supply and demand will not be greatly disturbed at the new equilibrium, the location of the supply will shift more toward centrally planned economies, and location of demand will gradually shift toward developing countries. A new trade pattern may thus evolve in the world fertilizer market. Rising import demand from China and India may have a further destabilizing effect on the world market as a result of large purchases. China's imports of chemical fertilizers have been rising sharply: they increased from about 1 million tons of nutrients in 1976 to a little more than 3 million tons in 1983. Investment in expanding China's domestic production capacity has slackened considerably in recent years and the new economic measures seem to imply greater dependence on imports than in the past.[12]

Margin between Retail and Ex-PDP Prices. The margin between the price from the primary distribution point (ex-PDP) and retail prices depends on market equilibria and the extent of competition. When the supply is plentiful or even mildly tight, the difference between ex-PDP and retail prices ranges from 5 to 17 percent of the ex-PDP price. When supply is inadequate relative to demand, requiring some quota allocation to dealers, the difference between prices becomes wider.

The shortage of fertilizer in October-November 1984 caused retail prices to differ from the ex-PDP price by 15 to 50 percent (see the technical paper by Quasem). Quasem's paper indicates that in situations with roughly adequate supply (such as that in 1981), the increase in the ex-PDP price is almost entirely transmitted to farmers.

If the sale price is increased at ex-PDP levels during scarcity, would the retail price go up the full extent of the price increase? Data are not adequate to test this question empirically for a severe scarcity situation. But economic logic would suggest that during a scarcity situation dealers make abnormal profits. Therefore, an increase in the ex-PDP price during a time of short supply may not be passed on in the form of an increase in the already inflated farm-

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[11]U.S. Department of Energy, Energy Projections to the Year 2000, a supplement to the National Energy Policy Plan (Washington, D.C.: U.S. Government Printing Office, 1981).

[12]Bruce Stone, "Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency, and Response," in U.S. Congress Joint Economic Committee (ed.), Chinese Economy in the Eighties (Washington, D.C.: U.S. Government Printing Office, 1985).

gate price. An increase in price during such a situation will only reduce dealers' abnormal profits.

To understand this logic, careful discussions were initiated with dealers during field trips. Dealers explained that they would prefer to make a larger number of trips (greater volume of sales) with a smaller profit per trip to making a fewer number of trips (smaller sales volume) and having a higher profit per trip. This means that dealers' time and working capital remain underutilized during scarce-supply situations; its implication is a higher cost per unit of fertilizer marketed. Therefore, the extent of abnormal profit may be lower than what would be indicated by apparent price differences. (It follows from this logic that farmgate prices of fertilizer will also increase if ex-PDP price is raised sharply during a scarcity period without a simultaneous effort to diffuse the supply scarcity.) Moreover, situations of extreme shortage have typically prevailed for a fairly short period, so that farmers are soon paying prices that, although lower than the scarcity period prices, reflect the ex-PDP price increase when compared with more normal periods.

To summarize the discussion on phasing, current conditions relating to rice price, world prices of fertilizer (present and prospective), and strength of demand relative to supply all indicate that this may be an appropriate time to increase the price of fertilizer to eliminate or reduce subsidy, by accommodating most of the needed price increase in one or two installments, as a more gradual change could synchronize with a rising world price, entailing a larger total increase in prices in the future. That would produce a more destabilizing effect than a large increase now.

RICE-FERTILIZER PRICE RELATIONS AND MANAGEMENT OF THE RICE PRICE

The value of fertilizer to farmers is the marginal product of fertilizer times the price of the rice that farmers produce with fertilizer. For the time being, complexities involving the use of fertilizers by subsistence farmers may be ignored. In previous sections the economic subsidy was evaluated without any consideration of rice prices. It was implicitly assumed that rice prices were consistent with world markets. Here this issue is examined.

The approach has been adopted that the price of fertilizers, instead of being distorted by aid financing, should be determined by free market forces. Where export alternatives exist or imports of fertilizers entail expenditure of foreign exchange that could otherwise be used for imports of rice, an international trade dimension is necessarily involved. Under this situation, efficient use of resources requires that the relative prices of fertilizer and rice in the domestic market equal their relative prices in the world market. Thus it follows that the market price of fertilizer should

be equal to the relative world price times the domestic price of rice.[13]

This formulation is, however, a partial approach in the sense that an economy may be producing an n number of goods employing an x number of factors of production, tradable and nontradable. If there are strong complementary factors or substitutability among factors of production, but all are used in production of the n number of goods, correcting distortion only in relative prices of one product and a factor of production may not produce an optimal price relation. But in the present case, both fertilizer and rice are tradable and most fertilizers are used on rice. Therefore, a partial approach may not be as unreliable as one might think. Moreover, this part is simply an extension of the previous argument suggesting the border price for valuation of fertilizers. This is then explored in the context of the rice price, which may not be maintained at world levels for political as well as welfare reasons.

Being a small country, Bangladesh is unlikely to have large effects on world markets for fertilizer and rice. Thus if fertilizer prices are corrected in line with the world market in a single-minded fashion without any consideration for the rice price (or, for that matter, prices of other agricultural products that use fertilizer) one distortion may be corrected and others may be accentuated.[14]

Ratios of rice and urea prices in domestic and world markets[15] are presented in Tables 22 and 23 and shown graphically in

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[13]If DPr, DPf, WPr, and WPf are, respectively, domestic price of rice, domestic price of fertilizers, world price of rice, and world price of fertilizers, then

$$DPf/DPr = WPf/WPr \quad \text{or} \quad DPf = DPr(WPf/WPr).$$

Dr. Shahadatullah, a member of the Bangladesh Planning Commission, has provided a lucid exposition of this general relation in one of his papers on fertilizer subsidy.

[14]Rice price is a proxy for agricultural prices. Under conditions in Bangladesh, where about 80 percent of fertilizers are applied on rice, this proxy seems to be a reasonable representation.

[15]The comparison of the fertilizer-rice price ratio at wholesale border prices overestimates farm-level incentives. For comparisons at the farmgate, the marketing cost between farmgate and wholesale levels should have been deducted from the wholesale price in the case of rice and added to the wholesale price in the case of fertilizers. This fine-tuning in border pricing could not be done due to data problems.

Table 22--Ratios of rice and urea prices in domestic and world markets, 1972-73 to 1983-84

Year	Urea to Rice Price, Domestic Market	Urea to Rice Price, World Market		Domestic to World Rice Price	Domestic to World Urea Price	
		Export Parity	Import Parity		Export Parity	Import Parity
1972-73	0.25	0.55	0.64	1.22	0.55	0.47
1973-74	0.28	0.57	0.76	0.79	0.39	0.29
1974-75	0.23	0.66	0.78	1.41	0.49	0.41
1975-76	0.45	0.59	0.73	0.74	0.56	0.45
1976-77	0.49	0.50	0.61	0.69	0.68	0.56
1977-78	0.40	0.51	0.62	0.78	0.60	0.50
1978-79	0.42	0.49	0.59	0.69	0.60	0.49
1979-80	0.41	0.56	0.65	0.83	0.61	0.53
1980-81	0.61	0.75	0.87	0.79	0.65	0.56
1981-82	0.56	0.59	0.69	0.78	0.74	0.63
1982-83	0.58	0.58	0.70	0.87	0.88	0.73
1983-84	0.52	0.81	0.95	1.23	0.78	0.67

Source: Constructed on the basis of price information in Appendix 1.

Note: All prices are wholesale border prices.

Table 23--Ratios of three-year moving average rice and urea prices in domestic and world markets, 1973-74 to 1983-84

Year	Urea to Rice Price, Domestic Market	Urea to Rice Price, World Market		Domestic to World Rice Price	Domestic to World Urea Price	
		Export Parity	Import Parity		Export Parity	Import Parity
1973-74	0.22	0.61	0.86	1.14	0.42	0.29
1974-75	0.33	0.61	0.75	0.98	0.53	0.43
1975-76	0.37	0.58	0.70	0.93	0.60	0.49
1976-77	0.44	0.53	0.65	0.74	0.61	0.50
1977-78	0.41	0.50	0.60	0.72	0.59	0.48
1978-79	0.39	0.52	0.62	0.77	0.57	0.48
1979-80	0.48	0.59	0.70	0.77	0.62	0.53
1980-81	0.52	0.62	0.73	0.80	0.67	0.57
1981-82	0.56	0.63	0.74	0.82	0.76	0.65
1982-83	0.57	0.65	0.76	0.94	0.83	0.70
1983-84	0.55	0.68	0.81	1.03	0.83	0.70

Source: Constructed on the basis of price information in Appendix 1.

Note: All prices are wholesale border prices.

Figures 4 and 5. Table 22 and Figure 4 show these ratios with actual prices, whereas in Table 23 and Figure 5 the moving average of prices is used to construct the ratios, thus smoothing out the effects of fluctuations.

It can be seen that Bangladesh has made commendable progress over the past decade in bringing up its urea-to-rice price ratio toward world levels. In the early 1970s about 0.22 to 0.40 units of rice were needed to buy one unit of urea in Bangladesh. In the early 1980s, this urea price was about 0.52 to 0.57 units of rice. In contrast, the world market shows an exchange rate of 0.50 to 0.68 units of rice for one unit of urea throughout the decade.

One of the reasons for the increase in Bangladesh's urea-to-rice price ratio was an increase in the nominal prices of urea. In the early 1970s nominal prices of urea were only 40 to 60 percent of world prices, whereas in the early 1980s the nominal prices of urea in domestic markets were about 70 to 80 percent of world prices. The low world prices of urea that have prevailed during this later period have been one of the factors enabling Bangladesh to achieve this progress. Nevertheless, the urea price has to increase further or the rice price to fall slightly to equalize domestic and world price ratios of urea and rice. Because the difference between domestic and world urea prices is larger than the difference between domestic and world rice prices, it seems logical to bridge the gap by raising urea prices.

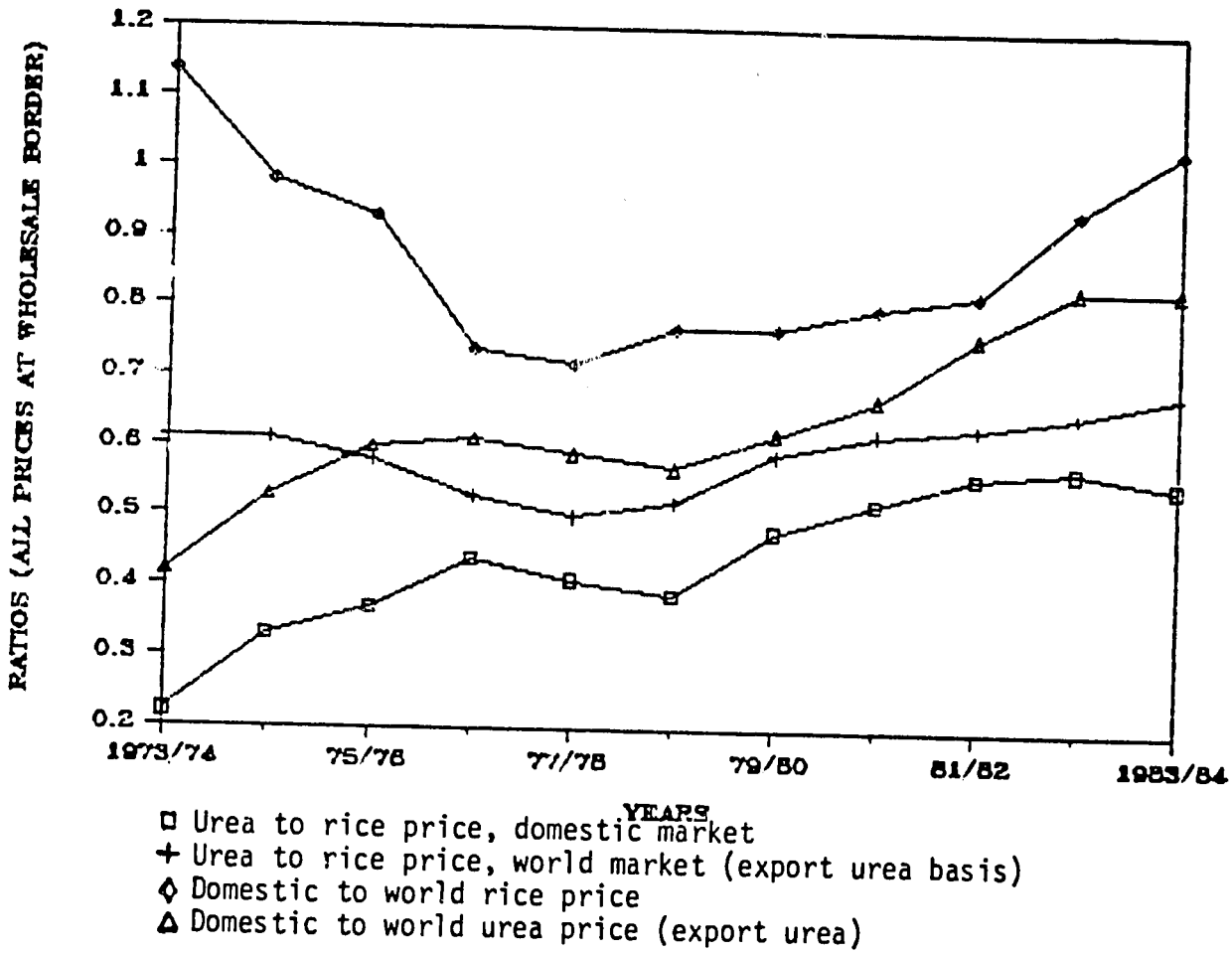
The rice-TSP price ratios in domestic and world markets presented in Tables 24 and 25 show a pattern similar to the rice-urea price ratios. The same sort of conclusions are therefore applicable to TSP.

The moving average urea-rice price ratio in the world market was 0.68 in 1983-84. The same ratio in the domestic market was 0.55. The domestic price of urea was Tk 148 per maund and the domestic price of rice was Tk 268 per maund (the rice price in 1983-84 was at par with the world price).

To equate the domestic urea-rice price ratio with the world ratio (that is, to raise the domestic ratio of 0.55 to the world level of 0.68), with the domestic rice price remaining constant, would require the domestic fertilizer price to be raised from Tk 148 to Tk 182 per maund. This would mean an increase in the price of urea in 1983-84 of about 23 percent, such is the size of the price distortion in fertilizer prices in 1983-84, using the criterion of world price.

If, however, the price of rice in 1983/84 were Tk 218 per maund, rather than Tk 268, then the urea price of Tk 148 would put the domestic urea-rice price ratio on par with the world urea-rice price ratio. In that event, even though parity would be obtained, both

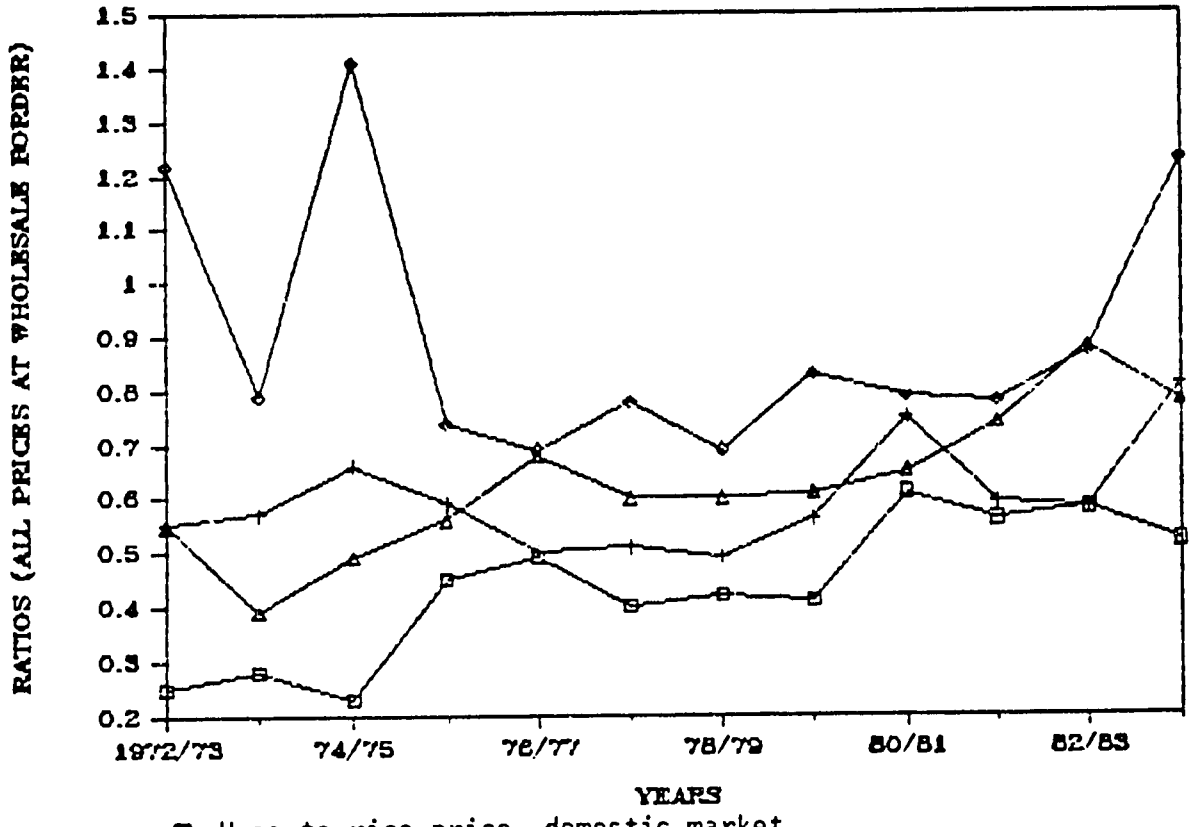
Figure 4--Ratios of moving average rice and urea prices in domestic and world markets, 1973/74 to 1983/84



□ Urea to rice price, domestic market
+ Urea to rice price, world market (export urea basis)
◊ Domestic to world rice price
Δ Domestic to world urea price (export urea)

Source: Constructed on the basis of price information in Appendix 1, Tables 27-32.

Figure 5--Ratios of rice and urea prices in domestic and world markets, 1972/73 to 1983/84



- ▫ Urea to rice price, domestic market
- + Urea to rice price, world market (export urea basis)
- ◊ Domestic to world rice price
- △ Domestic to world urea price (export urea)

Source: Constructed on the basis of price information in Appendix 1, Tables 27-32.

Table 24--Ratios of rice and TSP prices in domestic and world markets, 1972-73 to 1983-84

Year	TSP to Rice Price, Domestic Market	TSP to Rice Price, World Market		Domestic to World TSP Price	
		Export Parity	Import Parity	Export Parity	Import Parity
1972-73	0.17	0.58	0.67	0.36	0.31
1973-74	0.18	0.56	0.66	0.26	0.22
1974-75	0.18	0.65	0.77	0.39	0.33
1975-76	0.35	0.56	0.70	0.46	0.37
1976-77	0.39	0.41	0.52	0.65	0.52
1977-78	0.31	0.39	0.50	0.62	0.48
1978-79	0.32	0.39	0.49	0.57	0.45
1979-80	0.31	0.48	0.57	0.55	0.46
1980-81	0.49	0.61	0.73	0.64	0.53
1981-82	0.48	0.49	0.59	0.76	0.64
1982-83	0.55	0.54	0.66	0.88	0.72
1983-84	0.49	0.76	0.90	0.79	0.67

Source: Constructed on the basis of price information in Appendix 1.

Note: All prices are wholesale border prices. TSP is triple superphosphate.

Table 25--Ratios of moving average rice and TSP prices in domestic and world markets, 1973-74 to 1983-84

Year	TSP to Rice Price, Domestic Market	TSP to Rice Price, World Market		Domestic to World TSP Price	
		Export Parity	Import Parity	Export Parity	Import Parity
1973-74	0.14	0.61	0.71	0.27	0.23
1974-75	0.26	0.59	0.71	0.43	0.36
1975-76	0.29	0.54	0.66	0.51	0.41
1976-77	0.35	0.45	0.57	0.57	0.45
1977-78	0.32	0.40	0.50	0.58	0.46
1978-79	0.30	0.42	0.52	0.54	0.44
1979-80	0.36	0.49	0.60	0.57	0.47
1980-81	0.42	0.52	0.62	0.65	0.54
1981-82	0.51	0.54	0.66	0.76	0.63
1982-83	0.54	0.59	0.70	0.87	0.72
1983-84	0.51	0.64	0.77	0.83	0.69

Source: Constructed on the basis of price information in Appendix 1.

Note: All prices are wholesale border prices.

rice and urea prices in the domestic market would be lower than in the world market.

Management of Domestic Foodgrain Prices

Average domestic prices of rice fluctuate rather widely in Bangladesh. The price of coarse rice was at the world level during 1973-74, 1974-75, and 1983-84. Current (1984-85) prices are higher. But in the mid-1970s rice prices plummeted, reducing the profitability of using fertilizers. Without effective support of rice prices in such years, increased fertilizer prices may create a situation where the domestic fertilizer-rice price ratio could surpass world ratios.

Current world prices, as well as the prices of the early 1970s, reflect food crises that the government must try to combat. If fertilizer prices are increased by, say, 20 to 25 percent, with a simultaneous effort to bring rice prices down to the real levels of the mid-1970s, incentives for increased domestic production may be reduced.

Thus, the government is caught in a real dilemma between concern for poor foodgrain consumers and the need to reduce input subsidies for producers. Three options appear to be relevant for resolution of this conflict. Subsidized foodgrains for target groups of the poor and free market prices for others is an option often suggested by economists. The political and administrative infeasibility of targeting is often advanced to counter this option. Subsidizing other inputs or investments in agriculture (such as irrigation and credit) is another option for compensating for low foodgrain but high fertilizer prices. As the paper by Hossain indicates, this is equivalent to subsidizing irrigation instead of fertilizers. In fact, both a food subsidy and a subsidy on irrigation are being provided currently by the government of Bangladesh, although the explicit food subsidy bypasses a vast majority of the rural poor. The third option is simply to continue the present subsidy on fertilizer, as well as those on other inputs and foodgrains. The ideal solution would be to make the foodgrain subsidy program a poverty program by targeting the rural poor through food-for-work activities and to restructure public works to create employment and income for the poor. Ultimately, solution of poverty lies in increased production in both agriculture and nonagricultural sectors, particularly using labor-intensive methods. However, to apply this long-run solution in a resource-constrained economy like Bangladesh would necessarily imply some sacrifice in the short run.

Public Marketing and Intrayear Price Fluctuations

It may be argued that farmers sell their products during harvest-time, and therefore the average annual price is a poor indicator of farm-level incentives. This is not exactly correct.

The link between the average annual price and the farm-level harvest-season price is provided by the marketing margin, both seasonal and spatial. However, public marketing (procurement, open market sales, and ration distribution) could influence this margin significantly.

The seasonal pattern of rice prices in Bangladesh, normalized for trend increases, is shown in Figure 6. The seasonal pattern in the 1960s was substantially different from those of the early and mid-1970s, as well as from those of the late 1970s and early 1980s. During the early and middle 1970s the fall in November-January prices (the main harvest season) was quite drastic. In recent years this trend of a harvest-season price fall has been largely arrested. It is worth noting that during 1978-83 the period when prices were at their low point lengthened to cover a number of months. In the past, low prices were limited to the November-January period; recently the bottom line has extended to the period of June-August. The expansion of Boro production through high-yielding varieties may have brought about this change in the seasonal pattern of rice prices.

In analyzing farm-level incentives (such as domestic to world price comparisons) a normal marketing margin is incorporated to obtain a valid conclusion. Problems arise when the estimates of spatial and seasonal margins vary widely, as is indicated in Figure 6. It is therefore important to identify the causal factors in the variation of marketing margins, particularly the seasonal one. Why do harvest-season prices deviate widely from the annual average?

To explain the deviation of harvest-season prices of rice from the annual average, the author in a previous study regressed the deviations against the December-January price in reference to the annual average, total rice production, ration distribution, procurement, the value of jute production, and an index of industrial production.[16] Surprisingly, all the variables except procurement turned out to be significant in influencing the harvest-season price deviation for the data from 1964 through 1974/75. About 65 percent of the variations in harvest-season prices were explained by these variables.

Domestic procurement did not play a price-supporting role before 1975/76 and has done so in only some years since then. High levels of procurement during 1977/78-1982/83 (with a few exceptions) are consistent with the improvement in harvest-season price dips during the period shown in Figure 6. This indicates that procurement has made a positive contribution in the government's effort to support prices. In recent years, another policy variable--open market sales

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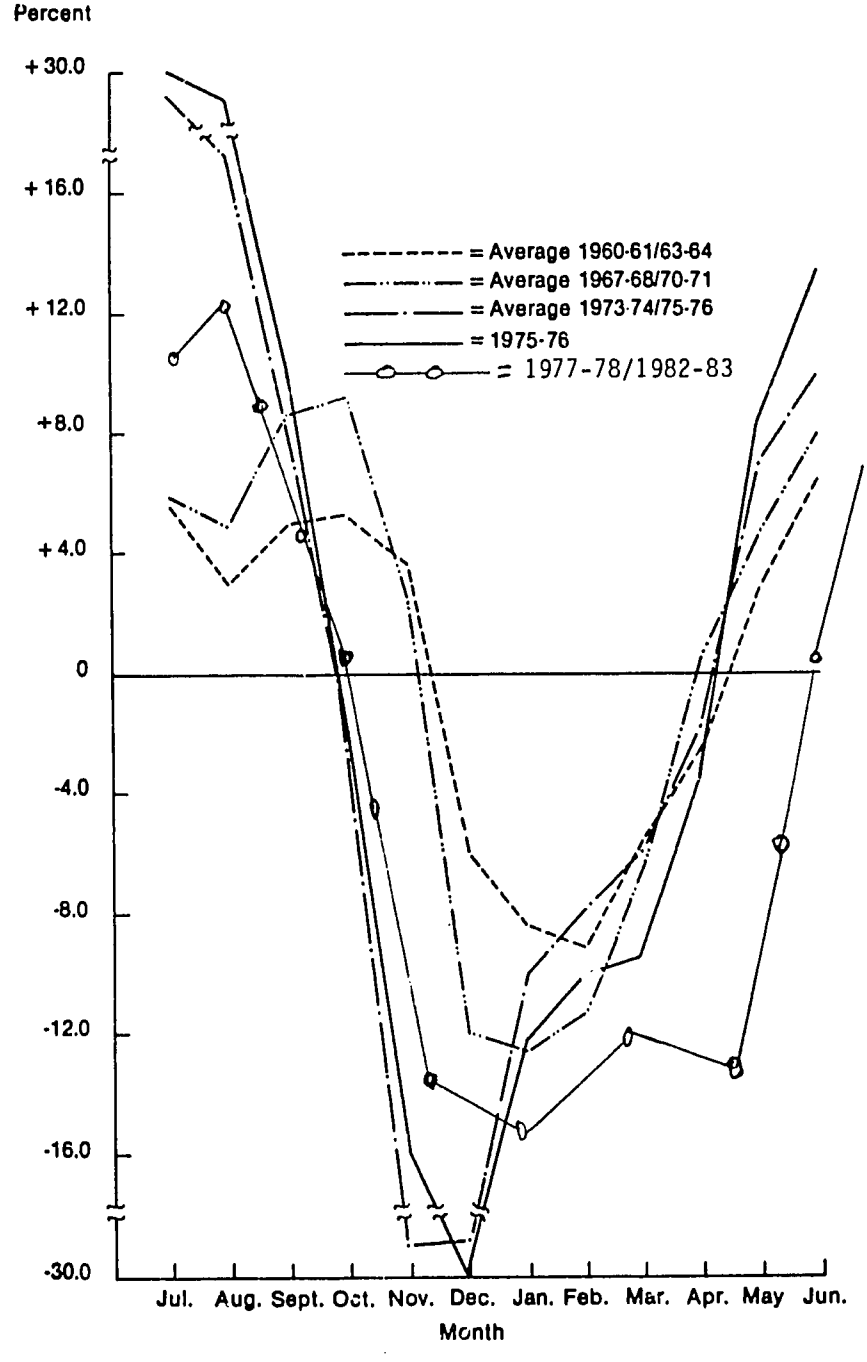
[16]Raisuddin Ahmed, Foodgrain Supply, Distribution, and Consumption Policies Within a Dual Pricing Mechanism: A Case Study of Bangladesh, Research Report 8 (Washington, D.C.: International Food Policy Research Institute, 1979).

Figure 6--Percent of deviation of normalized monthly prices of rice from annual averages, Bangladesh



Source: Raisuddin Ahmed, Foodgrain Supply, Distribution and Consumption Policies Within a Dual Pricing Mechanism: A Case Study of Bangladesh, Research Report 8 (Washington, D.C.: International Food Policy Research Institute, 1979), p. 56, updated for 1977-83.

by the government--has also been used as an instrument for bringing down prices in months of high prices. Simultaneously, rationing has lost its influence on market prices mainly because ration prices have been raised upward, closer to the market price, resulting in reductions of ration offtakes.

Procurement cannot support the market price unless it becomes an instrument to achieve a target price, rather than a target quantity. The present policy is oriented more toward a quantity target than a price target. A policy to procure rice at a target price would automatically consider general economic activity, prices and production of jute, production of rice, and other factors that influence harvest-season prices of rice. A policy to procure a quantity of rice may fail to achieve the price support objective if the procurement price is determined without regard for the expected market price and not supported by the required funds. An advance assessment of the procurement target is of course necessary for budgetary or financing purposes. Thus, both procurement price and quantity must be determined in advance, but procurement should be geared to the price target in the market. Price target procurement implies public procurement, primarily in good harvest years. It is obvious that fixing the procurement price and quantity has to be done systematically. Determining average prices and deriving farm-gate (primary market) and seasonal prices from this average can be done by using historical relations in a formal quantitative framework and making allowance for marketing margins. This formulation is not presented in this report but it is intended that it will be made available at a later date.

Open market operation--the sale of public foodgrains in the open market--is meant to bring down prices during the lean months. It is therefore designed to benefit consumers more than producers, but it has a subtle, indirect effect on producers' incentives or disincentives.

If the two instruments--procurement and open market sales--squeeze the upper and lower bounds of seasonal prices to the extent that the seasonal price difference does not cover the storage cost (including interest costs, normal profits, and other storage costs) then private stores may not find it profitable to carry stock.

By itself, such a result is not harmful to producers. In fact, it may minimize the effects of speculation in the grain market and thus benefit both producers and consumers. Analysis by Roger Montgomery, in fact, shows that the open market sale is designed to

stabilize that portion of price fluctuation that is caused by apprehensive buying and selling by traders.[17]

Montgomery has shown that open market sales are more powerful than modified rationing in influencing market prices. However, this policy instrument has to be based on careful analysis of price relations and implemented with a demonstrated ability to convince traders.

Besides procurement and open market sales, public construction, employment-creating programs, and general economic activities can support the incomes of consumers and therefore prices in harvest season, if the timing of these activities coincides with the arrival of foodgrains in the market. Whether farm-level incentives can be strengthened further to compensate for all or part of the effects of removal of subsidy in fertilizers will depend on how well these policy instruments are designed and implemented.

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[17]Roger Montgomery, "Open Market Grain Sales as a Public Policy Instrument for Moderating Food Price Fluctuations in Bangladesh," U.S. Agency for International Development, Dhaka, 1983 (mimeographed).

APPENDIX 1: SUPPLEMENTARY TABLES

Table 26--Weighted average of wholesale domestic prices of coarse rice, 1972-73 to 1983-84

Year	Weighted Average	Moving Average
	(taka/ton)	
1972-73	2,017	...
1973-74	2,692	3,441
1974-75	5,615	3,881
1975-76	3,337	3,995
1976-77	3,032	3,360
1977-78	3,711	3,608
1978-79	4,081	4,397
1979-80	5,398	4,664
1980-81	4,514	5,273
1981-82	5,907	5,614
1982-83	6,422	6,506
1983-84	7,186	6,804

Source: World Bank, South Asia Programs Department, Bangladesh: Economic Trends and Development Administration, Vol. II, Report 4822 (Washington, D.C.: World Bank, 1984).

Table 27--World rice prices, 1972-73 to 1983-84

Year	f.o.b. Price	c&f Price	f.o.b. Price	c&f Price	Border Price	Moving Average Border Price
	(U.S. $/ton)		(taka/ton)			
1972-73	165.35	184.89	1,287	1,439	1,655	...
1973-74	342.05	372.10	2,725	2,964	3,409	3,016
1974-75	359.35	390.40	3,190	3,465	3,985	3,974
1975-76	241.05	265.15	3,580	3,938	4,529	4,301
1976-77	220.40	246.80	3,409	3,817	4,390	4,565
1977-78	247.85	274.60	3,748	4,152	4,775	5,026
1978-79	311.80	337.80	4,747	5,142	5,913	5,738
1979-80	339.95	366.70	5,262	5,676	6,527	6,052
1980-81	278.09	304.09	4,545	4,970	5,716	6,600
1981-82	301.14	327.89	6,035	6,571	7,557	6,878
1982-83	242.85	269.60	5,771	6,406	7,367	6,911
1983-84	175.00	201.00	4,375	5,025	5,810	6,589

Sources: F.o.b. prices are from World Bank, Price Prospects for Major Primary Commodities, Vol. II (Washington, D.C.: World Bank, July 1982); and recent information from the relevant World Bank desk.

Notes: The world price is for Thai 35 percent broken rice on a government-to-government sales basis. Two consecutive calendar year prices are averaged to obtain the price for the financial year. Border prices are calculated by adding internal transportation and incidental cost to c&f price; official exchange rate is used.

Table 28--Ex-PDP or equivalent wholesale prices of fertilizers, 1972-73 to 1984-85

Year	Retail Sales Price[a]			Commission	Wholesale Price		
	Urea	TSP	MP		Urea	TSP	MP
				(taka/ton)			
1972-73	536	389	268	40	496	349	228
1973-74	804	536	402	44	760	492	358
1974-75	1,340	1,072	804	59	1,281	1,013	745
1975-76	1,608	1,286	1,072	117	1,491	1,169	955
1976-77	1,608	1,286	1,072	117	1,491	1,169	955
1977-78	1,608	1,286	1,072	138	1,470	1,148	934
1978-79	1,876	1,474	1,206	159[a]	1,717	1,315	1,047
1979-80	2,412	1,876	1,474	180	2,232	1,696	1,294
1980-81	2,948	2,412	1,876	180	2,768	2,232	1,696
1981-82	3,538	3,082	2,412	241	3,297	2,841	2,171
1982-83	3,966	3,752	2,948	246	3,270	3,506	2,702
1983-84	3,966	3,752	2,948	265	3,701	3,487	2,683
1984-85	4,363	4,127	3,243	275	4,088	3,852	2,968

Source: Bangladesh Agricultural Development Corporation.

Notes: Retail prices are average if prices were changed at mid-year. Ex-PDP indicates that these are the prices at the primary distribution point. TSP is triple superphosphate and MP is muriate of potash.

[a]This is the weighted average of PDP and BSC commission rates for years from 1979 to 1984.

Table 29--World urea prices, 1972-73 to 1983-84

Year	f.o.b. Price	c&f Price	f.o.b. Price	c&f Price	Border Price: Export Parity Basis	Border Price: Import Parity Basis	Moving Average of Border Price: Export Parity	Moving Average of Border Price: Import Parity
	(U.S.$/ton)				(taka/ton)			
1972-73	77.1	96.3	600	749	909	1,058	...	...
1973-74	205.3	246.4	1,635	1,963	1,947	2,587	1,829	2,597
1974-75	256.9	308.3	2,280	2,736	2,632	3,088	2,411	2,993
1975-76	155.0	198.8	2,302	2,953	2,654	3,305	2,496	3,020
1976-77	119.7	149.6	1,851	2,314	2,203	2,666	2,435	2,979
1977-78	136.1	170.2	2,058	2,574	2,449	2,965	2,510	3,038
1978-79	158.9	198.6	2,418	3,023	2,877	3,482	2,988	3,565
1979-80	197.5	237.0	3,057	3,668	3,638	4,249	3,592	4,236
1980-81	219.1	262.9	3,580	4,297	4,260	4,977	4,124	4,818
1981-82	187.4	225.0	3,756	4,509	4,475	5,228	4,327	5,110
1982-83	147.1	184.1	3,495	4,375	4,245	5,125	4,480	5,286
1983-84	153.6	185.0	3,840	4,625	4,721	5,506	4,483	5,316

Source: The f.o.b. prices are from World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, 1982 and 1983), and recent information from the relevant World Bank desk.

Notes: The f.o.b. price is ex-U.S. Gulf ports and Western Europe for all years except 1983-84. For 1983-84 it is the average export price ex-Chittagong/Chalna. The border price on an export parity basis is the f.o.b. price plus the internal distribution cost. This price is relevant for valuation of domestic urea. The border price on an import parity basis is the c&f price plus distribution cost. This is relevant for valuation of imported urea.

Table 30--World TSP prices, 1972-73 to 1983-84

Year	f.o.b. Price	c&f Price	f.o.b. Price	c&f Price	Border Price: Export Parity Basis	Border Price: Import Parity Basis	Moving Average of Border Price: Export Parity	Moving Average of Border Price: Import Parity
	(U.S.$/ton)				(taka/ton)			
1972-73	84.0	103.3	654	802	963	1,111	...	...
1973-74	202.0	243.1	1,609	1,937	1,921	2,249	1,827	2,138
1974-75	253.0	304.4	2,246	2,702	2,598	3,054	2,349	2,827
1975-76	146.5	190.3	2,176	2,826	2,528	3,178	2,311	2,833
1976-77	94.0	123.9	1,454	1,916	1,806	2,268	2,066	2,609
1977-78	97.5	131.6	1,474	1,990	1,865	2,381	1,996	2,503
1978-79	122.0	161.8	1,857	2,462	2,316	2,921	2,428	3,006
1979-80	163.0	202.5	2,523	3,134	3,104	3,715	2,962	3,606
1980-81	170.5	214.4	2,787	3,503	3,467	4,183	3,430	4,123
1981-82	149.7	187.3	3,000	3,753	3,719	4,472	3,727	4,509
1982-83	136.5	173.5	3,244	4,123	3,994	4,873	4,051	4,856
1983-84	142.3	173.7	3,558	4,343	4,439	5,224	4,217	5,049

Source: The f.o.b. prices are from World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, 1982 and 1983), and recent information from the relevant World Bank desk.

Notes: The f.o.b. price is ex-U.S. Gulf ports. The border price on an export parity basis is the f.o.b. price plus the internal distribution cost. The border price on an import parity basis is the c&f price plus distribution cost.

Table 31--World prices, muriate of potash, 1972-73 to 1983-84

Year	f.o.b. Price	c&f Price	f.o.b. Price	c&f Price	Border Price Import Parity	Moving Average Border Price
	(U.S. $/ton)		(taka/ton)			
1972-73	39.0	58.3	304	454	763	...
1973-74	51.5	92.5	410	737	1,049	1,085
1974-75	70.9	122.9	629	1,091	1,443	1,503
1975-76	68.2	112.2	1,013	1,666	2,018	1,699
1976-77	53.0	83.0	820	1,284	1,636	1,795
1977-78	53.7	88.7	812	1,341	1,732	1,817
1978-79	66.6	106.6	1,014	1,623	2,082	2,168
1979-80	96.4	136.3	1,491	2,110	2,691	2,680
1980-81	114.2	158.2	1,867	2,586	3,266	3,127
1981-82	97.0	135.0	1,944	2,705	3,424	3,395
1982-83	78.5	115.5	1,865	2,745	3,495	3,583
1983-84	78.0	118.0	1,950	2,950	3,831	3,591

Sources: World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, 1982 and 1983), and recent unpublished information from the World Bank.

Notes: The f.o.b. price is ex-Vancouver. The border price is the c&f price plus the internal distribution cost. The moving average border price is the three-year moving average. The moving average of 1983-84 reflects the actual price of the first four months of 1984-85.

Table 32--Comparison of free market world prices and prices of fertilizers under tied aid in Bangladesh, 1983-84

Fertilizer	Source	c&f Price Under Tied Aid	Free Market c&f Price	Difference[a]
		(U.S. $/ton)		(percent)
Urea	USAID grant	210.25	185.00	13.65
	Saudi grant	205.00	185.00	10.81
	USAID grant	242.34	185.00	31.00
	Cash foreign exchange	183.00	185.00	-1.08
TSP	NORAD grant	198.72	175.00	13.55
	UK grant	199.74	175.00	14.14
	ADB grant	188.74	175.00	7.85
	IFAD credit	192.78	175.00	10.16
	Dutch grant	182.34	175.00	4.19
	Danish grant	203.30	175.00	16.17
	KFW grant	174.39	175.00	...
	Dutch grant (bulk)	190.15	175.00	8.66
	Rumania barter	192.00	175.00	9.71
MP	CIDA grant	141.30	120.00	17.75

Sources: Import data are from Bangladesh Agricultural Development Corporation. Free market data are from World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, 1982 and 1983), and recent unpublished information from the World Bank.

Note: The period was from July 1983 through September 1984.

[a]The percentage difference is the c&f price under tied aid minus the free market price divided by the free market price times 100.

APPENDIX 2: METHOD OF CALCULATING PRICES ON THE BASIS OF MOVING AVERAGE

At some point in the current year t (say, 1984-85), one must undertake the task of determining the target price, PT, for the year t+1 (1985-86) on the basis of the three most recent moving averages, MAP_1, MAP_2, and MAP_3.

Step 1: Estimate MAP_1, MAP_2, and MAP_3, as follows:

$$MAP_3 = \frac{P_t + P_{t-1} + P_{t-2}}{3}, \text{ centered at year t-1;}$$

$$MAP_2 = \frac{P_{t-1} + P_{t-2} + P_{t-3}}{3}, \text{ centered at year t-2; and}$$

$$MAP_1 = \frac{P_{t-2} + P_{t-3} + P_{t-4}}{3}, \text{ centered at year t-3;}$$

where P is the actual price at year t_n (n varying from 1 to 4).

Step 2: Calculate growth rates g_1 and g_2:

$$g_1 = \frac{MAP_2 - MAP_1}{MAP_1}, \text{ and}$$

$$g_2 = \frac{MAP_3 - MAP_2}{MAP_2}.$$

Step 3: Estimate average growth rate G:

$$G = \frac{g_1 + g_2}{2}.$$

Step 4: Estimate PT_{t+1}:

$$PT_{t+1} = MAP_3 \ (1+G)^2.$$

Note: 2 equals the number of years between t+1 and t-1 (where MAP_3 is centered).

4. FERTILIZER CONSUMPTION, PRICING, AND FOODGRAIN PRODUCTION IN BANGLADESH

Mahabub Hossain

Rice and wheat occupy about 83 percent of the cropped area in Bangladesh, yet the country has to meet nearly one-tenth of its consumption of cereals through imports. It is well known that in Bangladesh, the potential for increasing food production through expansion of arable land is extremely limited, but the potential for substantially increasing crop yields is good. The level of paddy yield is currently about 2.0 tons per hectare, which is one of the lowest in the world.[1] Even within the country, yields vary considerably.[2] Low yields result from the extensive use of traditional technology, relieved only by late and limited expansion in the use of modern inputs--high-yield variety seeds (HYVs), irrigation, and chemical fertilizers. Obviously any food production growth strategy in Bangladesh must focus on increasing the use of modern inputs and technology.

Although chemical fertilizers were introduced in the country in the 1950s, use was mostly limited to tea gardens and government experimental farms until the early 1960s.[3] With the objective of popularizing the use of modern agricultural inputs with farmers, the government established the Bangladesh Agricultural Development Corporation (BADC) in 1961. It was entrusted with the responsibility of procuring and distributing essential agricultural inputs. As a state monopoly in these activities, BADC started selling fertilizers

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[1]Average yields for 1982 were 4.6 tons per hectare for China, 6.2 for the Republic of Korea, 5.7 for Japan, 3.8 for Indonesia, 2.9 for Burma and Malaysia, 2.4 for Vietnam, and 2.0 for Thailand and India. Data are from Food and Agriculture Organization of the United Nations, FAO Production Yearbook, 1982 (Rome: FAO, 1983).

[2]The present yield per hectare is about 3.20 tons in Chittagong and 1.32 tons in Faridpur District. Data are from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, October 1984.

[3]The total consumption was only 2,000 tons of nutrients in 1952/53, increasing to 11,000 tons in 1959/60, a rate of application of less than one pound per acre of sown area.

to farmers at highly subsidized prices,[4] which kept the nitrogen fertilizer (nutrient) to paddy price ratio low throughout the sixties.[5]

At least partly because the price environment was favorable, fertilizer sales increased briskly from about 50,000 tons of materials in 1962/63 to about 304,000 tons in 1970/71. With rapidly increasing sales, the high subsidy rates began to put a heavy burden on the government budget. This, together with soaring agricultural prices in the early 1970s and an increase in procurement cost, led the government to gradually raise prices and reduce subsidies beginning in July 1972, which raised the nitrogen fertilizer (nutrient) to paddy price ratio gradually to 2.1 by 1982/83. This period also coincided with rapid but decelerating rates of growth in fertilizer consumption and with an expansion in the use of complementary inputs, especially HYVs and modern irrigation. These complexities make the task of properly assessing the effects of changing prices on fertilizer use more difficult. But since fertilizer consumption per acre of land is still low, and the country has little choice but to try to sustain rapid growth in fertilizer consumption if it is to become self-sufficient in food as early as possible, an analysis of the effects of prices on fertilizer consumption and on food production assumes crucial importance. This analysis is the main objective of this paper.

Many recent studies have addressed problems of supply and distribution of fertilizers, including a comprehensive work done by the International Fertilizer Development Center (IFDC). BADC also maintains and regularly publishes records of stocks and sales of fertilizers by regions. This chapter is partly based on these secondary data and reports. In addition, unpublished results of fertilizer trials at different locations of the country have been compiled from the records of the Bangladesh Agricultural Research Institute (BARI), and primary data on the effect of price increases on different groups of farmers have been collected through farm surveys.

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[4]It is estimated that in 1968/69, the average rate of subsidy was 58 percent for urea and TSP, and 67 percent for MP. See F. Kahnert et al., Agriculture and Related Industries in Pakistan (Paris: Organization for Economic Cooperation and Development [OECD] Development Center, 1970), p. 421.

[5]The nutrient/paddy price ratio was around 1.5 in the early sixties. But because the price of fertilizer did not change and the price of paddy increased, the ratio improved throughout the sixties and then reached 0.8 by 1971/72.

GROWTH OF FERTILIZER CONSUMPTION

Trends in Consumption of Different Types of Fertilizers

Fertilizer use was insignificant even 20 years ago, as Table 1 shows. In 1962/63, consumption was only about two nutrient pounds per acre of cropped land. Since then, the growth of consumption has been impressive and steady. The annual rate of growth was about 17 percent during 1964-71, 13 percent during 1971-77, and 8 percent during 1977-84. It decelerated during the early seventies because of the War of Liberation, diversion of resources for reconstruction of the economy, and successive bad weather years between 1973 and 1975. In only five years during the whole period did sales decline absolutely from sales in the previous year: 1964/65, 1971/72, 1974/75, 1978/79, and 1981/82. The drop in sales during 1971/72 and 1974/75 was due to the War of Liberation and the breakdown at the Ghorasal fertilizer factory, which disrupted supply for four months. Fertilizer sales were only stagnant for two consecutive years during one period, 1979-82.

In spite of generally rapid growth, present applications remain low. The average rate of application is only about 36 nutrient pounds per cropped acre, compared to the recommended dosage of about 234 pounds for HYVs and 104 pounds for local varieties of paddy.[6] Obviously the potential for further increase in use is considerable.

Urea and triple superphosphate (TSP) are the main fertilizer materials used by farmers. They accounted for about 86 percent of total consumption in 1983/84. The other main products are diammonium phosphate (DAP) and muriate of potash (MP). DAP was introduced in 1979/80 when it was made available through a U.S. grant. However, imports of DAP have been discontinued since July 1984. In 1983/84 the $N:P_2O_5:K_2O$ (or NPK) ratio was 1:0.5:0.09 against the recommended ratio of 1:0.76:0.48 for HYVs and 1:1:0.37 for local varieties.[7] The $N:P_2O_5$ ratio, however, improved considerably after the late sixties, when it was 1:0.33.

Growth of Consumption by Season

The trends in fertilizer sales in the country's three distinct cropping seasons are shown in Table 2. Fertilizer is applied on the main paddy crop, Aman, between July and October when no other fertilizer-using crops are widely cultivated. November to March is the fertilizer application season for various Rabi crops, such as

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[6]M. A. Jabbar, "Supply, Delivery System and Utilization of Chemical Fertilizers in Bangladesh," a report prepared for the Bangladesh Ministry of Agriculture, Dhaka, 1980, p. 13.

[7]Ibid., p. 13.

Table 1--Long-term trends in fertilizer consumption, 1962/63 to 1983/84

Period	BADC Sales				Nutrient Contents	
	Urea	TSP/(DAP)	MP	Total	Total	Pounds per Cropped Acre
	(1,000 metric tons of materials)				(1,000 metric tons of nutrients)	
1962/63	42	3	2	51	27	2
1963/64	76	23	4	104	50	4
1969/70	200	66	15	282	132	9
1970/71	215	76	17	309	144	10
1975/76	316	112	22	463	216	15
1976/77	355	127	23	524	244	18
1977/78	455	194	42	727	340	24
1978/79	478	181	48	715	332	23
1979/80	545	250(40)	50	855	400	28
1980/81	570	259(41)	46	889	420	28
1981/82	527	261(50)	46	843	398	27
1982/83	629	279(73)	51	968	458	31
1983/84	708	355(94)	63	1,129	544	36
Annual growth rate						
1964/71	16.0	18.6	23.0	16.8	16.3	14.0
1971/77	11.3	14.3	13.8	13.0	13.1	13.3
1977/84	7.6	10.6	7.0	7.6	8.1	7.0

Sources: Bangladesh Agricultural Development Corporation, Annual Report, various issues.

Notes: The BADC is the Bangladesh Agricultural Development Corporation. Figures within parentheses are sales of diammonium phosphate (DAP). TSP is triple superphosphate. MP is muriate of potash.

Table 2--Trends in fertilizer consumption by seasons, 1965/66 to 1983/84

Year	Aman Season (July - October)		Rabi & Boro Season (November - March)		Aus Season (April - June)	
	Total Sales	Pounds per Cropped Acre	Total Sales	Pounds per Cropped Acre	Total Sales	Pounds per Cropped Acre
	(1,000 metric tons)		(1,000 metric tons)		(1,000 metric tons)	
1965/66	45	6.4	28	13.4	35	8.2
	(41.7)		(25.9)		(32.4)	
1970/71	109	15.9	130	45.2	72	23.2
	(35.0)		(41.8)		(23.2)	
1977/78	214	31.3	326	111.0	72	23.2
	(28.8)		(43.9)		(27.2)	
1980/81	265	37.2	429	125.9	195	46.3
	(29.8)		(48.3)		(21.9)	
1982/83	245	34.7	508	138.0	216	51.6
	(25.3)		(52.4)		(22.3)	
1983/84	267	37.3	629	170.7	233	55.9
	(23.6)		(55.7)			

Sources: Developed from appendix tables of Raisuddin Ahmed, Food-grain Production in Bangladesh, An Analysis of Growth: Its Sources and Related Policies (Dhaka: Bangladesh Agricultural Research Council, 1977); and Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various issues.

Note: Figures within parentheses are the percentages of annual sales in the indicated season.

potato, mustard, wheat, tobacco, and winter vegetables, as well as Boro paddy, which is often grown under irrigated conditions. Premonsoon Aus paddy and jute are treated with fertilizer from April to June. Of the total cropped area of about 33 million acres in 1982/83, 15.8 million acres (48 percent) are cropped during the Aman season,[8] 9.2 million (28 percent) during the Aus season, and 8.1 million (25 percent) during the winter season when Boro paddy and Rabi crops are grown. Over the two decades, the area under Aman and Aus crops remained almost stagnant, while the area under winter crops increased rapidly from about 4.5 million acres in 1965/66 to 9.2 million acres in 1982-83.[9]

It is clear from Table 2 that the major focus of growth in fertilizer use has been on Boro and Rabi crops cultivated during the winter season. During 1983/84 about 56 percent of all fertilizer materials were sold during the winter season, an increase from about a quarter in 1965/66 and two-fifths in 1970/71. During the 13-year period following the independence of Bangladesh (1971-84), fertilizer sales increased about 4.8 times for the Boro season, compared to 3.2 times for the Aus, and 2.5 times for the Aman seasons. Since the area sown with Aus and Aman crops did not increase over time, the findings indicate that fertilizer use has spread widely during these seasons as well.

The spectacular growth in fertilizer consumption during the Boro season was the result not only of the expansion of area under winter crops, but also of the rapid increase in fertilizer application rates per cropped acre. During the 1971-84 period, application rates increased by about 22 pounds of materials per acre for the Aman season and 33 pounds for the Aus season, but by about 126 pounds per acre for the Boro season. Another important point to note is that the growth in fertilizer application rates has tended to decelerate in recent years for the monsoon (Aman) and premonsoon (Aus) seasons, while growth rates have remained high for the winter season crops.[10]

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[8]This figure includes area under different types of pulses, some of which are grown during the Boro season.

[9]Bangladesh Bureau of Statistics, Agricultural Production Levels in Bangladesh, 1947-72 (Dhaka: BBS, 1974); and Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983).

[10]The annual rate of growth was 10.2 percent for Aman, 10.4 percent for Aus, and 13.7 percent for Boro season crops during the 1970/71 - 1977/78 period. The annual rate of growth fell to 3.0, 3.2, and 7.4 percent, respectively, for the three seasons between 1977/78 and 1983/84.

Since applications on the winter crops are already high, sustaining the past rate of growth in use may be difficult in the future unless, of course, development of irrigation facilities allows additional crops to be planted. Because the growth in fertilizer intensity for the Aman and Aus crops has already decelerated considerably, an initial examination of seasonal trends indicates that further deceleration in the overall growth of fertilizer use in the country is possible.

Regional Variation in Growth

The extreme variation in fertilizer consumption among different regions of the country can be noted in Table 3. More than 120 pounds of fertilizer materials were used per acre of cropped land in 1983/84 in five districts--Bogra, Chittagong, Dhaka, Kushtia, and Comilla. These districts account for about 22 percent of the gross cropped area and 40 percent of fertilizer consumption in the country. At the other extreme, consumption is less than 50 pounds per acre in the districts of Noakhali, Sylhet, Khulna, Faridpur, and Barisal (including Patuakhali). These districts account for about 40 percent of the cropped area but only 12 percent of Bangladesh fertilizer consumption. In Faridpur and Barisal, the consumption is only about 25 pounds. Consumption is highest in the Bogra district (163 pounds), where it has recently come to exceed consumption in the districts of Chittagong and Comilla. If fertilizer consumption throughout the country could be raised to Bogra's level, total consumption would more than double, rising to about 2.45 million tons. Distribution of commercial fertilizer by weight among the districts is shown in the Appendix, Table 46.

In some of the regions where applications are high, growth in fertilizer consumption has already tended to stagnate. In Chittagong, consumption rose quickly in the sixties, reaching 92 pounds per acre per year by 1970/71, but since then the rate of growth has decelerated rapidly. Over the period 1970/71 to 1977/78, consumption increased by about 6 pounds per acre per year--a rate similar to the rates in Bogra, Dhaka, Kishoregonj, and Pabna, but considerably lower than the rate of increase achieved in Comilla and Kushtia during this period. The increase in consumption for Chittagong and Comilla over the period 1977/78 to 1983/84 was one of the lowest in the country. The rate of growth in the group as a whole during this latest period was still higher than in the rest of the country, primarily because of the rapid increase in consumption in Bogra, Dhaka, and Kushtia, where use had formerly expanded somewhat more slowly than in Chittagong and Comilla.

The medium application districts of the north and southwest parts of the country (the dry zone) were, however, the major source

Table 3--Growth of fertilizer consumption in different regions, 1962/63 to 1983/84

Regions	Fertilizer Consumption				Annual Rate of Increase	
	1962/63	1970/71	1977/78	1983/84	1971-78	1978-84
	(lbs. of materials/cropped acre)				(lbs./acre)	
High-application regions	9.8	44.5	100.0	135.4	7.9	5.9
Bogra	10.7	38.8	84.0	163.4	6.4	13.2
Chittagong	23.3	92.1	136.9	145.6	6.4	1.5
Dhaka	8.7	43.4	80.9	131.2	5.4	8.4
Kushtia	2.4	18.8	86.9	127.3	9.7	6.7
Comilla	6.0	36.4	110.6	121.5	10.6	1.8
Medium-application regions	2.8	15.8	44.1	74.9	4.0	5.1
Rajshahi	3.7	15.6	42.8	90.1	3.9	7.9
Dinajpur	4.3	15.4	49.3	85.7	4.8	6.1
Pabna	1.3	15.0	50.1	85.0	5.0	5.8
Kishoreganj	6.2	27.5	66.9	77.6	5.6	1.8
Mymensingh[a]	1.7	17.4	46.4	71.9	4.1	4.3
Chittagong Hill Tracts	4.0	12.6	24.6	71.1	1.7	7.8
Jessore	1.7	11.3	42.7	70.1	4.5	4.6
Rangpur	2.3	11.3	26.2	59.0	2.1	5.5
Low-application regions	1.7	14.0	27.9	31.3	2.0	0.6
Noakhali	4.9	28.6	54.9	44.0	3.8	-1.8
Sylhet	1.6	8.5	25.0	33.2	2.4	1.4
Khulna	2.2	13.9	20.4	32.2	0.9	2.0
Faridpur	1.0	5.5	15.4	27.6	1.4	2.0
Barisal[b]	0.8	18.5	29.2	25.2	1.5	-0.7
Mean	4.8	23.9	55.2	81.2	4.5	4.3
Coefficient of variation	109	82	59	50	59	83

Sources: Estimated from figures reported in various statistical publications of Bangladesh Agricultural Development Corporation and Bangladesh Bureau of Statistics.

[a]Includes Tangail and Jamalpur districts.

[b]Includes Patuakhali district.

of absolute fertilizer consumption growth in the recent period.[11] The increase in consumption per acre was slow in these districts during the sixties, but from this low base it grew relatively quickly after the early seventies. Average consumption for these districts increased from about 16 pounds of materials per acre in 1970/71 to about 44 pounds in 1977/78 and further to about 75 pounds in 1983/84. The share of these districts in total fertilizer use increased from 34 percent in 1970/71 to 41 percent in 1977/78 and 48 percent in 1983/84. Rapid expansion in the area under wheat cultivation after 1975/76 and the rapid development of groundwater resources for irrigation after 1978/79 were the main factors behind the accelerating growth in fertilizer consumption in these districts.

The performance of the low application districts was by far the worst during the most recent period. Consumption per acre increased by only about 2 pounds per acre per year up to 1977/78 and fell to a rate of 0.6 pounds per year during the 1978-84 period. In two of the five districts, Noakhali and Barisal, where consumption grew moderately until 1977/78, it has since declined in absolute terms. These five districts have adverse ecological conditions for agricultural development: Khulna, Barisal and Noakhali are located in the coastal belt and suffer from saline intrusion during the dry season and frequent high-depth tidal flooding of fields. These agro-ecological constraints inhibit the spread of HYVs and reduce the returns on fertilizer application.[12] Faridpur and Sylhet are low-lying districts where large areas remain submerged under water for much of the year. Flood depths are so high that farmers grow either deep-water Aman (Faridpur) or local Boro (Sylhet) on submerged land where the effectiveness of fertilizer is also low. Because of siltation from flooding, the nutrient requirements of the soil may also be somewhat lower in these districts than in other areas of Bangladesh. Unless massive investments are made to protect the land from saline intrusion and to bring about suitable flood control and drainage, it is quite possible that better extension service, improvement in fertilizer supply lines, and a more favorable price environment may not be enough to ensure a respectable growth of fertilizer consumption in these districts.

Diffusion of Fertilizer Use

Time-series data for the area of land treated with fertilizers or the rate of application on particular crops are not available. But estimates have been made and have appeared in various micro-

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[11]Total fertilizer consumption increased by about 0.39 million tons between 1977/78 and 1983/84, of which 0.24 million tons (60 percent) were from these districts. Between 1970/71 and 1977/78, the share of these districts in incremental consumption was 46 percent.

[12]See Chapter 5, by S. M. H. Zaman.

studies, though an understanding of the problems of fertilizer adoption is rarely the central focus of such research. Survey data from three of these studies are examined here.

The first in-depth survey to provide this type of information was conducted in 1969/70. It was undertaken by the Pakistan Institute of Development Economics (PIDE) in three relatively advanced areas, for the purpose of understanding the problems of modernization on small farms.[13] The information was collected from 600 farms randomly selected from a list of households within two unions (precincts) from each of three selected upazillas (administrative units smaller than a district).[14] The crop-specific fertilizer application rates estimated from the survey, when applied to the official crop acreage for the year, overestimate fertilizer consumption by about 5 percent compared to national sales for the year.

The second survey was conducted by the Ministry of Agriculture of Bangladesh in 1977 to collect some basic information on agriculture for the Two-Year Plan. One village was randomly selected from each of 12 districts, and 10 percent of the farmers were randomly selected from a census of all households in the selected villages. The national estimate of fertilizer consumption based on official sown area data is biased downwards by about 8 percent.

The most comprehensive survey on fertilizer use was conducted by the International Fertilizer Development Center (IFDC), which, in collaboration with the Bangladesh Agricultural Research Council (BARC), started collecting information from sample farms regularly during the 1979 Aman season. A multistage random sampling method was used in the survey, which covered 2,400 sample farms and about 10,000 sample plots in 117 villages from 20 upazillas scattered throughout 16 of 21 Bangladesh districts. The findings of the survey have been published for three years: 1979/80, 1980/81, and 1981/82.[15]

The survey findings regarding the extent of adoption of fertilizer use for different crops are reported in Table 4. The figures

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[13]M. Irshad Khan, "Modernization of Small Farms in East Pakistan: A Study in Allocative and Structural Efficiency," Pakistan Institute of Development Economics, Dhaka, 1971 (mimeographed).

[14]Bangladesh Ministry of Agriculture, Agro-Economic Research Division, "Bangladesh Agriculture in 1978," Dhaka, 1978 (mimeographed).

[15]Bangladesh Agricultural Research Council (BARC) and International Fertilizer Development Center (IFDC), Agricultural Production, Fertilizer Use and Equity Considerations: Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Table 4--Diffusion of fertilizer use according to sample surveys, 1969/70 to 1981/82

Crop	Holdings Using Fertilizers		Plots Using Fertilizers		
	1969/ 70	1976/ 77	1979/ 80	1980/ 81	1981/ 82
			(percent)		
Rice					
Local Aus	32	56	51	47	43
HYV broadcast Aus	n.g.	} 88[a]	66	84	72
HYV transplanted Aus	75		86	97	98
Local broadcast Aman	n.g.	...	28	7	29
Local transplanted Aman	21	51	56	44	58
HYV Aman	n.g.	87	86	85	83
Local Boro	n.g.	48	13	6	7
HYV Boro	94	98	94	97	97
Wheat	42	54	79	78	70
Kawon	34	...	...	85	79
Jute	26	39	33	27	42
Sugarcane	61	56	...	...	71
Pulses	5	5	8	3	5
Oilseeds	...	...	29	31	50
Potato	5	57	56	38	44
Tobacco	79	65	96	87	99
Chili	...	...	51	67	72
Spices	...	...	12	24	19
Vegetables	...	...	62	71	53

Sources: Data for 1969/70 from M. I. Khan, "Modernization of Small Farms in East Pakistan: A Study in Allocative and Structural Efficiency," Pakistan Institute of Development Economics, Dhaka, 1971 (mimeographed); for 1976/77, Bangladesh Ministry of Agriculture, Agro-Economic Research Division, "Bangladesh Agriculture in 1978," Dhaka, 1978 (mimeographed); and for 1979/80 to 1981/82, Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Notes: Where n.g. appears, the crop was not grown. Where ellipses (...) appear, the percentage was not estimated.

[a]This figure is for both HYV broadcast Aus and HYV transplanted Aus.

for 1969/70 and for 1976 are in percent of holdings using fertilizer, while those for 1979/80 and 1980/81 are in percent of plots. The former would typically exceed the latter because if a holding has a number of plots under a particular crop, any one of which is treated with fertilizer, the entire holding would be regarded as having adopted, while in the latter case only the treated plot is counted. This must be kept in mind when comparing the figures, but several important conclusions can still be drawn from the table.

First, most of the farmers growing HYV cereals, and a significant majority growing such cash crops as sugarcane and tobacco, used fertilizer as early as 1969/70. Since then, diffusion among the remaining farmers growing these crops has been slow. For HYV Boro, which is an irrigated crop, about 94 percent of the holdings were treated with fertilizer in 1969/70. This proportion has remained constant at around 98 percent since 1976/77. For HYV-transplanted Aus, most of the land was irrigated, and fertilizer diffusion was nearly complete even a decade ago. Only HYV Aman and HYV broadcast Aus, which are mostly rainfed, show some potential for further diffusion on lands already sown with HYVs, but the proportion of fertilized area of these crops has fluctuated around 85 percent since 1976/77. Thus, it appears that the scope for increasing fertilizer consumption by expanding fertilizer use to previously nontreated land growing HYVs has been limited for some time.

Second, the diffusion of fertilizer use on local varieties of paddy, jute, and minor Rabi crops was far from complete even by 1981/82. Nearly half of the land under these crops is still not treated with fertilizers. For local Aus and transplanted Aman, which are sown on about half of the cropped land in the country, diffusion was rapid in the early 1970s but has eased off since 1976/77. Only on land sown with jute and oilseeds has rapid diffusion continued in recent years. Surveys conducted for this study in two villages in Dhaka, however, show that a much larger proportion of the area under these crops could be treated with fertilizers. These surveys will be discussed in more detail later.

Third, very little land under broadcast Aman, local Boro, and pulses is treated with fertilizer even now. Some pulses do not need nitrogen fertilizer, and pulses in general are less responsive to fertilizer. Broadcast Aman and local Boro are normally grown under waterlogged conditions; hence, fertilizer application is less likely to be effective. These crops still account for about one-sixth of the total cropped acreage of the country, and they are major crops in the districts of Faridpur and Sylhet. Thus, a significant proportion of such land is likely to remain unfertilized unless investment in flood control and drainage reduces the proportion of area under these crops.

The Intensity of Fertilizer Use

The quantity of fertilizer used per acre of treated land, as estimated from these surveys for different crops, is reported in Table 5. It should be noted that the intensity of use is high for the high-yielding paddy varieties, wheat, and certain Rabi crops, such as potatoes, tobacco, oilseeds, and vegetables. For HYVs, the rates of application on the primarily rainfed, broadcast crops are about one-half of those on the mostly irrigated, transplanted crops. The rate of application on local varieties is nearly one-third of that for HYVs. The rate of application on HYVs did not increase much over time, but the rate of application on local varieties of paddy, jute, and minor crops showed an appreciable increase in the intensity of use. During the period 1979-82, however, the intensity of use on most crops stagnated. The application rate in fact declined for the local varieties of Aus and Aman, and these crops still account for about half of total sown acreage in Bangladesh.

The present levels of application are considerably below the levels recommended for almost all foodgrain crops. The highest levels of application for the 1979-82 period, as a proportion of the recommended dosage for the crop, were about 60 percent for HYV Boro, Aus, and local transplanted Aman, and 45 percent for local Aus. Thus there appears to be a large potential for raising fertilizer consumption by increasing the rate of application on treated land.

Fertilizer use per acre of cropped land (Table 6) is the product of the proportion of land treated with fertilizers and the rate of application on treated land. There is a larger difference in the amount of use per cropped acre between local and high-yielding rice than there is in the rates of application on treated land, since diffusion over the local varieties has been significantly less extensive. The difference has, to some extent, been narrowed over time. Still, the rate of use on local varieties is about one-third of the rate of use on HYVs during the Aman season and as little as one-tenth the rate during the Aus season.

Locational Variation in Fertilizer Use

The IFDC/BARC survey also showed large variations in fertilizer use per acre on the same crop between different locations (see the Appendix, Tables 47 and 48). This suggests that better extension services and supply management might result in further growth in consumption and that low-consuming areas might become high-consuming ones. It should be noted that in some locations, like Rangunia in Chittagong and Nandigram in Bogra, use has approached the recommended levels for both local varieties and HYVs. But in other locations, for example, in Dinajpur, Rangpur, Faridpur, Khulna, and Sylhet, applications on both local and HYVs are low. Estimates of the coefficients of variation for the diffusion and for the rate of

Table 5--Rate of fertilizer application on treated land for different crops, 1969/70 to 1981/82

Crop	1969/ 70	1976/ 77	1979/ 80	1980/ 81	1981/ 82
	(lbs. of materials/acre)				
Rice					
Local Aus	59	41	95	89	70
HYV broadcast Aus	...	...	132	108	123
HYV transplanted Aus	264	161	251	274	251
Local broadcast Aman	...	...	149	85	80
Local transplanted Aman	62	51	128	83	99
HYV Aman	...	168	169	167	190
Local Boro	...	60	108	108	163
HYV Boro	244	209	257	255	289
Wheat	83	167	173	182	164
Jute	50	136	76	119	78
Sugarcane	80	150	...	...	352
Oilseeds	24	...	117	224	220
Potato	...	618	246	439	456
Tobacco	338	160	291	164	314
Chili	...	...	98	221	218
Vegetables	...	...	184	275	193

Sources: Data for 1969/70 from M. I. Khan, "Modernization of Small Farms in East Pakistan: A Study in Allocative and Structural Efficiency," Pakistan Institute of Development Economics, Dhaka, 1971 (mimeographed); for 1976/77, Bangladesh Ministry of Agriculture, Agro-Economic Research Division, "Bangladesh Agriculture in 1978," Dhaka, 1978 (mimeographed); and for 1979/80 to 1981/82, Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Note: The application rate per acre of land treated with fertilizer was not reported in the 1969/70 and 1976/77 surveys; it has been estimated from the figures on application per acre of cropped land by dividing it by the proportion of cropped land treated with fertilizer.

Table 6--Intensity of fertilizer use per cropped acre, 1979/80 to 1981/82

Season and Crop	Fertilizer Use				
	1969/70	1976/77	1979/80	1980/81	1981/82
	(lbs. of materials/acre)				
Aman season					
Local broadcast paddy	...	...	42	6	23
Local transplanted paddy	13	26	72	45	52
HYV paddy	n.g.	146	146	140	159
Sugarcane	49	84	n.a.	39	257
Boro and Rabi season					
Local paddy	...	29	14	10	36
HYV paddy	237	205	242	246	280
Local wheat	35	23	38		
HYV wheat	n.g.	90	142	142	114
Pulses	2	2	9	2	6
Oilseeds	16	34	34	70	110
Potato	...	352	138	168	201
Tobacco	267	104	279	107	305
Chili	...	...	50	148	157
Vegetables	...	118	114	162	103
Spices	...	53	16	15	48
Aus season					
Local paddy	19	23	42	39	33
HYV broadcast paddy	...	142	87	91	88
HYV transplanted paddy	198	...	243	265	247
Jute	13	53	25	33	33

Sources: Data for 1969/70 from M. I. Khan, "Modernization of Small Farms in East Pakistan: A Study in Allocative and Structural Efficiency," Pakistan Institute of Development Economics, Dhaka, 1971 (mimeographed); for 1976/77, Bangladesh Ministry of Agriculture, Agro-Economic Research Division, "Bangladesh Agriculture in 1978," Dhaka, 1978 (mimeographed); and for 1979/80 to 1981/82, Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals: IFDC, 1982 and 1984).

Notes: Where n.g. appears, the crop was not grown. Where n.a. appears, the data were not available.

application across these locations are given in Table 7. There is clearly less variation by location in the diffusion of fertilizer use for HYVs than for local varieties. The same is true of variations in applications per acre.

Natural factors, such as the extent and depth of flooding and soil quality may cause some of the variations in fertilizer use on local varieties. Little fertilizer is used on the local varieties of paddy in selected locations of Barisal, Dinajpur, Sylhet, Faridpur, Rajshahi, and Dhaka (local Boro) districts. The quantity of fertilizer used for the three local varieties in these areas is only four to six pounds per acre. The selected areas in the districts of Sylhet, Faridpur, Rajshahi, and Dhaka are in a depressed basin where these crops are grown under waterlogged conditions and Barisal suffers from the problem of frequent flooding from high tides. Because of siltation from floods, the fertilizer requirements of soils in these areas may also be low. Dinajpur is a highland area; the low use of fertilizer in this district may be due to high concentration of landholdings and to tenurial problems.

Irrigation may also partly explain the locational difference in fertilizer use. The IFDC/BARC report only includes data on fertilizer application under irrigated and rainfed conditions for paddy crops for the 1980 season (see Table 8). It may be noted that irrigation is practiced not only in the Boro season but also in the Aus and Aman seasons, particularly where HYVs are grown. Except for Boro season crops, fertilizer use is positively associated with irrigation of both local varieties and HYVs. Approximately half as much fertilizer is used on rainfed land as on irrigated land. Cross-section data for 20 locations during 1981/82 on the percent of land irrigated (I), and the amount of fertilizer used per cropped acre (F), show the following linear relationships:

Local Aman:	$F = 45 + 2.4\ I;$	$R^2 = 0.49$
HYV Aman:	$F = 93 + 1.6\ I:$	$R^2 = 0.45$
Local Aus:	$F = 34 + 0.96\ I;$	$R^2 = 0.02$
HYV Aus:	$F = 110 + 1.61\ I;$	$R^2 = 0.38$

As the findings indicate, more than 40 percent of the variations in fertilizer use is explained by variations in the use of irrigation. A 10 percent increase in irrigated land is associated with an incremental use of about 16 pounds for HYV Aus and Aman and 24 pounds for local Aman. In the case of local Aus, the relationship is weak.

Because of the diversity of natural conditions and differing availability of irrigation facilities, one would expect some variation in fertilizer use by region. But such factors cannot explain the large locational variations in fertilizer use by crop observed in the IFDC/BARC survey. Thus, there remains a large potential for raising fertilizer consumption through policy interventions in the areas of research, extension, and supply management.

Table 7--Locational variation in fertilizer application to foodgrain crops, 1980-82

Crop	Coefficient of Variation in Use per Acre			Coefficient of Variation for 1980	
	1980	1981	1982	Percentage of Plots	Per Acre Use on Treated Land
	(percent)				
Local Aman	63	88	n.g.	55	27
Local Aus	110	105	113	86	45
Local Boro	110	102	63	...	...
HYV Aman	42	53	n.g.	19	35
HYV Aus	42	47	50	14	31
HYV Boro	24	46	30	2	23
HYV wheat	31	55	75	9	29

Source: Estimated from Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984). The figures are reported in Appendix Tables 47 and 48 of this paper.

Notes: Where n.g. appears, the crop was not grown. Where ellipses (...) appear, the percentage was not estimated.

Table 8--Irrigation and fertilizer use in paddy crops, 1980

Crop	Proportion of Land Irrigated	Fertilizer Use		Crop Yield	
		Irrigated Land	Rainfed Land	Irrigated Land	Rainfed Land
	(percent)	(lbs. of materials/acre)		(metric tons/acre)	
Local paddy					
Boro	68.9	16	11	0.73	0.71
Aus	1.0	63	41	0.77	0.63
Aman	0.5	88	35	0.78	0.81
HYV paddy					
Boro	81.9	232	284	1.34	1.41
Aus	39.1	276	134	1.49	1.02
Aman	17.5	255	118	1.41	1.13

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 (Muscle Shoals, Ala.: IFDC, 1982), Tables VI.3 and VI.4, p. 72.

Share of Crops in Total Fertilizer Consumption

The shares of various crops in total fertilizer consumption for 1969/70, 1977/78, and 1983/84 have been worked out by applying per acre fertilizer application data for the crops reported in Table 6 to the national crop acreage data published by the Bangladesh Bureau of Statistics.[16] The crops included account for about 95 percent of the total sown area in the country. As mentioned earlier, total fertilizer consumption calculated from these figures was quite close to national fertilizer sales for the corresponding years. The estimated consumption is higher by about 5 percent for 1969/70 and 1.5 percent for 1983/84, but about 8 percent lower for 1977/78. The share of these crops in total sown area and in total fertilizer consumption is reported in Table 9. Rice and wheat accounted for about 87 percent of total fertilizer consumption in the country in 1980/81 (81 percent for rice and 6 percent for wheat). HYVs of rice and wheat have been the main focus of fertilizer consumption growth. The share of these crops increased from about 25 percent in 1969/70 to 46 percent in 1977/78 and further to about 61 percent in 1983/84. The increase has come partly through reallocation of land from local varieties to HYVs. The share of HYVs in total sown area was only about 2 percent in 1969/70; it rose to about 24 percent by 1983/84. In spite of the rapid diffusion of fertilizer use on local varieties, their share of total consumption has fallen over time because of the fall in their cropped area and because rates of application have not increased as fast as on HYVs.

Table 9 also gives an estimate of the share of irrigated land in total fertilizer consumption. Irrigation is used mostly to grow Boro rice, potatoes, and vegetables. Some supplementary irrigation is also used for growing Aus and Aman HYVs. Fertilizer consumption on irrigated land has been estimated from BBS data on irrigated land for these crops, assuming that about twice as much fertilizer is used on irrigated land as on rainfed land (see Table 8), except for Boro crops, for which all fertilizer is assumed to be used on irrigated land. In 1983/84, about 14 percent of the cropped land was irrigated, but about 44 percent of fertilizer was used on irrigated land. The share of irrigated land in total fertilizer use increased from 28 percent in 1969/70. Total consumption increased by about 402,000

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[16]For 1983/84, fertilizer intensity coefficients for 1981/82 have been used, the latest year for which this information is given in the survey (BARC/IFDC, Agricultural Production, Fertilizer Use and Equity Considerations, 1980-82). For 1977/78, reconstructed data based on coefficients estimated by the Ministry of Agriculture 1976/77 surveys were used; for 1969/70, the coefficients estimated by M. I. Khan were used (M. I. Khan, "Modernization of Small Farms in East Pakistan").

Table 9--Estimates of the share of various crops in total sown area and in fertilizer consumption, 1969/70, 1977/78, and 1983/84

Season and Crop	Percentage of Total Sown Area			Percentage of Total Fertilizer Consumption		
	1969/70	1977/78	1983/84	1969/70	1977/78	1983/84
Aus season	35.6	33.3	29.5	30.8	27.4	17.7
Local Aus	27.5	23.1	20.9	24.6	10.6	7.0
HYV Aus	0.14	3.3	4.0	1.3	9.4	8.8
Jute	8.0	6.9	4.6	4.9	7.4	1.9
Aman season	49.7	49.5	48.8	33.5	37.3	39.1
Broadcast Aman	16.8	14.1	11.6	...	...	0.9
Local transplanted Aman	31.5	29.9	27.5	29.6	22.9	17.7
HYV Aman	0.10	4.2	8.4	0.9	12.2	16.5
Sugarcane	1.3	1.3	1.3	3.0	2.2	4.0
Boro season	14.6	17.3	21.7	35.7	35.3	43.3
Local Boro	5.2	3.8	2.7	7.1	2.2	1.2
HYV Boro	1.9	5.4	8.4	21.0	22.0	29.2
Wheat	1.0	1.6	4.3	1.6	2.5	6.1
Other Rabi crops	6.5	6.5	6.3	6.0	8.6	6.8
HYV paddy and wheat	2.1	14.5	25.1	24.8	46.1	60.6
Irrigated crops	6.7	10.7	14.0	28.2	39.0	44.1

Source: Developed by applying crop-level fertilizer application rates (Table 6) to the official crop acreage data for the corresponding years, published by the Bangladesh Bureau of Statistics.

tons of materials over the period 1977/78 to 1983/84; about 81 percent of this increment is associated with increased use on HYVs and 51 percent with increased use on irrigated lands. For the period 1969/70 to 1977/78, these shares of incremental consumption were 60 and 46 percent, respectively. Thus, HYVs and irrigation have been increasingly important in the growth of fertilizer use.

DEVELOPMENT OF FACTORS INFLUENCING FERTILIZER CONSUMPTION

This section will briefly review the pattern of development of several price and nonprice factors that influence fertilizer consumption. The findings of the previous section indicated that the major nonprice factors that have shifted the demand curve historically are the availability of irrigation and the adoption of HYVs. The provision of agricultural credit that could ease cash availability constraints and the fertilizer distribution system that influences fertilizer supply are other nonprice factors discussed in this section.[17]

Development of Irrigation

Before modern irrigation was introduced in Bangladesh, cultivators irrigated Boro paddy by lifting surface water through such traditional devices as swing baskets and wooden dhones. It is estimated that by the early sixties, nearly 5 percent of cultivated land (940,000 acres) was irrigated by these traditional methods, mostly in the depressed basins of Sylhet, Mymensingh, and Rajshahi districts. The subsequent development of modern irrigation may have partly replaced these traditional methods.

The initiative for development of modern irrigation facilities had to be taken by the government since farmers were unwilling or unable to make large lump-sum investments in irrigation equipment. This difficulty was undoubtedly related to the small average size of farms and the extent to which individual holdings in Bangladesh are apt to be fragmented and scattered. The earliest approach of the government to the expansion of irrigation facilities was through construction of large-scale multipurpose irrigation, flood control, and drainage projects implemented by the Bangladesh Water Development Board. A number of major projects were implemented during the sixties and seventies. These have been largely successful in protecting coastal and river belt areas from saline intrusion and

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[17]This section draws heavily from Mahabub Hossain's earlier work, "Increasing Food Availability in Bangladesh: Constraints and Possibilities," a report prepared for the Ministry of Agriculture and Forests, Dhaka, April 1984.

flooding, but they played only a minor role in irrigation. In addition, the capacity of these projects remains underutilized. Total area irrigated by such projects was only about 155,000 acres in 1969/70, increasing to about 0.56 million acres by 1983/84 (see Table 10).

BADC's program of expanding irrigation through supply of small-scale irrigation equipment was more successful. Most of the expansion followed upon subsidized rental to farmers of small low-lift pumps.[18] The number of pumps fielded rose quickly from about 2,000 in 1962/63 to about 36,000 by 1974/75. The numbers since then have fluctuated between 36,000 and 42,000 with very slow expansion of the area irrigated. This phenomenon reflects the increasing scarcity of surface water supplies during the dry season.

The promotion of groundwater development started late, beginning in 1967/68, and moved at a slow pace through 1977/78. Initially, deep tubewells (DTWs) were rented to bona fide farmers' cooperatives, which formed water users' groups with contiguous plots within no less than a 50-acre area. The group would bear the operating costs and pay a pump rental to BADC. Beginning in 1978/79, the government started selling this equipment to groups and private individuals with a subsidy of about 75-80 percent. The number of DTWs in operation increased from around 800 in 1970/71 to approximately 4,500 in 1976/77, and then more rapidly to about 14,200 by 1983/84. The area irrigated by DTWs reached 814,000 acres (3.8 percent of cultivated land) by 1982/83. Since the mid-seventies, the government has promoted shallow tubewells (of less than 0.5 cusec capacity), which are sold to farmers without any subsidy. The number of shallow tubewells (STWs) increased rapidly from only about 5,000 in 1976/77 to about 104,000 in 1982/83. The area irrigated by STWs reached about 1.2 million acres (5.7 percent of cultivated land) by 1982/83.

Trends in the area under modern irrigation are reviewed in Table 10. It should be clear that the rate of increase has accelerated since the mid-seventies.[19]

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[18]It is estimated that during 1965/66 and 1966/67, the government subsidy, assuming full recovery of rental charges, was about 68 percent for a cusec pump and 57 percent for two cusec pumps. See F. Kahnert et al., Agriculture and Related Industries in East Pakistan (Paris: OECD Development Center, 1970).

[19]Part of the increase is due to expansion of area covered per unit of irrigation equipment since 1977/78, as reported by BADC. However, many have argued that the growth in capacity utilization reported by BADC may be overestimated.

Table 10--Trends in the development of modern irrigation facilities, selected years

Year	Irrigation Equipment Units in Operation			Area Irrigated		Share of Arable Land Irrigated by Modern Methods
	Low-Lift Pump	Shallow Tubewell	Deep Tubewell	BADC	BWDB	
	(thousands)			(1,000 acres)		(percent)
1969/70	17.8	...	1.0	675	155	2.6
1973/74	35.3	1.0	1.5	1,398	103	7.2
1975/76	36.4	4.0	3.8	1,491	114	7.7
1977/78	36.7	12.3	7.5	1,798	153	9.4
1979/80	37.4	22.4	9.8	2,395	284	12.8
1980/81	36.1	38.4	10.1	2,563	324	13.6
1981/82	38.2	66.5	11.5	3,304	342	17.2
1982/83	42.2	104.1	13.8	3,675	420	19.2
1983/84	40.9	n.a.	14.2	n.a.	558	n.a.

Sources: Bangladesh Agricultural Development Corporation, Annual Report, various issues; and World Bank, South Asia Programs Department, Bangladesh: Economic Trends and Development Administration, Vol. II: Statistical Appendix, Report No. 4822 (Washington, D.C.: World Bank, 1984).

Notes: Figures for shallow tubewells include those fielded by Bangladesh Krishi Bank, as estimated in Bangladesh Agricultural Development Corporation (BADC), Report on Sale of Shallow Tubewells in the North-West and South-Eastern Districts of Bangladesh (Dhaka: BADC, 1984). The figures on low-lift pumps and deep tubewells for 1983/84 are from the Bangladesh Ministry of Finance, "Bangladesh Economic Survey, 1983/84." The total irrigated area estimated from figures provided by the Bangladesh Agricultural Development Corporation and the Bangladesh Water Development Board (BWDB), however, exceeds the figure provided by the Bangladesh Bureau of Statistics. When n.a. appears, the data were not available.

The potential for irrigation development in Bangladesh is considerable since three-fourths of the arable land in the country still has no access to irrigation facilities. Although accurate information is not available, it is estimated that about 40-45 percent of the arable land could be covered with modern irrigation facilities, given the available water resources during the driest months of March-April.[20] Only about a third of this potential has so far been exploited. The potential could be further increased by investing in water control structures on numerous rivers and canals in the country for the purpose of retaining monsoon flows.

Diffusion of High-Yielding Seeds

High-yielding paddy varieties were introduced in Bangladesh during the 1966/67 Boro season. Beginning in 1970, cultivators started growing them in the Aman and Aus paddy seasons, basically under rainfed conditions. Trends in the expansion of HYVs in various seasons appear in Table 11. The proportion of cropped acreage

Table 11--Expansion of area under HYVs, 1969/70 to 1983/84

Year	Share of HYV Areas in Sown Area				Area under Paddy and Wheat HYVs	
	Aus Paddy	Aman Paddy	Boro Paddy	Wheat	Total Area	Share of Cropped Land
	(percent)				(1,000 acres)	(percent)
1969/70	0.6	0.2	26.5	...	652	2.1
1973/74	4.3	14.5	56.0	23.6	3,900	12.7
1975/76	10.3	9.7	55.9	58.8	4,053	13.0
1977/78	12.6	8.6	58.6	83.3	4,188	13.4
1979/80	13.3	14.6	63.0	94.9	5,954	18.6
1980/81	15.7	15.9	64.4	96.7	6,835	21.0
1981/82	15.0	15.9	68.9	96.7	7,021	21.5
1982/83	15.1	17.9	75.4	95.9	7,521	22.9
1983/84	15.9	17.7	76.1	96.0	7,795	23.6

Sources: Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983); and BBS, Monthly Statistical Bulletin, October 1984.

[20] A. Bottrall, Review of Irrigation Management Practices in Bangladesh (Dhaka: Centre for Development Science, 1983).

planted with HYVs increased steadily to about 13 percent by 1975/76 and to nearly 24 percent by 1983/84. During the early years the increase came from expansion of the area under Boro crops associated with the increase in irrigated area and with some reallocation of land previously planted with local varieties of Aus and Boro.[21] During the late seventies, a rapid rise in the area under wheat and a shift from local to HYV Aman paddy contributed to the growth of HYV acreage. The expansion has slowed down since 1980/81 because of stagnation in the area under wheat and HYV Aus. At present, the entire wheat area and three-fourths of the Boro paddy area are planted with HYVs. But HYVs account for only one-sixth of Aus and Aman cropped acreage. This proportion is expanding at a very slow pace.

The pattern of diffusion of HYVs in different regions of the country is shown in Table 12. HYV coverage expanded rapidly throughout the period in the eastern and northeastern part of the country (wet zone), except in the districts of Noakhali and Sylhet where the rate of expansion slowed down over the 1977-83 period. Expansion in the northern districts was slow through 1977/78, but has proceeded rapidly since then owing to groundwater irrigation development and to the rapid growth in wheat acreage that has taken place in this region. The diffusion has been very slow in the coastal districts of Barisal, Patuakhali, Khulna, and Faridpur where only about one-tenth of the total sown area has so far been planted with HYVs.

It was reported earlier that little fertilizer is used on broadcast Aman and local Boro. The proportion of area under these two crop varieties in different regions of the country has also been reported in Table 11. There is a high concentration of the area under these two crops in particular regions. While about one-sixth of total sown area is under these two crops nationally, the proportion is more than one-third in the districts of Faridpur and Sylhet, one-fifth in Comilla, Dhaka, Pabna, and Jessore, and negligible in Chittagong, Bogra, Dinajpur, and Rangpur. This difference in cropping pattern, which is related to agroecological variations within the country, has an important bearing on the fertilizer consumption capacity of different regions.

Available information based on soil conditions and land levels indicates that there is considerable scope for expansion of HYV acreage in the country. It is estimated that by 1982/83, only about 40 percent of the potentially suitable area had been covered by HYVs

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[21]The area under Boro paddy and wheat increased from 2.5 million acres in 1969/70 to 4.8 million in 1983/84. The area under Aman paddy remained stagnant at around 15 million acres while the area under Aus declined from 10.9 to 9.2 million acres.

Table 12--Diffusion of HYVs in different regions, 1970/71, 1977/78, and 1982/83

Regions	Share of Rice and Wheat HYV in Total Sown Area			Share of Land Under Local Boro and Broadcast Aman in Sown Area		
	1970/71	1977/78	1982/83	1970/71	1977/78	1982/83
	(percent)					
High-fertilizer-consuming region	6.6	23.1	36.3	21.0	17.2	15.0
Bogra	3.8	13.1	29.8	1.9	1.1	...
Chittagong	15.0	44.6	66.1	5.0	...	...
Comilla	6.7	25.5	35.9	34.2	29.1	25.8
Dhaka	5.7	18.0	28.0	29.2	27.2	24.8
Kushtia	2.3	8.5	25.3	14.7	11.9	7.8
Medium-fertilizer-consuming region	3.5	9.8	22.4	12.9	14.3	11.5
Mymensingh	3.6	12.4	26.2	9.6	14.1	11.5
Kishoreganj	5.6	22.3	33.4	35.8	27.1	14.9
Chittagong Hill Tracts	6.1	33.7	40.3	7.9	1.6	...
Rajshahi	3.2	7.3	16.5	10.2	19.2	17.7
Dinajpur	3.2	6.0	20.4	2.5	0.9	...
Rangpur	2.0	6.1	19.3	2.0	3.2	1.8
Pabna	5.6	6.4	14.9	28.4	24.9	21.2
Jessore	3.1	7.3	16.9	21.2	22.9	18.2
Low-fertilizer-consuming region	3.9	11.9	15.5	24.8	20.8	19.6
Faridpur	1.6	4.4	10.5	35.7	37.9	33.5
Noakhali	5.6	30.7	38.0	15.0	7.7	4.9
Sylhet	2.9	14.3	14.8	45.2	36.7	34.3
Khulna	2.5	5.5	10.4	15.3	9.1	9.3
Barisal	6.4	9.0	11.3	6.7	7.5	7.4

Source: Estimated from figures provided by Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983); and BBS, Monthly Statistical Bulletin, August 1984.

in the Boro season, 35 percent in the Aman season, and only about 18 percent in the Aus season.[22]

The main constraint to expansion of HYV area, particularly during the Boro and Aus seasons, seems to be irrigation facilities, which are expanding slowly. The IFDC/BARC survey found that during 1981/82, about 96 percent of the plots under HYV Boro and 80 percent under transplanted HYV Aus were irrigated. The district-level cross-section data for 1981/82 also reveal a particularly close relationship between the adoption of Boro and wheat HYVs and the area irrigated by modern methods.[23] The diffusion of HYVs in the monsoon season depends not only on the availability of supplementary irrigation but also on flood depths and the duration of the monsoon. It is estimated that about one-third of transplanted Aman land (3.6 million acres) is flooded to depths of 20 to 40 inches during the season and therefore is not suitable for growing HYV Aman.[24] As noted earlier, a large proportion of the area in Faridpur, Sylhet, Comilla, Dhaka, Pabna, Rajshahi, and Jessore districts is so deeply flooded that only deep-water broadcast Aman and local Boro could be grown. In Chittagong Division and the districts of Mymensingh and Kishoregonj, where HYV Aman coverage has expanded rapidly, almost reaching its estimated potential, the monsoon arrives early and stays late. Thus, average yearly rainfall is much higher in these areas than in the northern and southwestern regions where HYV coverage is still low. Until supplementary irrigation is undertaken for highlands, and flood depths are reduced through drainage and flood control projects in lowland areas, further diffusion of HYVs during the monsoon season will be difficult to achieve.

Supply of Institutional Credit

The role of credit supply at reasonable rates of interest in the process of fertilizer consumption expansion cannot be overemphasized. Fertilizer is a major cash input to farming. The cost of material inputs per acre of land at 1982/83 prices is estimated at Tk 2,080 for HYV Boro and Tk 152 for transplanted local Aman. Fertilizers account for Tk 490 (24 percent) of the costs of the former and Tk 91 (60 percent) of the costs of the latter. Over the period 1977-82, material input costs increased by about 88 percent in nominal terms

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[22]Mahabub Hossain, "Increasing Food Availability in Bangladesh, Constraints and Possibilities," a report prepared for the Bangladesh Ministry of Agriculture and Forests, Dhaka, April 1984, p. 19.

[23]Ibid., Technical Appendix 3.

[24]Md. Abul Quasem, "Adoption of HYV Paddy in Bangladesh: Its Potential Acreage and Constraints," Farm Economy 3 (No. 1, 1982): 71.

for locally transplanted Aman and 209 percent for HYV Boro.[25] The majority of farmers in Bangladesh are poor and produce primarily for family consumption. They may find it difficult to grow enough marketable surplus to bear the increasing costs of these inputs. Many of them cultivate land under sharecropping arrangements. The surplus generated from cultivating such lands is apt to be extracted by landowners through a high rental, generally half of the gross produce. There are informal markets for credit in villages, but the rates of interest are so high that it may prove uneconomical to borrow on these markets for fertilizer purchase. A shortage of production loans on reasonable terms thus may restrain the diffusion of improved agricultural technology, including chemical fertilizers.

Institutional credit facilities have expanded greatly to cater to the needs of farmers, particularly since 1976/77. A number of institutional lending agencies providing agricultural loans are now operating in rural areas. The Bangladesh Jatyo Samabaya Bank is the oldest agency, followed by the Bangladesh Krishi Bank established in 1961, the cooperatives of the Bangladesh Rural Development Board, which started operations in 1971, and the nationalized commercial banks whose activities in rural areas accelerated with the introduction of the Special Agricultural Credit Program in 1977. During 1983/84 about 3,225 rural branches of these banks were providing credit, serving an average of about 20 villages per branch.

Trends in the supply of institutional agricultural credit over the period 1970/71 to 1983/84 appear in Table 13. The supply was insignificant before independence, but within three years it increased threefold, and the rate of growth has accelerated since the mid-seventies. During the period 1977/78 - 1983/84, the supply of credit increased by about 36 percent per year in nominal terms and about 20 percent in real terms, after discounting for the increase in the price of agricultural inputs. The real value of credit per unit of cropped land (at 1975/76 prices) increased from Tk 40 per acre in 1977/78 to Tk 114 in 1983/84. Still, the amount of credit may be considered low in relation to demand. The amount of credit disbursed per acre in 1982/83 was only about 12 percent of the total cost of cereal production, and 40 percent of the cost of material inputs.[26] Total agricultural credit disbursed during 1983/84, however, was 2.3 times 1983/84 fertilizer sales valued at official prices.

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[25]Hossain, "Increasing Food Availability in Bangladesh," p. 34.

[26]The amount of credit disbursed at current prices was Tk 206 per acre of sown area, in comparison to the estimated cost of cultivation of cereals of Tk 1,740 for all inputs and Tk 512 for material inputs. See Hossain, "Increasing Food Availability in Bangladesh," p. 34.

Table 13--Trends in the supply of agricultural credit from institutional sources, 1970/71 to 1983/84

Period	Amount of Credit Disbursed	Credit at Constant Prices[a]	Real Value of Credit	
			Per Acre of Sown Area	Per Acre of HYV Land
	(Tk million)		(Tk)	
1970/71	153	414	13	364
1973/74	307	435	15	112
1975/76	461	467	15	114
1977/78	1,569	1,257	40	300
1979/80	2,821	1,616	51	271
1980/81	3,734	1,797	55	263
1981/82	4,238	1,815	56	259
1982/83	6,788	2,792	85	371
1983/84	10,087	3,772	114	484

Source: A. M. A. Rahim, "Credit Institutions and Policies in Bangladesh," Bangladesh Krishi Bank, Dhaka, 1984 (mimeographed).

[a]These figures were obtained by deflating nominal values by the price index of agricultural inputs (1975/76 = 100) estimated in Mahabub Hossain, "Increasing Food Availability in Bangladesh, Constraints and Possibilities," a report prepared for the Bangladesh Ministry of Agriculture and Forests, Dhaka, April 1984, p. 66.

Another aspect of the supply of agricultural credit indicated in various microstudies is that only a small proportion of the cultivators have access to such loans. The findings of the IFDC/BARC survey on the availability of institutional credit to farmers are reported in Table 14. With the assumption that the borrowing cultivators received loans in only one of the three seasons during the year, it is estimated that during 1980/81, only 14 percent of the cultivators received credit and during 1981-82, only 11 percent. Although the amount of credit received per acre increased from Tk 102 in 1980/81 to Tk 141 in 1981/82, the proportion of farmers receiving credit did not. It appears from the findings that there has been a movement toward concentration of credit among a small group of recipients. The IFDC/BARC survey also finds that the medium and large farmers have much better access to credit than do small and marginal cultivators (Table 15).

Table 14--Estimates of the availability of institutional credit to farmers, 1979/80-1981/82

Season	Percent of Farmers Receiving Credit	Amount Received per Acre
		(Tk)
1979/80		
Aman	n.e.	n.e.
Boro	6.1	45
Aus	2.8	20
1980/81		
Aman	4.6	21
Boro	3.2	42
Aus	5.9	39
1981/82		
Aman	3.1	23
Boro	4.6	73
Aus	3.6	45

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Table 15--Availability of institutional credit for different groups of farmers, 1981/82

Size of Farm	Share of Farmers Receiving Credit		Amount of Credit Received per Acre	
	Boro Season	Aus Season	Boro Season	Aus Season
(acres)	(percent)		(Tk)	
1.0 or less	1.2	0.6	13	9
1.01 - 2.5	4.0	2.9	67	36
2.51 - 5.0	7.7	5.3	91	48
More than 5.0	7.2	6.9	84	58
All farms	4.6	3.6	73	45

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80. (Muscle Shoals, Ala.: IFDC, 1982).

What is the contribution of institutional credit in financing fertilizer consumption? No information is available at the national level that can answer this question. Nor did the IFDC/BARC survey focus on the issue. A study conducted in two villages of Dhaka District during 1977/78 by Quasem and Hossain found that on average one-fourth of total fertilizer costs were financed from institutional credit, but that the proportion was only about 10 percent for small farms. Since both fertilizer consumption and prices have increased substantially since then, the authors decided to conduct another survey in those two villages to understand the situation as of 1983/84.[27] Findings from these surveys are reported in Table 16. Less than one-fourth of the cultivators surveyed received credit from institutional sources during 1983/84, and the proportion is about one-sixth among smallholders. The contribution of institutional credit in financing fertilizer consumption declined over the period from 24 percent in 1977/78 to about 15 percent in 1983/84. The relative position of small farmers, however, seems to have improved. In 1977/78, about 47 percent of the costs were financed through noninstitutional loans for Chandra village and 23 percent for Banguri; these proportions fell to 16 and 10 percent in 1983/84. However, this may be due to their improved economic conditions as a larger proportion of the costs were met from their own surpluses. The share of institutional credit in total fertilizer costs remained lower for small farms (around 10 percent for both periods).

The limited contribution of agricultural credit in financing fertilizer consumption in spite of the rapid increase in disbursement may be due to a number of factors reported in various microstudies. Short-term crop loans are often disbursed too late for timely fertilizer and irrigation investments. This leads to a diversion of credit for financing consumption activities or for nonagricultural investment. Local bank officials often claim an illegal "service charge" of 10 to 15 percent of the loan, which may be one of the factors contributing to poor repayment performance. More than 60 percent of institutional credit in Bangladesh is not repaid on time, and more than 30 percent remains unpaid even five years after the due date.[28] A part of the new loan is often used to repay the old loan, reducing the effectiveness of credit in promoting productive activities. The Bangladesh Krishi Bank provides part of the credit in the form of fertilizer. But since credit is disbursed irrespective of temporal requirements for fertilizer application, and because of the problems of storage, farmers sometimes exchange the bank fertilizer coupons for cash.

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[27]The methodology of the survey and the findings regarding changes in fertilizer consumption are reported below.

[28]Government of Bangladesh and World Bank International Development Agency, Bangladesh Agricultural Credit Review, Vol. III, Statistical Appendix (Dhaka, 1983).

Table 16--Share of credit in financing fertilizer costs, Chandra and Banguri villages, 1977/78 and 1983/84

Village/ Size of Holdings	Share of Farms Obtaining Credit from Institutional Sources, 1983/84	Institutional Credit		Non-Institutional Credit		Own Surplus	
		1977/ 1978	1983/ 1984	1977/ 1978	1983/ 1984	1977/ 1978	1983/ 1984
(acres)	(percent)						
Chandra							
2.50 or less	14.0	10.5	9.8	46.7	15.7	42.8	74.5
2.51 - 5.00	48.5	28.2	32.7	21.5	0.3	50.3	67.0
More than 5.00	33.3	23.9	18.3	15.0	2.8	61.1	78.9
All farms	23.8	24.1	15.8	19.7	10.8	56.2	73.4
Banguri							
2.50 or less	17.7	11.1	11.8	23.0	10.4	65.9	77.7
2.51 - 5.00	38.5	30.0	22.7	3.6	9.7	66.4	67.6
More than 5.00	30.0	26.4	16.5	nil	nil	73.6	83.5
All farms	23.1	23.7	14.6	7.7	9.6	68.6	75.8

Sources: For 1977/78, M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979). For 1983/84, a field survey carried out for the present study in the same villages.

Note: The cultivators were asked to report the percentage of total fertilizer cost financed from various sources. The figures reported here are unweighted averages from the report.

Changes in the Fertilizer Distribution System and the Availability of Fertilizer

Supply bottlenecks may also constrain the growth of fertilizer consumption. Availability of fertilizer to farmers may depend, among other things, on the distribution system. Following its establishment in 1962, BADC had a complete monopoly of fertilizer distribution. The system has changed in recent years.[29]

Under the old marketing system (OMS), BADC used to deliver fertilizer to farmers through appointed dealers who could lift the input from BADC's Thana Sales Centers (TSCs) or from godowns of the Thana Central Cooperative Association (TCCA) where the dealers were registered. Each dealer could sell fertilizer only in his specified area of operation and received a commission from BADC based on the distance of his area of operation from the TSC or TCCA godown. By 1978, there were approximately 21,000 active fertilizer dealers covering 4,472 unions in the country. The OMS period saw occasional shortages of fertilizers leading to black-market sales at higher prices that could be attributed partly to local monopolies in fertilizer distribution enjoyed by the appointed dealers.

The new marketing system (NMS) was introduced on an experimental basis in Chittagong Division on December 1, 1978, and had been expanded throughout the country by July 1, 1980. The NMS allows any person, group, or organization to register as a dealer who is allowed to buy, sell, and transport fertilizer anywhere in the country except in the border belt. To save distribution costs, BADC consolidated its sales at major commercial centers known as Primary Distribution Points (PDPs). To attract viable wholesalers to the fertilizer business and to economize on delivery costs, BADC introduced a minimum quantity restriction on fertilizer being lifted from PDPs and provided higher discounts for lifting large amounts. BADC also introduced a training and credit program for fertilizer dealers.

At first, the dealers were to sell fertilizer to farmers at government-regulated prices. This, however, hampered the movement of fertilizer to remote areas because the transport costs were to be absorbed by the dealers. So the NMS was further modified by allowing traders to set their own prices. Price deregulation was first introduced in the Chittagong Division in April 1982 and was expanded to the whole country on April 1, 1983.

The BADC is still responsible for the procurement of fertil-

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[29]For details, see Kenneth L. Moots, Evaluation of the Bangladesh New Marketing System (Muscle Shoals, Ala.: International Fertilizer Development Center, 1982). See also the technical paper in this volume by M. A. Quasem.

izers, for distribution to PDPs and those remote TSCs that were not closed down, and for maintaining adequate aggregate stocks.

The extent to which the availability of fertilizer has constrained the growth of fertilizer consumption and the impact of NMS is addressed in detail in other chapters.[30] It does not appear from the data on fertilizer sales and stock movements for the last six years that supply up to the PDP level has been a major constraint. The monthly figures for stocks and sales from July 1977 to October 1984 have been plotted in Figures 1 and 2 for urea and TSP. For urea, the stocks were adequate (more than three times higher than monthly sales) most of the time, particularly during the post-NMS period. There are only a few brief spells during the seven-year period when stocks were very close to sales: August to December 1978, September 1981 to January 1982, and February to March and September to December 1984.

Since sales themselves may be affected by availability, a better way of assessing the supply situation may be to relate stocks to target sales (expected demand) based on past trends. Stocks as a percentage of target sales have been plotted in Figure 3. Again, aside from the fall of 1984 and brief periods in 1978/79 and 1981/82, stocks were close to or higher than three times monthly sales. The distribution of stock/target sales ratios for urea and TSP between the pre- and post-NMS periods is shown in Table 17. The stocks were less than three times the expected sales only a quarter of the time for urea and about an eighth of the time for TSP.

IFDC has also monitored farm-gate prices of fertilizer and paddy in a number of locations in Bangladesh since September 1981 and publishes the results on a monthly basis. These data show that the farm-gate prices of fertilizers were close to official prices for most of the period.[31] Of the 35 months for which the data are available, the farm-gate price was more than 10 percent higher than the official price for two months, 5 to 10 percent higher for four months, and 2 to 5 percent higher for seven months. The price spread was high when the actual stock of fertilizer fell below the BADC planned levels (equivalent to three months' sales for urea and five months' sales for TSP).[32] The data also show that the increase in the official price was almost fully transmitted to the farmers and that the farm-gate price did not increase significantly when prices were deregulated, allowing traders to charge the market clearing price. Assuming that the IFDC price survey accurately reflects the

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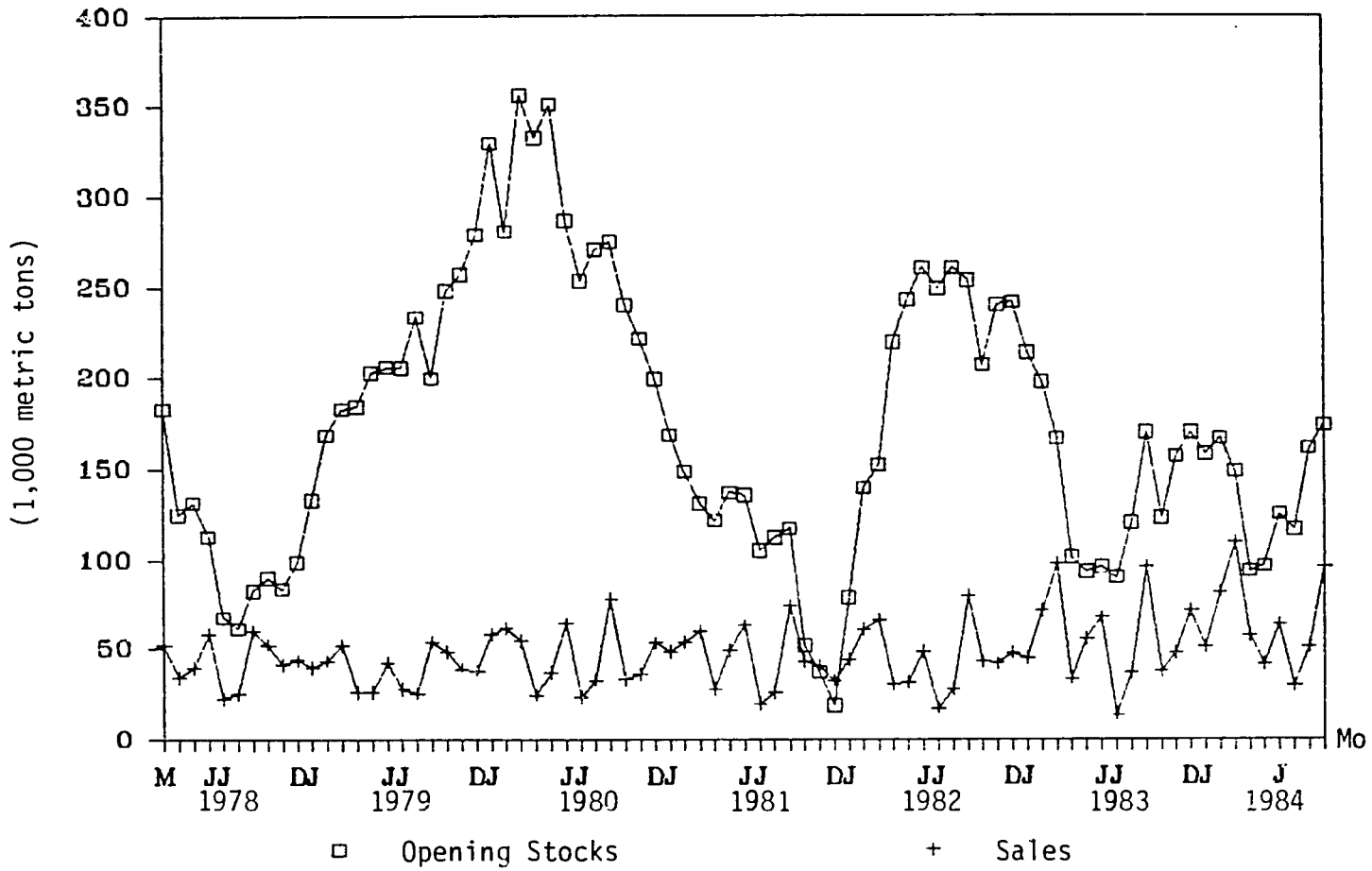
[30]See Chapter 6, by A. Samad, and Chapter 7, by M. A. Quasem.

[31]The official prices are the ex-PDP prices, which include the commissions paid to fertilizer traders.

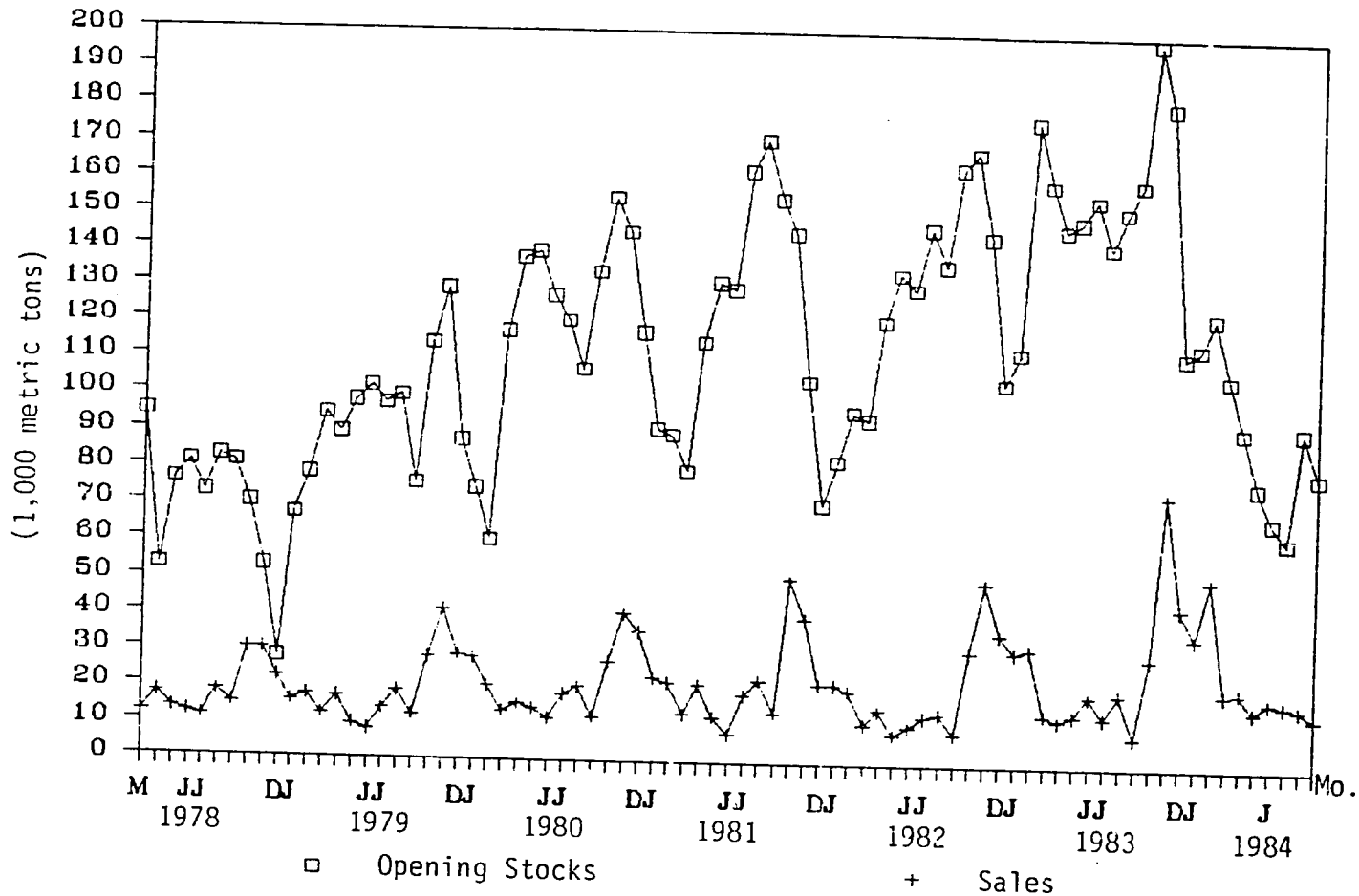
[32]For details, see the chapters by Quasem and Samad.

Figure 1--Opening stocks and sales of urea, by month, 1978-84



Source: Based on data from Bangladesh Agricultural Development Corporation.

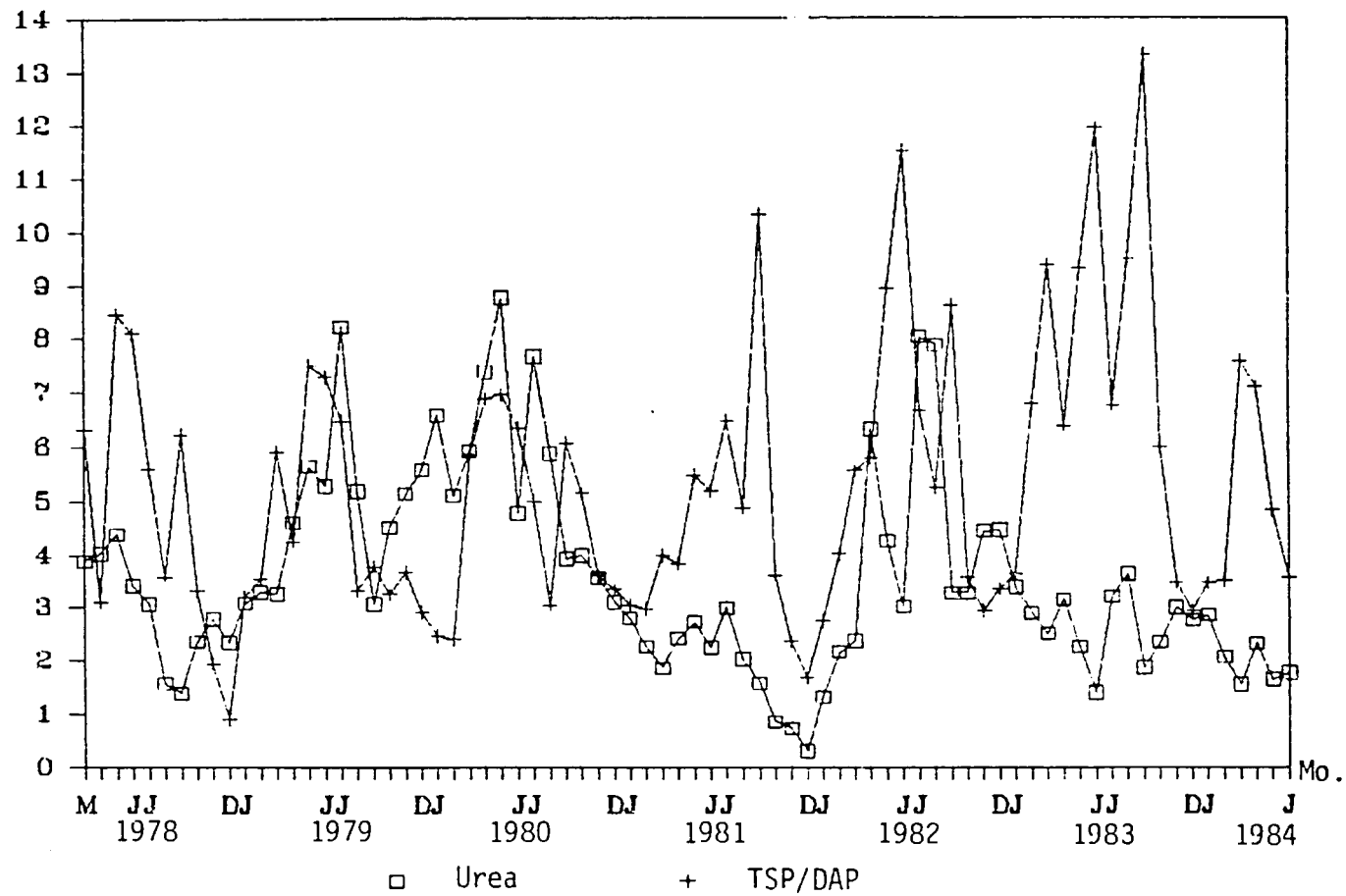
Figure 2--Opening stocks and sales of TSP/DAP, by month, 1978-84



Source: Based on data from Bangladesh Agricultural Development Corporation.

Note: TSP is triple superphosphate; DAP is diammonium phosphate.

Figure 3--Ratio of actual opening stocks to sales targets for urea and TSP/DAP, by month, 1978-84



Source: Based on data from Bangladesh Agricultural Development Corporation.

Note: TSP is triple superphosphate; DAP is diammonium phosphate.

Table 17--Sizes of stocks under the old and new marketing systems, July 1977-June 1980 and July 1980-June 1984

Stocks as a Percentage of Target Sales	Urea		TSP	
	July 1977-June 1980	July 1980-June 1984	July 1977-June 1980	July 1980-June 1984
	(percent of months)			
Less than 200	8.3	8.3	5.6	2.1
201 - 300	13.9	18.8	16.7	10.4
301 - 400	22.2	25.0	22.2	12.5
401 - 500	13.9	16.7	16.7	12.5
More than 500	41.7	31.3	38.9	62.5
Number of months	36	48	36	48

Note: TSP stands for triple superphosphate. The new marketing system was introduced throughout the country by July 1, 1980.

extent of price variation in the country, all this indicates that supply was not a serious constraint to the growth of fertilizer consumption.

Movement of Fertilizer and Produce Prices

The trend of official retail prices of different types of fertilizers and the growers' price of paddy can be seen in Table 18. The weighted average price per nutrient ton was fixed at Tk 572 for a long time, from 1960 until June 1972. But it was increased by nearly five times over the next five years (1972-77) and again by 2.6 times between July 1977 and July 1982. Prices for different types of fertilizers increased at similar rates. For the 12-year period between 1971/72 and 1983/84, the rate of growth per year was 25 percent for urea, 24.5 percent for TSP, and 20 percent for MP.

This consistently rapid growth of fertilizer prices was mainly the result of a gradual withdrawal of subsidies. The rate of budgetary subsidy was about 50 percent for urea and more than 70 percent for TSP and MP in 1975/76. By July 1982, the subsidies stood at only 4 percent for urea and had been reduced about a third for TSP and MP (Table 19). BADC's procurement and distribution costs for these inputs increased about 6 percent per year between 1975/76 and 1983/84, the prices charged to farmers increasing by about 14 percent for urea and 15 percent for TSP and MP.

Table 18--Trend in prices of fertilizer and paddy, 1969/70-September 1984

Year	Price of Fertilizer: Urea	TSP	MP	All[a]	Growers' Price of Paddy	Wholesale Price of Coarse Rice	Fertilizer/Paddy Price Ratio	Fertilizer/Rice Price Ratio
	(Tk/nutrient ton)				(Tk/metric ton of materials)			
1969/70	589	589	286	573	537	...	1.07	...
1970/71	589	589	286	572	497	...	1.15	...
1971/72	589	589	286	571	686	...	0.83	...
1972/73	1,152	844	446	1,040	1,138	2,017	0.91	0.52
1973/74	1,742	1,152	670	1,554	1,731	2,692	0.90	0.58
1974/75	2,921	2,331	1,340	2,626	3,238	5,614	0.81	0.47
1975/76	2,921	2,331	1,340	2,706	1,955	3,306	1.38	0.82
1976/77	3,483	2,787	1,795	3,242	1,741	3,031	1.86	1.07
1977/78	3,483	2,787	1,795	3,189	2,192	3,710	1.45	0.86
1978/79	4,073	3,215	2,010	3,725	2,542	4,080	1.47	0.91
1979/80	5,252	4,073	3,465	4,770	3,273	5,397	1.46	0.88
1980/81	6,029	4,850	2,894	5,547	2,698	4,513	2.06	1.23
1981/82	7,154	6,083	3,644	6,645	3,440	5,906	1.93	1.13
1982/83	8,628	8,146	4,904	8,326	4.020	6,420	2.07	1.30
1983/84	8,628	8,146	4,904	8,307	4,344	7,185	1.91	1.16
July - September 1984	9,491	8,961	5,394	9,138	5,252	...	1.74	...
Annual rate of growth								
1972/73 to 1977/78	24.8	26.9	32.1	25.1	14.0	13.0	9.8	10.6
1977/78 to 1982/83	19.9	23.9	22.3	2.1	12.8	11.6	7.4	8.6

Source: Bangladesh Bureau of Statistics, 1983 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1984); and BBS, Monthly Statistical Bulletin, various issues.

Note: TSP is triple superphosphate; MP is muriate of potash.

[a]The average price weighted by the consumption of different types of fertilizer.

Table 19--Trends in BADC procurement and distribution costs for different types of fertilizers, 1975/76 to 1983/84

Year	Cost to BADC			Official Issue Prices			Rate of Budgetary Subsidy		
	Urea	TSP	MP	Urea	TSP	MP	Urea	TSP	MP
	(Tk/metric ton of materials)						(percent)		
1975/76	2,841	4,149	2,800	1,361	1,089	816	52	74	71
1976/77	2,948	3,985	2,990	1,633	1,307	1,089	45	67	64
1977/78	2,564	3,785	2,221	1,633	1,307	1,089	36	65	51
1978/79	3,222	4,460	2,670	1,905	1,497	1,225	41	66	54
1979/80	3,426	4,926	3,330	2,450	1,905	1,497	28	61	55
1980/81	2,741	5,841	4,092	2,994	2,450	1,769	-9	58	57
1981/82	3,793	5,474	3,856	3,291	2,802	2,189	13	51	43
1982/83	4,118	5,945	4,370	3,966	3,752	2,948	4	37	33
1983/84	4,480	6,025	4,354	3,966	3,752	2,948	11	38	32
Annual rate of growth	5.9	4.8	5.7	14.3	16.7	17.4	...	...	...

Sources: Government of Bangladesh and United States Agency for International Development, Joint Evaluation of the Fertilizer Distribution Project (Dhaka, 1982); and Bangladesh Agricultural Development Corporation (BADC), unpublished reports.

Notes: TSP is triple superphosphate; MP is muriate of potash.

The prices of agricultural produce also increased rapidly after the early 1970s.[33] The price index for agricultural products went up by about seven times within the 14-year period from 1969/70 to 1983/84. The rate of growth first accelerated in the early seventies. Within three years, from 1971/72 to 1974/75, the index moved from 121 (1969/70 = 100) to 370, increasing at a rate of 37 percent per year. It remained stagnant for the next three years and started accelerating again in 1977/78. Over the next six years, the index moved from 397 to 727, increasing at a rate of about 11 percent per year. The growers' price of paddy increased at a faster average annual rate (17.4 percent) than did general agricultural prices (15.2 percent).

[33]For details, see Mahabub Hossain, "Trend in Agricultural Prices and Its Impact on Farm Economy, 1969-81," Farm Economy 3 (No. 1, 1982): 16-32.

All in all, price movements during the period as a whole were unfavorable for farmers. In Table 18, the ratio of fertilizer to paddy prices became favorable to farmers in the early seventies, moving from 1.1 in 1969/70 to 0.8 in 1974/75. Then the ratio increased steadily, reaching 2.06 by 1980/81. Because of faster increases in paddy prices, the ratio has again moved in favor of farmers since 1982/83. Despite the July 1984 fertilizer price increase, the ratio for July-September 1984 was 1.74, lower than in 1976/77.

PRICE RESPONSE OF FERTILIZER CONSUMPTION

The effect of prices on fertilizer consumption is quantified by estimating a fertilizer demand function. Since fertilizer is an input, the demand for fertilizer is a derived demand that depends on the use of land and other complementary inputs such as irrigation and HYV seeds, the quality of soil and agroclimatic factors, the price of fertilizer in relation to the prices of crop output, and the prices of complementary inputs. The fertilizer demand curve shows the relationship between the quantity of fertilizer demanded and the price of fertilizer--the fertilizer/crop price ratio--with other factors held constant. The effect of changes in prices is measured by the price elasticity of fertilizer demand, which shows the percentage change in fertilizer demand for a given percentage change in price. The effects of changes in other factors are shown as shifts in the demand curve.

Review of Previous Studies

A number of estimates of the price elasticity of fertilizer demand in Bangladesh are already available. Khan et al. used time-series data for the 1968/69 - 1977/78 period to fit a demand function that related fertilizer use per acre of cropped land to the index of fertilizer prices relative to paddy prices and to the proportion of area under HYVs (as a shift variable).[34] A dummy variable was also used to represent supply disruptions during the War of Liberation (1971/72) and during the breakdown of the Ghorasal Fertilizer Factory (1974/75). The estimated function shows a perverse demand function (upward sloping), with an elasticity of 0.26. The authors argued that there was a large unfulfilled demand for fertilizer because of price control and supply constraints, and hence farmers might increase use of fertilizer over time, even if the price rose.

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[34]M. Sekandar Khan, "Fertilizer Distribution in Bangladesh," A report prepared for the Ministry of Agriculture and Forests, University of Chittagong, 1981.

Khan et al. also estimated a function from a cross section of 1979/80 data collected from 180 farms in a Chittagong District village and argued that "at the farm level fertilizer use is more of a demand variable, because of wider availability of fertilizer to any individual farmer."[35] The amount of fertilizer used per acre of cultivated land on the farm was related to the farm-gate price of fertilizer,[36] the proportion of HYV acreage to total cultivated land, the amount of credit received from both institutional and noninstitutional sources, the level of education of the farmer, the size of the holding, and the proportion of cultivated area owned. About 41 percent of the variation in farm-level fertilizer use was explained by the model, and the regression coefficient associated with farm-gate fertilizer price was found to be negative. The price elasticity of fertilizer demand was estimated to be -3.47.

IFDC also estimated demand functions for fertilizer using a cross section of farm survey data for 1979/80 and 1981/82. The quantity of fertilizer nutrients per acre of land was related to the NPK/paddy price ratio, the use of labor per acre, the number of school years completed by the farmer, and a set of dummy variables representing HYV use, farm size, cropping seasons, and geographical locations. The plot-wise survey data for the paddy crop was used to estimate the model for 1981/82. For 1979/80, farm level data was used and separate estimates were made for different cropping seasons.

For 1979/80, the model explained about 55 percent of the variation in farm-level demand for fertilizers. The HYV acreage and irrigation, labor use, and farmer's level of education were found to have a significantly positive influence on fertilizer consumption, while the proportion of poorly drained land, the size of land owned, and the proportion of sharecropped land were found to have a statistically significant negative effect. It was estimated that price factors alone contributed about 4 percent of the variation in fertilizer consumption.[37] The elasticity of fertilizer demand with respect to the relative NPK-paddy price ratio was estimated to be -0.35 for the Boro season, -1.32 for the Aus season, and -1.0 for the Aman season. The NPK-paddy price variable was not included in the equation estimated by pooling the data for the three seasons

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[35]Ibid., p. 40.

[36]The transport charge from the place of purchase to the farm was added to the price paid by the cultivator.

[37]M. S. Khan, "Fertilizer Distribution in Bangladesh," p. 151.

together, so the estimate for the year is not available.[38] The elasticity with respect to the absolute prices for the year was estimated to be -2.5. However, if the value of seasonal elasticities is weighted by the share of fertilizer consumption in respective seasons, the average elasticity with respect to relative prices of fertilizer and paddy comes to -0.83.

The model was also estimated for the three seasons together, using plot level data for 1981/82. The model explained about 61 percent of the variation in fertilizer consumption. The elasticity of demand with respect to the NPK-paddy price ratio was estimated to be -0.26 for all farms, -0.27 for farms of 2.5 acres or less, and -0.24 for farms of more than 2.5 acres.

Problems of Estimation of Price Responsiveness

Thus different estimates of the price elasticity of demand for fertilizer are obtained from different methodologies. The wide discrepancy among the estimates raises questions about the usefulness of forecasting fertilizer demand based on any of these elasticities.

In fact, one should not place much confidence in any estimate of a price elasticity based on cross-section data for a particular year. It is preferable for the included values of the variables to show large variations in order to produce a reliable estimate of their relationship. Price variations among farms for a particular year are usually low, and the variations observed may partly be caused by reporting errors. The IFDC/BARC survey for 1979/80 found the coefficient of variation in urea prices among farms to be 4.0, 4.2, and 5.9 respectively for the Boro, Aus, and Aman seasons. This minor variation seems to be due to differences in the costs of transport to different locations.[39] For a particular locality the price variation among farms would be even lower. Only time-series data can ensure enough variability for an estimate of the parameter to be reliable.

There are, however, problems with accomplishing this using time-series data for an input like fertilizer, which has been sold at subsidized prices to ensure farmers a supernormal profit, thus

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[38]It is not clear why the NPK/paddy price ratio was used in equations for the seasons and not in the aggregate equation for all seasons. The survey found little variation in fertilizer prices paid by farmers (the coefficient of variation was only 4 to 6 percent) but a larger variation in paddy prices (9 to 33 percent). So the relative price variable would also have shown comparably large variations.

[39]BARC/IFDC, Agricultural Production, Fertilizer Use and Equity Considerations, 1979-80, p. 84.

encouraging its use. It is estimated that at producer prices for 1966/67, investment in fertilizer yielded a value-cost ratio of 8:1 for local varieties of rice, and 16:1 for HYVs, even with fertilizer applications as high as 120 nutrient pounds per acre.[40] Under these exceedingly favorable benefit-cost ratios, farmers are expected to use fertilizer on new land and raise application rates on already treated land even if the fertilizer-crop price ratio is substantially raised.

Also, during the first years of diffusion of this input, the application rate remains suboptimal because of the lack of knowledge about optimum doses and apprehension about the risk involved in using large increments of a new input. A rise in prices during this early period may thus accompany an increase in consumption because of the tendency on the part of the users to move from suboptimal to optimal input combinations, which by itself would shift the demand curve to the right

The fertilizer-crop price ratio has been raised almost continuously since 1972. The important question is whether the price ratio has now reached a level at which the cultivator earns only normal profits from the use of this input so that he is likely to respond to further price increases by cutting fertilizer purchases. A complementary question is whether farmers are sufficiently familiar with the new input so that the scope for further expansion of use through diffusion to currently unfertilized land and to farmers not yet using fertilizer is limited.

These are difficult questions to answer, and the answers depend not only on the output response to fertilizer use, which is discussed in the next section, but also on the risk involved in production, the degree of risk aversion among cultivators, the nutrient requirement of soils in different regions, and other agroclimatic factors.

After considering the output response to fertilizer use and the risk involved in production, BADC suggested that a nutrient-paddy price ratio of 2.0 may provide an adequate incentive to experienced users, but a price ratio of 1.5 may be too high for a new adopter or for further diffusion by users on marginal land.[41]

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[40] F. Kahnert et al., Agriculture and Related Industries in East Pakistan, Table 74, p. 424.

[41] See M. A. Jabbar, "Supply, Delivery System and Utilization of Chemical Fertilizers in Bangladesh," p. 40-41. This issue will be discussed further in the next section.

Table 18 shows that the fertilizer-paddy price ratio reached a level of 1.86 during the 1976/77 crop year. According to BADC's criterion, this is high enough that farmers could respond to further price increases by cutting consumption, or could find it uneconomical to apply fertilizer in high doses in locations characterized by a low output response to fertilizers.

There had been very little diffusion of fertilizer use on individual cereal crops since 1976/77. Thus 1976/77 through the present may be an appropriate temporal focus for estimating the current relationship between prices and fertilizer demand.

Fertilizer Demand Function--An Estimate from Pooled Time-series Cross-section Data

Since time-series data for 1976/77 to 1983/84 includes only eight observations, and one should use both price and nonprice shifter variables to estimate the demand function, the time-series data have been pooled with district-level cross-section data in order to achieve a reasonable number of degrees of freedom for estimating the parameters. The district-level data for 1983/84 are not yet available, so the study covers 1976/77 to 1982/83.

The consumption of fertilizer per acre of cropped land (Di) is taken as a proxy for demand. It is hypothesized to be a function of the following price and nonprice factors:

PRC_f = the price of urea per pound paid by the farmers in the district (Tk per maund of materials).

PRCp = the price of paddy expected by growers in the district approximated for period t by the price in period t-1 (Tk per maund).

IRGN = the area irrigated by modern methods as a percentage of total cultivated land in the district.

HYV = the area under HYV paddy as a percentage of sown area in the district.

RABI = the area under oilseeds, tobacco, and potatoes as a percentage of sown area.

WHT = the area under HYV wheat as a percentage of sown area in the district.

PADL = the area under local T. Aman and Aus paddy as a percentage of cropped land.

DRN = the area under deep water Aman and local Boro as a percentage of sown area.

IRGN, HYV, WHT, and RABI have been incorporated to capture the shift in demand from rapid increases in irrigation and area under HYV paddy, wheat, and other Rabi crops that require large amounts of fertilizer, the diffusion of fertilizer use on local varieties of paddy and Rabi crops, and also to capture the effect of large variations in these variables between districts. The DRN variable is used to represent particularly important agroecological factors: deep water Aman and local Boro are grown in low-lying areas on poorly drained and regularly silted land, upon which farmers typically use little fertilizer.

The consumption of fertilizer may also be constrained by its availability. During most of the period there was adequate stock at the national level. This, however, does not preclude the possibility of shortages at the district or farm levels.

In his chapter Quasem uses district data on monthly stocks and sales of fertilizer to show that PDP supply was rarely a problem up to 1983/84, at least for the low-consuming districts. In order to see whether there was a localized problem of supply he scanned press reports of abnormal price increases and fertilizer shortages published in the national newspapers since 1975 and listed the reported districts for the period up to 1983/84. This information has been used to construct a dummy variable (DUM) with an assigned value of 1 for each district reporting a shortage during each period. This dummy may be interpreted as a supply variable in the model.

It may also be argued that abnormal weather, such as droughts or excessive rain, may also affect fertilizer consumption. In order to see these effects, a rainfall variable (RAIN) has been incorporated into the equation. The observations for this variable have been calculated as the absolute difference of actual rainfall from normal rainfall in the district.

The data on farm-gate prices of fertilizer for different districts are available from IFDC surveys that monitored fertilizer and paddy prices since 1981. The BADC ex-PDP (issue) prices have been adopted for all districts for the period up to 1980/81. The IFDC surveys show that the farm-gate prices of fertilizer at survey locations were not much different from the corresponding ex-PDP prices and that price differences between districts were quite small. So the use of ex-PDP prices for all districts for earlier years may not normally introduce a significant distortion. The information on the growers' price of paddy for different districts is available from publications of the Bangladesh Bureau of Statistics.

The price of fertilizer relative to the price of the crop determines the profitability of fertilizer application. Since the effect of price may be asymmetric, both relative prices (PRC_f/PRC_p) and absolute prices have been used in separate equations. The use

of absolute prices as separate variables has the advantage that one can quantify the response of fertilizer use specifically to changes in crop prices.

Both the linear and the log-linear form of the model have been estimated using data for the entire 1976/77 - 1982/83 period, and for the shorter 1978/79 - 1982/83 period. The estimated parameters are presented in Tables 20 and 21. The linear form gives a much better fit to the data than does the log-linear form: for the 1978/79-1982/83 period the value of the adjusted R^2 is found to be 0.85 for the linear model, and 0.75 for the log-linear model. This result may be interpreted to indicate that farmers' response to a change in price depends upon the price from which it is changed. If the price elasticity of fertilizer demand were constant, the double log function would have given a better fit to the data.

When the dependent variable is measured in absolute terms of total tons of fertilizer sales in the district, and the explanatory shift variables are also measured in nonstandardized form (in thousand acres), rather than as proportions of cropped area in the district, the log-linear form gives a better fit to the data. The estimated parameters for this specification of the equation for the 1976/77 - 1982/83 period are presented in the last two columns of Table 21. The value of the adjusted R^2 was 0.88, and the estimated t-values for the price variables are larger; for several shifter variables such as IRGN, HYV, WHT, and DRN, the t-values were similar to those obtained for the linear form of the alternative specification.

As the results indicate, the price of fertilizer has a negative effect on fertilizer demand, while the price of output has a positive effect. The values of all price elasticities were found to be significantly different from zero. Listed below are four price elasticities of demand estimated from the coefficients of the linear equations and evaluated using the 1983/84 observations of the independent variables.

The elasticity of demand for fertilizer with respect to:	Using estimated values of the parameters from the equation for the periods: 1976-83	1978-83
Price of fertilizer	-0.48	-0.65
Price of paddy	0.32	0.51

The log-linear form gives an elasticity of -0.75 with respect to changes in fertilizer prices and 0.64 with respect to changes in output prices.

Table 20--Fertilizer demand functions, linear form, 1976/77-1982/83 and 1978/79-1982/83

Explanatory Variable	1976/77 - 1982/83		1978/79 - 1982/83	
	Equation 1	Equation 2	Equation 1	Equation 2
Constant	-35	-18	-114	-90
Price variables				
PRC_f	-0.219 (2.75)	...	-0.298 (3.66)	...
PRC_p	0.164 (1.17)	...	0.258 (2.01)	...
PRC_f/PRC_p	...	-20.54 (3.06)	...	-27.22 (3.67)
Nonprice variables				
IRGN	1.902 (9.02)	1.908 (9.03)	1.625 (7.90)	1.642 (8.04)
HYV	1.634 (9.49)	1.593 (9.34)	2.515 (9.32)	2.471 (9.29)
WHT	3.157 (5.15)	3.000 (5.02)	4.413 (6.44)	4.278 (6.40)
RABI	6.678 (6.44)	6.790	9.045 (7.81)	9.112 (7.92)
PADL	0.367 (3.29)	0.367 (3.29)	1.276 (5.48)	1.276 (5.51)
DRN	0.198 (1.16)	0.176 (1.03)	1.194 (4.21)	1.64 (4.14)
RAIN	-0.059 (1.53)	-0.064 (1.65)	-0.028 (0.68)	-0.035 (0.83)
Supply dummy	4.946 (1.54)	5.384 (1.65)	2.037 (0.66)	2.841 (0.93)
$\bar{R}^2$	0.80	0.80	0.85	0.85
F	57.8	63.8	61.7	68.8
N	145	145	105	105

Source: Estimates based on district-level data published by the Bangladesh Bureau of Statistics.

Notes: The dependent variable is the quantity of fertilizer materials used per acre of sown area (pounds). Figures within parentheses are estimated t-values.

Table 21--Fertilizer demand functions, log-linear form, 1976/77-1982/83 and 1978/79-1982/83

Explanatory Variable	Fertilizer Use Per Cropped Acre 1976/77-1982/83		Fertilizer Use Per Cropped Acre 1978/79-1982/83		Fertilizer Use in the District 1976/77-1982/83	
	Equation 1	Equation 2	Equation 1	Equation 2	Equation 1	Equation 2
Constant	0.84	1.24	0.73	0.66	6.29	5.76
Price variables						
PRC_f	-0.549	...	-0.639	...	-0.754	...
	(2.81)		(2.60)		(4.44)	
PRC_p	0.590	...	0.626	...	0.639	...
	(1.98)		(2.00)		(2.49)	
PRC_f/PRC_p	...	-0.538	...	-0.638	...	-0.787
		(2.86)		(2.61)		(4.80)
Nonprice variables						
IRGN	0.381	0.381	0.390	0.390	0.376	0.373
	(7.23)	(7.25)	(5.92)	(5.96)	(8.38)	(8.37)
HYV	0.404	0.406	0.468	0.468	0.470	0.463
	(6.88)	(7.02)	(5.80)	(5.90)	(10.24)	(10.31)
WHT	0.088	0.089	0.117	0.116	0.148	0.141
	(2.19)	(2.35)	(2.35)	(2.46)	(4.90)	(4.90)
RABI	0.461	0.456	0.396	0.398	0.313	0.325
	(5.00)	(5.13)	(3.29)	(3.46)	(4.34)	(4.64)
PADL	0.190	0.185	0.207	0.209	0.048	0.055
	(1.82)	(1.82)	(1.38)	(1.43)	(1.06)	(1.24)
DRN	-0.009	-0.009	0.007	-0.007	-0.085	-0.085
	(0.42)	(0.42)	(0.24)	(0.24)	(5.39)	(5.40)
RAIN	-0.062	-0.062	-0.018	-0.019	-0.048	-0.050
	(2.40)	(2.40)	(0.63)	(0.64)	(2.11)	(2.23)
Supply dummy	0.053	0.052	0.056	0.056	-0.327	-0.306
	(0.73)	(0.72)	(0.76)	(0.77)	(0.51)	(0.47)
$\bar{R}^2$	0.72	0.72	0.75	0.75	0.88	0.88
F	37.80	42.30	31.50	35.40	101.40	113.0

Source: Estimates based on district-level data published by the Bangladesh Bureau of Statistics.

Notes: The dependent variable is the quantity of fertilizer materials used (pounds) per acre of sown area. Values of all variables have been converted to their natural logarithms. Figures within parentheses are estimated t values of the regression coefficients. For equations where absolute fertilizer consumption in the district is taken as the dependent variable, the explanatory variables, IRGN, HYV, WHT, RABI, PADL, and DRN, are measured in absolute values of 1,000 acre units.

Implications of the Findings

To completely eliminate the subsidy, fertilizer prices have to be raised about 30 percent from the 1983/84 level.[42] The high estimate of price elasticity implies that a 30 percent increase in fertilizer prices from the 1983/84 level would reduce fertilizer consumption by about 22.5 percent. To offset this negative effect, the paddy price would have to be raised by about 35 percent, that is, to about Tk 5,427 per ton (Tk 203 per maund). Table 18 shows that the price of paddy during the July-September 1984 period was only about 3 percent below this. Thus, if output prices are maintained at this level, a reduction of the subsidy may have little effect on fertilizer consumption.

Factors other than price also appear to be important in determining fertilizer consumption. The regression coefficients associated with the proportion of area under modern irrigation, and the area under HYV paddy and wheat, are statistically significant in all specifications of the model. The values of the coefficients indicate that a 10 percent increase in the area under modern irrigation would increase fertilizer consumption by about 16 pounds per acre, while a 10 percent increase in the proportion of area sown with HYVs would increase consumption by about 25 pounds per cropped acre. Thus any decline in consumption in response to higher fertilizer prices could be compensated for by an increase in the area under modern irrigation or a change in the cropping pattern in favor of the HYVs.

Abnormal rainfall appears to have a negative effect on fertilizer demand, but the coefficient is found to be statistically significant only in the log-linear specifications. The coefficient estimated for the dummy variable representing supply shortage as reported in the press carries a perverse sign. This positive coefficient indicates that consumption was actually higher in districts where shortages of fertilizer were reported. Presumably the causal relationship works the opposite way than that postulated in the model: the increase in consumption leads to supply problems because of the lag in supply adjustments, rather than supply affecting consumption. The value of the coefficient, however, is not found to be statistically significant.

FERTILIZER USE AND FOODGRAIN PRODUCTION

One is not interested in the growth of fertilizer consumption per se. Fertilizer use assumes importance because of its contribution to the growth in food production in order that the country may

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[42]See Chapter 3, by Raisuddin Ahmed, Table 8.

be able to achieve food self-sufficiency within the shortest possible time. The important questions therefore are: What is the response of foodgrain production to variations in fertilizer use? What, then, would be the effect of an increase in fertilizer prices on the growth of foodgrain production?

Growth in Foodgrain Production and Productivity

The production of two major foodgrain crops, rice and wheat, increased from 8.9 million metric tons in 1960/61 to 15.7 million in 1983/84. The annual rate of population growth was about 3.0 percent during the sixties and 2.6 percent during the 1970/71 - 1983/84 period. Foodgrain production thus barely kept pace with the growth of population. With the passage of time, rising per capita demand for food from increasing incomes and the growing nonagricultural population widened the gap between domestic production and the demand for food. Modest growth in production was made possible mainly through spectacular growth in wheat production of about 16 percent per year (albeit from a small base) from the early seventies. Data for the last few years indicate that wheat production can no longer be expected to grow so rapidly. The long-term rice production growth rate was only about 2.0 percent per year. Unless this rate of growth is considerably accelerated, it will be difficult to achieve food autarky even by the end of the Third Five-Year Plan (in 1989/90).[43]

Recent trends in the growth of foodgrain production and productivity per unit of land are shown in Table 22. The production growth was very slow in the early seventies owing to economic disruptions caused by the War of Liberation in 1971 and successive years of abnormal weather up to 1974/75. Production, however, has grown at a respectable rate of 3.0 percent per year since 1975/76, partly due to an increase in cropped acreage since 1978/79, presumably through the expansion of modern irrigation facilities. But growth in yields has also accelerated, from about 1.3 percent per year in the early seventies to about 1.9 percent since 1975/76.

As noted earlier, fertilizer consumption also grew rapidly throughout the period. But what has been the contribution of rising fertilizer consumption to growth in food production? A simple answer may be obtained by relating yields to fertilizer use. The following relationships between these variables have been estimated using ordinary least squares:

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[43]It is projected that even if production grows at a rate of about 3.5 percent per year, the country would still need to import 0.7 - 1.0 million tons of food by 1989/90 (Hossain, "Increasing Food Availability in Bangladesh," p. 46).

Table 22--Trends in fertilizer use per hectare and in foodgrain production, area, and yields, 1969/70 to 1983/84

Period	Production of Cereals	Area Under Cereals	Yield	Fertilizer Use per Hectare
	(1,000 metric tons)	(1,000 acres)	(metric tons/ hectare)	(kgs/ hectare)
1969/70	12,107	10,440	1.16	21
1970/71	11,253	10,043	1.12	24
1971/72	10,044	9,429	1.07	21
1972/73	10,181	9,753	1.04	32
1973/74	12,018	10,006	1.20	31
1974/75	11,402	9,922	1.15	24
1975/76	12,979	10,484	1.24	37
1976/77	12,010	10,208	1.24	43
1977/78	13,316	10,221	1.18	58
1978/79	13,340	10,378	1.29	55
1979/80	13,561	10,598	1.28	66
1980/81	14,972	10,909	1.37	67
1981/82	14,595	10,998	1.33	64
1982/83	15,307	11,110	1.38	73
1983/84	15,706	11,099	1.42	84
Trend rates of growth				
1969/70 - 1975/76	1.48	0.17	1.31	7.5
1975/76 - 1983/84	2.98	1.13	1.86	8.8

Sources: Estimated from Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh (various issues); and Bangladesh Bureau of Statistics, Monthly Statistical Bulletin of Bangladesh (various issues).

$$Y = 984 + \underset{(0.62)}{5.28}\ F; \qquad R^2 = 0.86, \text{ and}$$

$$LnY = 647 + \underset{(0.025)}{0.172}\ LnF; \qquad R^2 = 0.79,$$

where

Y = cereal yields in kilograms per hectare,
F = fertilizer use in kilograms per hectare, and
Ln = natural logarithm.

The figures within parentheses are standard errors of estimate.

The result shows that about 86 percent of the variation in foodgrain yield for 1969-84 is explained by variations in fertilizer use. One unit of fertilizer application increases foodgrain output by an average of about 5.3 units. The elasticity of fertilizer use estimated from the log-linear form was 0.17, implying that in order to increase foodgrain output by 3 percent per year, other things remaining unchanged, fertilizer consumption would have to increase by about 18 percent per year. The elasticity of estimated output may, however, depend on the level of fertilizer application. Since the effects of other factors, such as irrigation and HYV seeds, on crop yield have not been taken into account, this estimate of the output elasticity of fertilizer use may be biased upwards, as it may contain the effects of other complementary inputs. It is necessary to disassociate those effects in order to estimate the pure effect of fertilizer use on foodgrain output.

Fertilizer Response

Fertilizer response can be estimated from the results of fertilizer trials done as experiments on selected farmers' plots in which different doses of fertilizers in different combinations are applied, holding all other factors constant at optimum levels. This gives the maximum yield that can be obtained using different amounts of fertilizers. The fertilizer response may, however, be lower under actual farming conditions, owing to low and unbalanced application, suboptimal management practices, adverse weather conditions, and inoptimal mixes of complementary inputs such as irrigation, labor, and pesticides.

Response Ratios from Experiments on Farmers' Fields

The following response functions have been estimated using results of fertilizer trials on farmers' fields, conducted by the Bangladesh Agricultural Research Institute (BARI) during 1982/83:

$$Y = f(F), \text{ and}$$
$$Y = f(\text{urea, TSP, MP}),$$

where

Y = yield per acre (in pounds), and
F = quantity of fertilizer nutrients used per acre (in pounds),

and urea, TSP, and MP are the quantities of these different types of fertilizer used per acre (pounds of nutrients). Data for 1982/83 are available only for HYVs of paddy and wheat. For local varieties, the response functions were estimated by the author for the Government of Bangladesh and USAID Joint Evaluation of the Fertilizer Distribution Project I, using experimental results from the early seventies.

The estimated response functions and their associated response ratios for different types of fertilizer are shown in Tables 23 and 24. The following major points can be seen in these figures: First, the coefficients of F^2 (in the quadratic form of the equation) are not significantly different from zero.[44] This indicates that, in general, fertilizer application rates could be further increased without a serious decline in marginal returns.[45] Second, one unit of fertilizer nutrient produces about 10 units of paddy on the margin for Aus, Aman, and wheat and about 9 units for Boro. The response ratio is found to be quite stable as shown by the comparison of estimates for 1982 and 1983. Third, the response ratios for local varieties and for HYVs are similar. Fourth, the standard error of the estimated response coefficient is lower for irrigated HYVs (Aus, Boro, and wheat) than for rainfed crops (local paddy and rainfed HYV Aman and wheat). This indicates that fertilizer application is more risky for the latter crops. Lastly, in general, returns to nitrogen application are higher than those for phosphate and potash application, except for wheat, where the response to phosphate application was found to be the highest. The output response to potash was found to be statistically insignificant for the irrigated crops of HYV Boro and wheat. It is positive for the rainfed crops but the estimated response coefficient is quite low.

At the 1983/84 full-cost price of fertilizer and procurement price of paddy, the number of units of paddy needed to buy one nutrient unit of fertilizer is estimated at 2.2 for urea, 3.0 for TSP, 1.7 for MP, and 2.4 for all types together. The estimated

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[44]The coefficients are found to be negative only for HYV Boro and wheat, but they were not statistically significant.

[45]The maximum rate of application of NPK on experimental plots is 200 pounds of nutrients per acre for HYV paddy, 180 pounds for HYV wheat, and 100 pounds for local paddy.

Table 23--Fertilizer response on experimental plots, based on findings from trials, 1972-83

Foodgrain	Period of Experiment	Response Functions Constant	F	$\bar{R}^2$
		(pounds/acre)		
High-yielding varieties				
Aus	1983	1,759	10.87 (0.65)	0.98
Aman	1983	2,002	10.76 (1.54)	0.87
	1982	1,870	10.73 (1.18)	0.92
Boro	1983	2,315	8.44 (0.52)	0.98
	1982	3,369	8.98 (0.64)	0.96
Wheat rainfed	1983	946	8.52 (1.19)	0.88
	1982	1,172	10.39 (1.10)	0.93
Wheat irrigated	1983	992	9.81 (1.10)	0.93
	1982	1,491	11.91 (0.78)	0.97
Local varieties				
Broadcast Aus	1972-75	1,229	11.85 (0.99)	0.96
Transplanted Aman	1972-75	1,441	11.93 (1.48)	0.88
Boro	1972-75	1,701	11.77 (1.81)	0.92

Sources: For HYVs, the estimates are computed from unpublished Bangladesh Agricultural Research Institute data; for local varieties, from Government of Bangladesh and U.S. Agency for International Development, Joint Evaluation of the Fertilizer Distribution Project (Dhaka, 1982), p. 45.

Note: The regression coefficient of F measures pounds of increased crop output per additional pound of fertilizer nutrient application. Figures within parentheses are standard errors of estimates.

Table 24--Response of crop output to various types of fertilizer: results from experiments on farmers' plots

Foodgrain	Maximum Rate of Application			Incremental Crop Yield per Pound of Nutrients Used		
	Urea	TSP	MP	Urea	TSP	MP
	(lbs. of nutrients/acre)			(lbs./acre)		
High-yielding varieties						
Aus	89	53	36	12.3	11.4	5.6
Aman	107	53	36	13.0	14.1	2.7
Boro	107	53	36	12.7	10.6	nil
Wheat rainfed	71	53	36	8.4	11.7	2.3
Wheat HYV	89	53	36	10.7	14.1	nil
Local varieties						
Aus	40	40	20	7.0	n.a.	n.a.
Aman	40	40	20	6.8	n.a.	n.a.
Boro	40	40	20	6.4	n.a.	n.a.

Source: For HYVs, the estimates are computed from unpublished Bangladesh Agricultural Research Institute data. Estimates for local varieties are based on data from Kazi M. Badruddoza, "Experience in Farmers' Fields--Fertilizer Trials and Use in Bangladesh," in S. Ahmed and S. Muhammad (eds.), Proceedings: First Review Meeting, I.N.P.U.T.S. Project (Honolulu: East-West Center, 1976).

Notes: Incremental output-fertilizer ratios for the HYVs have been estimated from the linear estimate of regression coefficients of the function $Y = f(U, T, M)$ where Y = yield per acre of land (pounds) and U, T, and M are the quantities of urea, TSP (triple superphosphate), and MP (muriate of potash) applied per acre of land in nutrient pounds. For local varieties the estimates are obtained by dividing the incremental yield from the control plots with the maximum amount of fertilizer used per acre. Where n.a. appears, the data were not available.

response ratios thus show that the returns from fertilizer use are attractive. The response ratio is about four times higher than the price ratio for urea and three times higher than that for TSP. For MP the output-input ratio is similar to the price ratio.

Fertilizer Response at Different Locations

The response functions have also been estimated for different locations of the country. The estimation of the quadratic NPK function shows a significantly negative coefficient for F^2 in a number of places for HYV Aus and wheat. Eleven out of 15 locations for which the NPK function of HYV Aus has been estimated give a negative coefficient for F^2, indicating declining marginal returns. For wheat this was obtained in 4 out of 13 locations.

The incremental output-fertilizer ratios estimated from these functions for NPK as well as for different types of nutrients for these locations are reported in the Appendix, Tables 49-52. The results show consistently high returns for urea (nitrogen), but extreme variation among locations for TSP (triple superphosphate) and MP (muriate of potash). The results indicate that a single recommended dose is not appropriate for the entire country and that considerable economic efficiency in fertilizer use can be achieved through developing appropriate recommended rates for different locations and passing this knowledge to farmers through effective extension services.

The distribution of sample locations according to the response for different types of nutrients appears in Table 25. High response locations are those with an output-to-input ratio of at least three times the break-even price ratio, while the low (and marginal) response locations are defined as those with an output-to-input ratio less than twice the break-even price ratio. About 81 percent of the locations showed a high response to nitrogen, compared to 45 percent to phosphate, and 49 percent to potash. The locations characterized by response coefficients even lower than the break-even price ratio comprised only about 6 percent of the sample for urea, but 19 percent for TSP and 32 percent for MP. There is evidence of polarization in the response to MP: most of the locations are characterized by either a very high or a very low response. The findings thus indicate the need to have regular fertilizer trials in different agroecological locations of the country to bring about greater efficiency in fertilizer use.

The Department of Agricultural Extension undertook a Fertilizer Demonstration and Distribution Project (1980-83) to study the efficiency of fertilizer use in different parts of Bangladesh. The

Table 25--Distribution of sample locations according to output response to different types of fertilizer

Response	Urea		TSP		MP		NPK	
	Number of Locations	Share of All Locations	Number of Locations	Share of All Locations	Number of Locations	Share of All Locations	Number of Locations	Share of All Locations
		(percent)		(percent)		(percent)		(percent)
Negative or marginal (less than 1.0)	5	6.4	15	19.2	25	32.1	3	3.9
Low (1.0-2.0)	1	1.3	20	25.6	8	10.3	9	11.5
Medium (2.0-3.0)	9	11.5	8	10.3	7	9.0	15	19.3
High (over 3.0)	63	80.8	35	44.9	38	48.7	51	65.4
Total	78	100.0	78	100.0	78	100.0	78	100.0

Sources: For HYVs, the estimates are from unpublished Bangladesh Agricultural Research Institute data; for local varieties, from Government of Bangladesh and U.S. Agency for International Development, Joint Evaluation of the Fertilizer Distribution Project (Dhaka, 1982), p. 45.

Note: The responses have been classified on the basis of the ratios (listed in parentheses) of the response coefficients to the break-even fertilizer-to-output price ratios (2.2 for urea, 3.0 for TSP [triple superphosphate], 1.7 for MP [muriate of potash], and 2.4 for NPK [nitrogen, phosphorus, and potassium]).

project covered 51 upazillas in 19 districts of the country. A total of 1,364 demonstrations were conducted in 1981 on HYV crops in three seasons. Yield responses were obtained from the following trials in which recommended doses of different types of nutrients (kilograms per hectare) were combined:

Trial Number	Nitrogen	Phosphate	Potash	Sulfur	Zinc
1	0	0	0	0	0
2	90	0	0	0	0
3	90	67	0	0	0
4	90	67	45	0	0
5	90	67	45	15	0
6	90	67	45	0	6

The results obtained for different upazillas and soil types have already been reported.[46] These data have been used to estimate the incremental yields per unit of the recommended dose of different nutrients for different districts and locations classified by soil types. The results are shown in Tables 26 and 27.

It is clear from Table 26 that the output response ratios to nutrient application are generally low in the low fertilizer consuming districts. Only for the Boro crop, which is grown during the dry season, is there a medium response to nitrogen and phosphate in these districts. The response to phosphate is found to be higher than that of nitrogen in the northern region (except Bogra) and the southwestern districts (Jessore and Kushtia). Again, large differences between districts and crops are found in the response to potash. The response is low in the Khulna division and in the districts of Chittagong and Noakhali but high in Mymensingh, Jamalpur, Kishoregonj, Comilla, and Dinajpur.

Among locations of different soil types, the nitrogen response was found to be low in gray soil areas of the nonsaline tidal floodplain and the Old Brahmaputra floodplain. Potash response was found to be very high in the Old and Young Brahmaputra floodplains on noncalcareous gray and brown soils, and also in the Comilla Basin and tidal floodplain areas with gray soil. But the response was negligible in the Surma-Kushiara floodplain (Sylhet) and the Madhupur tract.

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[46]Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," report of the Fertilizer Demonstration and Distribution Project, Dhaka, 1984 (mimeographed).

Table 26--Response of paddy yields to various nutrients in different districts, 1981/82

District	Nitrogen			Phosphate			Potash		
	Aus	Aman	Boro	Aus	Aman	Boro	Aus	Aman	Boro
	(response ratio)								
High-consuming districts									
Bogra	9.0	10.4	9.6	5.3	4.9	6.2	4.4	4.0	5.1
Chittagong	6.1	6.3	5.5	4.4	2.6	6.6	2.3	1.6	2.4
Comilla	4.5	7.5	5.9	5.0	7.5	10.5	7.3	4.8	8.5
Dhaka	5.2	6.5	8.7	5.7	5.7	6.1	11.8	1.8	8.9
Kushtia	13.1	8.7	4.4	20.3	8.2	10.7	nil	2.7	0.7
Medium-consuming districts									
Kishoreganj	nil	9.0	6.5	nil	5.7	9.8	nil	8.1	13.8
Tangail	3.8	7.3	6.7	5.3	4.3	7.5	11.2	5.0	1.4
Jamalpur	8.6	6.7	nil	6.3	3.0	nil	16.0	6.0	nil
Mymensingh	6.9	9.7	5.6	8.4	7.4	9.0	9.3	9.9	7.8
Rajshahi	nil	11.3	nil	nil	6.5	nil	nil	6.5	nil
Pabna	7.5	7.8	7.4	8.6	8.3	13.1	6.5	3.9	11.1
Dinajpur	4.0	10.6	nil	4.6	5.6	nil	8.2	8.6	nil
Rangpur	6.7	8.2	nil	7.3	5.2	7.8	2.9	2.9	nil
Jessore	5.8	9.3	5.0	9.0	12.0	10.4	2.9	3.1	1.7
Low-consuming districts									
Noakhali	4.6	4.4	6.3	6.9	7.8	2.3	6.8	0.7	1.8
Khulna	nil	10.5	6.2	nil	7.6	8.7	nil	1.7	2.2
Sylhet	3.8	3.4	5.3	4.2	2.5	8.0	9.7	1.5	5.6
Barisal	nil	3.6	3.9	nil	5.3	8.2	nil	3.0	1.9
Faridpur	4.0	6.7	7.2	5.9	6.7	8.7	6.5	5.0	4.7
Bangladesh	6.0	7.9	6.8	7.0	5.7	8.0	7.1	5.5	5.4

Source: Computed from Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," report of the Fertilizer Demonstration and Distribution Project, Dhaka, 1984 (mimeographed).

Table 27--Response of paddy yields to various nutrients in locations characterized by different soil types, 1981/82

Soil Map Code	Soil Classification	Number of Demon-strations	Incremental Yield per Kilogram of Nutrient: Nitro-gen	Phos-phate	Potas-sium
			(kilograms)		
2	Calcareous alluvium soil	12	15.5	4.2	5.8
5	Gray floodplain soil				
	(a,b) Testa-Jamuna floodplain	186	7.2	6.2	5.3
	(c) Nonsaline tidal floodplain	13	2.5	4.4	7.2
19	Gray terrace soil (Barind tract)	16	14.0	4.0	3.8
18	Red-brown terrace soil (Madhupur tract)	35	5.7	11.0	nil
6	Gray and noncalcareous brown floodplain soils (Testa)	61	9.1	3.8	4.0
8	Gray and noncalcareous dark gray floodplain soils				
	(c) Young Brahmaputra floodplain	76	8.2	8.3	10.7
	(d) Old Brahmaputra floodplain	58	8.9	4.9	5.6
	(e) Old Meghna estuarine	78	6.3	7.8	3.4
9	Gray floodplain and acid basin soils				
	(a) Surma-Kushiyara floodplain	32	4.6	4.5	nil
	(b) Comilla basin	36	5.6	7.4	7.3
10	Gray piedmont soil	120	5.0	5.6	3.5
13	Calcareous gray and brown soils	313	6.9	8.9	3.0
15	Noncalcareous gray and brown soil				
	(a) Old Himalayan piedmont plain	42	8.2	5.2	8.9
	(b) Old Brahmaputra floodplain	18	2.5	6.3	10.1

Source: Computed from Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," report of the Fertilizer Demonstration and Distribution Project, Dhaka, 1984 (mimeographed).

Deficiency of Micronutrients

The low response of paddy yields to the major nutrients is attributed by many agricultural scientists to deficiencies of sulfur and zinc.[47] It is argued that the practice of using crop residues for fuel, the diminishing application of organic manures, and leaching and erosion of soils have contributed to rapid depletion of sulfur and micronutrients such as zinc. The problems have been accentuated over the last decade by an increase in the cropping intensity, rapid diffusion of HYVs, and inappropriate application of chemical fertilizers.

The incremental paddy yields per unit of zinc and sulfur application, as estimated from the yield response data of the Department of Agricultural Extension for different districts and soil types, are reported in Tables 28 and 29. The figures show widespread deficiencies of zinc and sulfur in the soils of Bangladesh. Sulfur deficiency was found to be more typical in the soils of northern (except Rajshahi) and central (except Kishoregonj and Sylhet) districts than of the coastal areas. However, there is no apparent correlation between soil type and sulfur deficiency.

Zinc deficiency appears to be even more widespread than that of sulfur. This deficiency is more pronounced in the deeply flooded areas and the coastal belt than among the well-drained soils. The results also suggest that the low response to fertilizer in the tidal floodplain soils of Barisal and Patuakhali and on calcareous soils of Jessore and Khulna may be due, at least in part, to zinc deficiency. For most locations, the response ratios are high compared to the break-even nutrient-paddy price ratio. Thus, marginal investment to facilitate more widespread application of these micronutrients may bring about a significant increase in the response of output to the major nutrients.

Fertilizer Response in Actual Farm Conditions

Fertilizer response under actual farming conditions was estimated by IFDC from its farm survey data for the major crops. The response was obtained by fitting a production function in which explanatory variables included the use of fertilizer and other inputs such as labor, pesticides, farm assets, irrigation, and HYVs. For fertilizer, the model specification included the quantity of NPK (F) used per acre and its quadratic term (F^2) to allow for a nonlinear relationship between crop yield and the quantity of fertilizer. The

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[47]See Chapter 5, by S. M. H. Zaman.

Table 28--Yield responses of paddy to zinc and sulfur applications in locations characterized by different soil types, 1981/82

Soil Map Code	Soil Type	Incremental Paddy Yield per Kilogram of Nutrient: Zinc	Sulfur
		(kilograms)	
2	Calcareous alluvium soil	59	...
5	Gray floodplain soil		
	(a) Testa-Jamuna floodplain	59	29
	(c) Jamuna-Korotowa floodplain	70	28
	(e) Nonsaline tidal floodplain	198	nil
6	Gray and noncalcareous brown floodplain soils		
	(a) Testa floodplain	61	33
8	Gray and noncalcareous dark gray floodplain soils		
	(a) Young Brahmaputra floodplain	37	50
	(b) Old Brahmaputra floodplain	35	15
	(e) Old Meghna estuarine	49	30
9	Gray floodplain and acid basin soils		
	(a) Surma-Kushiyara floodplain	24	6
	(b) Comilla basin	36	32
10	Gray piedmont soil	59	12
12	Noncalcareous dark gray floodplain soil	61	29
13	Calcareous brown and gray floodplain soils	70	32
15	Noncalcareous brown and gray soils		
	(a) Old Himalayan piedmont plain	45	34
	(b) Old Brahmaputra floodplain	82	39
18	Red-brown terrace soil (Madhupur tract)	13	26
19	Gray terrace soil (Barind tract)	75	6

Source: Computed from Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," report of the Fertilizer Demonstration and Distribution Project, Dhaka, 1984 (mimeographed).

Note: These can be compared to the break-even nutrient-paddy ratio, which is about 2.5 for sulfur and 4.0 for zinc.

Table 29--Yield responses of paddy to zinc and sulfur applications in different regions, 1981/82

District	Zinc			Sulfur		
	Aus	Aman	Boro	Aus	Aman	Boro
	(lbs. of paddy/lb. of nutrient)					
High-consuming districts						
Bogra	22	62	39	37	30	28
Chittagong	46	68	61	5	9	7
Comilla	29	33	58	26	26	30
Dhaka	69	63	50	28	18	20
Kushtia	83	63	120	26	58	37
Medium-consuming districts						
Kishoreganj	nil	33	88	nil	7	37
Tangail	30	67	53	38	26	31
Mymensingh	54	44	41	37	40	34
Jamalpur	neg	66	nil	25	28	nil
Rajshahi	nil	85	nil	nil	9	nil
Dinajpur	38	49	nil	24	37	nil
Pabna	86	66	117	29	19	43
Rangpur	60	70	nil	52	28	nil
Jessore	54	103	113	33	37	49
Low-consuming districts						
Noakhali	27	92	27	46	20	50
Sylhet	33	33	36	31	7	10
Khulna	nil	92	nil	nil	36	nil
Barisal	nil	137	102	nil	5	14
Faridpur	66	44	80	30	40	40
Bangladesh	44	82	66	31	26	28

Source: Computed from Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," report of the Fertilizer Demonstration and Distribution Project, Dhaka, 1984 (mimeographed).

Note: These can be compared with the break-even nutrient-paddy price ratio, which is about 2.5 for sulfur and 4.0 for zinc.

constant term in the fertilizer response function was estimated from the coefficients of the production function for the nonfertilizer variables, evaluated at their arithmetic means. The function was fitted to the farm data for 1979/80 and plot data for 1980/81 and 1981/82.

The estimated functions are reported in Table 30. For foodgrain crops, a linear relationship between fertilizer use and crop yields achieves the best fit in most cases, indicating that marginal returns are constant even at high levels of use. The coefficient of the quadratic term is significantly negative only for Boro season crops, showing that the marginal return declines with greater fertilizer application in the vicinity of current levels of use. Thus, the typical farmer is likely to cut fertilizer consumption in response to higher fertilizer prices only if he grows these crops.

As expected, the response ratios under actual farming conditions are much lower than those reported for experimental plots. The coefficient from the estimated fertilizer response function for F shows the output response to fertilizer application, except for equations with negative F^2 coefficients, for which the output response at the mean levels of fertilizer use is shown within parentheses. The response ratio is found to be high for almost all foodgrain crops for at least one of the three years but not necessarily for all years. The average response ratio for all foodgrains taken together is estimated to be only 4.3 units of paddy per unit of nutrient, which is less than half of that obtained by BARI from fertilizer trials on farmers' fields and about 60 percent of that found in the Fertilizer Demonstration Project. The responses may be low because of inappropriate and unbalanced application of different nutrients, inappropriate timing and method of application of fertilizer (basal versus top dressing), reduction of crop yield from drought, pest attack, or failure to clear weeds in time. In Chapter 5 Zaman argues that these factors seriously affect the efficiency of fertilizer use.

Benefit-cost ratios at the prevailing (July-August 1984) farm-gate prices of NPK and foodgrain crops, estimated using the average response ratio for the three years, are reported in Table 31. The exercise also used the minimum response-ratios, as subsistence farmers may be risk averse and may make their decisions on the basis of the assured return from fertilizer rather than the expected average return. The weighted average benefit-cost ratio comes to 2.5 for foodgrain crops at the present price and about 2.1 at the price of 1982/83 when the fertilizer-crop price ratio reached its peak. At the minimum response ratio, the benefit is found to be only marginally higher than the cost.

What would be the effect of the estimated change in fertilizer consumption on foodgrain output? To answer this question, it is necessary to calculate the output elasticity of fertilizer consump-

Table 30--Estimates of fertilizer response under farmers' operating conditions from IFDC/BARC surveys, 1979/80 - 1981/82

Crop	1979/80			1980/81			1981/82		
	Constant	F	F^2	Constant	F	F^2	Constant	F	F^2
Local T. Aman	16.42	1.95	...	22.05	4.52 (3.92)	-1.17	18.64	4.37	...
HYV T. Aman	19.20	2.46	...	29.02	3.77	...	25.36	6.00	...
Local Boro	18.35	7.53 (7.12)	-2.39	22.01	3.36	...	19.27	13.73	...
HYV Boro	31.37	4.37 (2.53)	-0.59	29.07	10.13 (5.62)	-1.51	34.72	4.07	...
Wheat	12.63	2.08	...	3.36	1.92	...	1.29	3.76 (3.17)	-0.42
Local Aus	16.45	3.33	...	10.26	11.90	...	12.46	1.32	...
HYV Aus	28.52	5.52	...	20.15	4.47	...	20.46	12.75 (6.75)	-2.74
Jute	14.66	2.21	...	14.07	4.16 (3.73)	-1.07	15.26	8.19	-1.56 (7.57)
Potatoes	58.27	17.97	...	38.50	21.00 (19.98)	-0.50	53.38	18.10 (15.86)	-0.92
Oilseeds	3.85	1.50	...	5.57	0.72	...	5.99	6.91 (5.28)	-1.22

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984), p. 101 (1982) and p. 183 (1984).

Note: Figures within parentheses show the estimated response ratios at mean fertilizer application.

Table 31--Estimated benefit-cost ratios for fertilizer use at prices of fertilizers and foodgrain crops prevailing in July-August 1984

Crop	Average Rate of Application	Response Ratio		Incremental Yield		Benefit-Cost Ratio	
		Minimum	Average	Minimum	Average	Minimum	Average
	(lbs./acre)			(lbs./acre)			
Local paddy							
Aus	16	1.3	5.5	21	88	0.8	3.2
Aman	21	2.0	3.6	42	76	1.2	2.1
Boro	17	3.4	8.1	58	138	2.0	4.7
HYV paddy							
Aus	86	4.5	5.6	387	482	2.6	3.2
Aman	77	2.5	4.1	193	316	1.4	2.4
Boro	133	2.6	4.1	346	545	1.5	2.4
Wheat	57	1.9	2.4	108	137	1.1	1.4
All crops[a]	40	2.1	4.3	84	172	1.2	2.5

Source: Based on data found in IFDC/BARC survey reports appearing in Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Notes: The benefit-cost ratio has been estimated using the farm prices of paddy prevailing during July-August 1984, and the ex-PDP prices of fertilizers for July to December 1984. The response ratios are based on survey data for 1979/80, 1980/81, and 1981/82.

[a]Weighted by the proportion of total sown area under the indicated crop variety, except for the response ratio, which is weighted by the proportion of total production under the crop.

tion. Table 32 gives the estimate of this output elasticity based on the average response ratio, and the yield and fertilizer application rates for 1981/82, as estimated from the IFDC/BARC survey. The estimated elasticities are low for local varieties of paddy, in the range of 0.05 to 0.08, but are quite high for HYVs, varying from 0.16 to 0.22. The weighted average elasticity for all foodgrain crops is estimated to be 0.1, which indicates that a 10 percent reduction in fertilizer nutrient consumption, all other variables remaining constant, would reduce foodgrain yield by about 1 percent.

Farm Budget and Fertilizer Cost

The effect of the change in fertilizer prices on food production may also depend on the importance of fertilizer in the total cost of production. If fertilizer cost is a low proportion of the total, even a large percentage increase in fertilizer prices may not have a severe effect on the cost of production. Hence the response of farmers may also be low. Also, if fertilizer is complementary to a whole package of inputs, other inputs in the package give a high return, and the cost is low in proportion to the cost of other inputs, the increase in fertilizer prices may be absorbed by farmers.

The estimated total cost of production per acre of land (including family labor but excluding rent) and the cost of material inputs (seed, fertilizer, water, pesticides) at 1982/83 prices are shown in Table 33. Fertilizer accounts for only about 9 percent of the total cost of production, 2-8 percent for local varieties, and 10-15 percent for HYVs.

Most of the cultivators in Bangladesh are, however, smallholders who generally supply labor and draft power from within the family. So they may be more concerned with the cost of material inputs, which approximates their cash cost of production. Fertilizer cost is a sizable proportion of the cost of material inputs. It is nearly one-third for all foodgrains taken together and more than 50 percent for both local and HYV Aman. Thus, if farmers respond specifically to the cash cost, rather than the total cost, of production, then a large percentage increase in fertilizer prices is likely to be a matter of considerable concern for them.

RESPONSE OF SMALL FARMERS

Agriculture in Bangladesh is dominated by small producers. According to the 1982 Pilot Agricultural Census, about 29 percent of the total land is in holdings of less than 2.5 acres. During the period 1960-82 the proportion of small farms increased by 16 percent, while the average size of smallholdings declined from 0.94 to 0.87

Table 32--Estimates of the elasticity of foodgrain output to changes in fertilizer use, 1981/82

Foodgrain	Average Yields	Fertilizer Consumption	Marginal Returns to Use of Fertilize s	Estimated Elasticities
	(lbs./acre)	(nutrient lbs./acre)	(lbs. of output/lb. of fertilizer)	
Local paddy				
Aus	1,450	16	5.5	0.06
Aman	1,393	21	3.6	0.05
Boro	1,803	17	8.1	0.08
HYV paddy				
Aus	2,165	86	5.6	0.22
Aman	2,271	77	4.1	0.14
Boro	3,417	133	4.1	0.16
Wheat	1,275	57	2.4	0.11
All crops[a]	1,726	40	4.3	0.10

Source: Estimates based on figures from Tables 6 and 31, and crop yield and price information published by the Bangladesh Bureau of Statistics, Monthly Statistical Bulletin of Bangladesh (various issues).

[a]Weighted by the proportion of total sown area under the indicated crop varieties.

Table 33--Share of fertilizer cost in farm budget, 1982/83

Foodgrain	Cost of Production Per Acre		Cost of Fertilizer		
	All Inputs	Material Inputs	Total Per Acre	Share of Total Cost	Share of Material Input Cost
	(Tk)		(percent)		
Local paddy					
Aus	1,419	248	58	4.1	23.4
Aman, broadcast	1,214	212	40	3.3	18.9
Aman, transplanted	1,219	152	91	7.5	59.9
Boro	2,858	1,286	63	2.2	4.9
HYV paddy					
Aus	2,534	922	315	12.4	34.2
Aman	1,939	552	279	14.4	50.5
Boro	3,894	2,080	490	12.6	23.6
Wheat	1,834	849	200	10.9	23.6
All crops[a]	1,740	512	150	8.6	29.3

Source: The estimates of costs of production are from Mahabub Hossain, "Increasing Food Availability in Bangladesh: Constraints and Possibilities," Food Strategy Review Exercise Technical Paper A (prepared for the Ministry of Agriculture and Forests and the International Labour Organisation), Bangladesh Institute of Development Studies, Dhaka, April 1984.

Note: The total cost of production includes the cost of family labor but excludes the cost of land. The cost of fertilizer has been calculated using fertilizer consumption data for 1981/82.

[a]Weighted by the proportion of total sown area under the crop.

acres,[48] indicating a growing trend toward landlessness. Small farmers produce mainly for their own consumption and have very little surplus production (over household consumption) to invest in a purchased input like fertilizer. They may also suffer from liquidity problems as they have limited access to institutional credit markets (see Table 15). The increase in fertilizer prices would hurt them most, as they gain little from any increase in crop prices. Thus, policymakers in Bangladesh must concern themselves with the special problems of small farmers.

National time-series data on fertilizer use by different farm size groups are not available. A few microstudies are available that show no systematic variation in fertilizer use among different sizes of farms. Some present evidence that small farmers actually use somewhat more fertilizer per acre of land than do larger landholders. Since none of these microstudies covers the same locality at different times, the results cannot be used to assess the response of the small farmers to changes in fertilizer prices.

The first national surveys to cover the equity issue in fertilizer use are the IFDC/BARC surveys. Since the results are available for three years from 1979/80 to 1981/82, when fertilizer prices were raised by about 40 percent, the findings can be used to compare the behavior of the small farmers and larger landholders (see Table 34). Such a comparison shows that, first, the fertilizer/crop price ratio for small farms is, in general, higher than that for large farms, but the difference is slight. Second, marginal and small farms use more fertilizer per acre than do larger farms, particularly during the Boro season, when the fertilizer-intensive crops are grown. Compared to larger farms, the marginal farms used 29 percent more fertilizer per acre during the Boro season in 1979/80, 35 percent more in 1980/81, and 79 percent during 1981/82.

Third, in spite of the increases in fertilizer-to-crop price ratios, fertilizer use did not decline over this three-year period. In fact, the application rate increased by about 30 percent for the Boro season, 9 percent for the Aus season, and 21 percent for the Aman season.

Lastly, the increase in fertilizer use was actually greater for the small and marginal farms. For Boro season crops, the increase in consumption over this period was 56 percent for marginal farms and 32 percent for small farms, compared to only 12 percent for the large farms.

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[48]Bangladesh Bureau of Statistics, Report on Bangladesh Pilot Agriculture, 1982 (Dhaka: BBS, 1983); and Government of Pakistan, 1960 Pakistan Census of Agriculture (Karachi: Agricultural Census Organization, 1962).

Table 34--Fertilizer use by different farm-size groups, 1979-82

Season	Marginal Farms	Small Farms	Medium Farms	Large Farms	All Farms
Urea/paddy price ratio					
Boro, 1979/80	0.92	0.88	0.86	0.86	0.88
Aus, 1980	0.99	0.99	0.98	1.05	1.00
Aman, 1980	0.92	0.93	0.92	0.89	0.92
Boro, 1980/81	1.11	1.09	1.06	1.08	1.09
Aus, 1981	1.11	1.12	1.10	1.14	1.11
Aman, 1981	0.99	0.97	0.92	0.92	0.96
Boro, 1981/82	1.04	1.03	1.03	1.03	1.03
Aus, 1982	1.12	1.07	1.02	1.02	1.04
Fertilizer consumption					
		(lbs. of materials/acre)			
Boro, 1979/80	117	100	78	91	98
Aus, 1980	70	60	56	67	58
Aman, 1980	68	63	69	65	66
Boro, 1980/81	127	95	84	94	100
Aus, 1981	69	65	82	69	72
Aman, 1981	75	80	86	77	80
Boro, 1981/82	183	132	130	102	127
Aus, 1982	74	58	66	60	63

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984)

Notes: Marginal farms have 1.0 acres or less. Small farms have between 1.0 and 2.5 acres. Medium farms have between 2.5 and 5.0 acres. Large farms have 5.0 acres or more.

These findings are, however, for the season as a whole, and hence changes in nonprice factors such as area under irrigation and cropping pattern might also have contributed to the change in fertilizer consumption. The survey indeed shows that the area under irrigation increased from 35 to 44 percent of the cropped land in the Boro season over this period, and the proportion of area under HYVs increased from 21 to 32 percent for the Aman season and from 16 to 21 percent for the Aus season.[49] Data on fertilizer consumption by crop for different groups of farms are needed for a conclusive assessment of the response of small farmers to changes in fertilizer prices. The results of the IFDC/BARC survey are not reported in this form.

Fertilizer consumption by crop for different farm sizes and tenurial groups is reported in a study by Quasem and Hossain.[50] The survey was conducted in two villages of Dhaka District during 1977/78. Since fertilizer prices were raised about 160 percent between 1977/78 and 1983/84, the authors decided to survey the villages again in order to collect data on fertilizer consumption at the farm level for 1983/84 and study the response of different groups of farmers to this rapid increase in prices.

The villages differ in their topography, soil type, and infrastructural facilities. Chandra Village is in a flood-free highland area, located in the red-terrace soil region of the Madhupur Tract. The other village, Banguri, is in a flood-affected area where the soil is loam or clay-loam. Chandra has good road communications with the upazilla headquarters, Kaliakoir, whereas Banguri is remote, about six miles away from a bitumen-paved road. During the 1977/78 survey, information was collected from 50 cultivator households from each village, selected by a stratified random sampling method from a census of all households in the village. During the course of the present study, information was collected from all cultivator households in the villages.

Table 35 shows the diffusion of fertilizer consumption over the 1977/78 to 1983/84 period, among farms of different sizes in these two villages. About 85 percent of the cultivators used fertilizers in 1977/78: among small farms the proportion was 60 percent in Chandra and 81 percent in Banguri. During 1983/84 almost all cultivators used fertilizer. The proportion of land treated with

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[49]BARC/IFDC, Agricultural Production, Fertilizer Use and Equity Considerations, 1979-80, p. 39; BARC/IFDC, Agricultural Production, Fertilizer Use and Equity Considerations, 1980-82, p. 59. See also Chapter 1 in this volume, by Gunvant M. Desai, Tables 5-10.

[50]M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh."

Table 35--Diffusion of fertilizer consumption by farm size in Chandra and Banguri villages, 1977-84

Village/ Landholding Group	Percentage of Cultivators Using Fertilizer		Percentage of Land Treated with Fertilizer		
	1977/78	1983/84	1977/78	1983/84	Change
Chandra					
Small	60.0	98.0	63.5	92.6	29.1
Medium	100.0	97.1	89.5	86.2	-3.3
Large	100.0	100.0	75.3	87.4	12.1
All cultivators	85.0	98.1	83.8	88.5	4.7
Banguri					
Small	80.9	100.0	46.6	80.7	34.1
Medium	86.7	100.0	53.1	81.3	28.2
Large	90.0	100.0	55.8	77.4	21.6
All cultivators	83.6	100.0	51.9	80.3	28.4

Sources: M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979); and 1984 field survey.

fertilizer in 1983/84 was about 89 percent in Chandra and 80 percent in Banguri. The increase over the period was only 5 percent in Chandra, but 28 percent in Banguri, where only about 52 percent of the land was treated in 1977/78. The diffusion was more rapid on small farms--the proportion of land treated increased by 29 percent in Chandra and by 34 percent in Banguri, compared with 12 and 22 percent, respectively, for the larger farms.

The diffusion of fertilizer use on major crops grown in these two villages is shown in Table 36. The proportion of area fertilized increased in the case of mustard, wheat (a new crop in the area) and mixed Aus-Aman (grown on lowlands during the monsoon season), on which little fertilizer was used in 1977/78. There can be further diffusion on jute and local Aus and Aman paddy, but the area under these crops treated with fertilizer did not increase over this period. Fertilizer application rates declined over the period, however, for HYV paddy and jute. They remained constant for local Aus and increased for local Aman, wheat, and mustard.

Table 36--Fertilizer use by crop in Chandra and Banguri villages, 1977/78 and 1983/84

Village/ Crop	Percentage of Land Fertilized		Amount of Fertilizer Used Per Cropped Acre		Amount of Fertilizer Used Per Acre of Treated Land	
	1977/78	1983/84	1977/78	1983/84	1977/78	1983/84
			(lbs. of materials)			
Chandra						
HYV	100.0	96.4	254	221	245	221
Local Aus	79.6	78.3	72	72	91	92
Local transplanted Aman	87.6	82.2	74	118	84	144
Mustard	...	35.8	...	54	...	150
Banguri						
Aus/broadcast Aman	6.9	61.1	8	51	116	84
HYV	100.0	100.0	407	264	407	264
Jute	74.0	60.6	105	44	142	72
Mustard	90.8	100.0	212	296	233	296
Wheat	...	98.4	...	237	...	241

Source: M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979); and 1984 field survey.

Changes in fertilizer consumption per acre of cropped land on different sizes of farms during this period are shown in Table 37. In Chandra, about 82 percent of total fertilizer use was on HYV paddy, while in Banguri about 37 percent was used on HYV paddy and 39 percent on mustard. The rate of fertilizer application on HYV paddy cultivated on small farms, in fact, declined over the period by about 15 percent in Chandra and by 40 percent in Banguri (where the application rate on this crop was high in 1977/78). Small farms also reduced fertilizer application in local Aus by 36 percent and on jute by 65 percent. Application also declined on medium and large holdings. The application rates increased only for mustard and local transplanted Aman. For mustard, rates increased about 80 percent on small farms and 15 percent on larger farms.

In spite of the reduction in fertilizer application rates on the major crops, fertilizer consumption per acre on all crops taken together increased over the period for all groups of farms (Table 38). The increase for small farms in Chandra was about 91 pounds per

Table 37--Changes in fertilizer use by farm size on various crops in Chandra and Banguri villages, 1977/78 and 1983/84

Village/ Crop	Small Farms		Medium Farms		Large Farms	
	1977/78	1983/84	1977/78	1983/84	1977/78	1983/84
	(lbs. of materials/cropped acre)					
Chandra						
HYV paddy	239	202	215	208	217	255
Local Aus	99	63	79	91	102	68
Local trans-planted Aman	92	119	91	116	70	119
Mustard	...	40	...	46	...	62
Banguri						
Mixed Aus-Aman	11	41	11	60	nil	59
HYV paddy	431	260	353	269	477	262
Jute	108	38	98	51	113	42
Mustard	170	306	208	290	244	281
Wheat	...	253	...	221	...	223

Sources: M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979); and 1984 field survey.

Table 38--Changes in fertilizer use by farm size on total cropped land in Chandra and Banguri villages, 1977/78 and 1983/84

Village/ Landholding Group	Fertilizer Used		
	1977/78	1983/84	Change
	(lbs. of materials/cropped acre)		
Chandra			
Small	76	167	91
Medium	96	173	77
Large	86	184	98
Banguri			
Small	97	178	81
Medium	119	171	52
Large	134	171	37

Source: M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979); and 1984 field survey.

acre of cropped land, and 81 pounds in Banguri, compared to 98 and 37 pounds, respectively, for large farms in the two villages. The proportionate increase in fertilizer use was greater on small farms in Banguri, where nearly half of the land was not treated with fertilizer in 1977/78.

It may appear anomalous that application rates on several individual crops declined, while rates on all crops (as a whole) increased. But this apparent inconsistency can be explained in terms of changes in cropping patterns (Table 39). The proportion of area under HYV paddy and mustard (on which more than 200 pounds of fertilizer materials are now used per acre) increased substantially over the period, at the expense of the crops receiving little fertilizer application, such as local Aus and Aman in Chandra, and mixed Aus-Aman (deep-water paddy) in Banguri. For small farms, the area under HYV paddy in Chandra increased from 25 percent of the cropped area in 1977/78 to about 70 percent in 1983/84. In Banguri, the area under HYV paddy and mustard increased from 24 percent in 1977/78 to 47 percent in 1983/84. The proportionate increase in area under these highly fertilizer-intensive crops was greater on small farms.

A comparison of the efficiency of fertilizer use on different sizes of farms may be of interest. Some evidence may be obtained by examining the applied balance of different types of fertilizer materials on various groups of farms. These findings for the two village surveys are reported in Table 40. Contrary to expectations, farmers tend to use more TSP on mustard and wheat. As indicated in an earlier section, the estimated output response in the case of wheat was greater for TSP application than for urea. TSP is used in relatively balanced doses on most crops, with the exception of local paddy varieties. Only MP was used in considerably lower proportions than recommended. This is understandable in view of the low yield response reported earlier. In one of the villages, the small farmers used proportionately more TSP (relative to urea) than did operators of larger farms. In the other village there was no significant difference. Thus, the hypothesis that small farmers are less efficient in using fertilizer than operators of larger farms is not supported by the survey data from Chandra and Banguri.

Table 41 presents the survey findings on the share of different groups of farms in total fertilizer consumption. During 1983/84 small farmers comprised more than two-thirds of all cultivators and controlled nearly one-fourth of the cultivated land in Chandra and two-fifths in Banguri. Their share of total fertilizer use in the village is sizable: 31 percent in Chandra and 43 percent in Banguri. That share is now slightly greater than their share of cultivated land. The share of small farms in total fertilizer use increased rapidly over the period. Thus, the small farmers do benefit from fertilizer subsidy.

Table 39--Changes in cropping patterns by farm size in Chandra and Banguri villages, 1977/78 and 1983/84

Village/Type of Farm/Crop	Small Farms		Medium Farms		Large Farms	
	1977/78	1983/84	1977/78	1983/84	1977/78	1983/84
	(percent of total cropped land)					
Chandra						
Owned Farms						
Local Aus	38.1	16.7	38.2	7.6	28.7	24.0
Local Aman	42.8	13.8	41.1	18.1	49.2	13.3
HYV paddy	8.2	67.3	14.1	68.7	14.8	53.7
Mustard	...	1.8	...	3.2	...	5.1
Jute	10.7	0.5	6.5	2.3	7.3	1.1
Other	...	...	...	...	...	2.6
Tenant Farms						
Local Aus	29.3	12.4	26.3	15.1	20.4	12.7
Local Aman	42.4	13.1	47.3	16.4	75.5	9.6
HYV paddy	28.3	72.3	26.5	66.9	4.1	73.1
Mustard	...	1.6	...	1.4	...	3.2
Jute	...	0.5	...	0.3	...	1.5
Other	...	...	...	...	...	...
Banguri						
All farms						
Mixed Aus/Aman	50.2	19.2	37.4	19.0	39.4	11.9
HYV paddy	8.6	22.2	15.5	22.4	7.7	32.0
Mustard	15.9	24.8	17.3	23.0	22.5	19.6
Wheat	...	10.5	...	19.5	...	6.7
Jute	25.3	19.4	29.7	19.2	30.3	20.5
Other	...	3.9	...	6.9	...	9.2

Sources: M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979); and 1984 field survey.

Table 40--Proportion of urea, TSP, and MP used on major crops, by farm size, Chandra and Banguri villages, 1983/84

Village/Crop	Small Farms		Medium Farms		Large Farms	
	TSP	MP	TSP	MP	TSP	MP
	(proportion of the quantity of urea applied)					
Chandra						
Local Aus	0.39	0.05	0.57	0.04	0.48	nil
Local Aman	0.71	0.06	0.86	0.03	0.50	0.04
HYV paddy	0.80	0.13	0.86	0.15	0.86	0.22
All crops	0.76	0.12	0.84	0.12	0.78	0.19
Banguri						
Mixed Aus/Aman	0.29	0.06	0.45	0.09	0.29	nil
HYV paddy	0.90	0.32	0.96	0.32	0.86	0.29
Wheat	2.03	0.41	1.73	0.37	1.36	0.30
Mustard	1.04	0.31	1.03	0.34	0.93	0.32
All crops	0.95	0.28	0.92	0.29	0.87	0.27

Note: The recommended proportions for HYV paddy are 1.0:0.76:0.48 and for local paddy, 1.0:1.0:0.38. TSP is triple superphosphate; MP is muriate of potash.

Table 41--Share of different sizes of farms in land cultivated and fertilizer consumption, Chandra and Banguri villages, 1977/78 and 1983/84

Village/Size of Farm	Share of All Farms	Share of Cultivated Land	Share of Total Fertilizer Consumption	
	1983/84	1983/84	1977/78	1983/84
	(percent)			
Chandra				
Small farms	66	26	7	31
Medium farms	22	31	16	33
Large farms	12	43	77	37
Banguri				
Small farms	71	40	30	43
Medium farms	23	40	39	38
Large farms	6	20	31	19

Sources: M. A. Quasem and M. Hossain, "Fertilizer Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979); and 1984 field survey.

EFFECTS ON FOODGRAIN OUTPUT AND FARMERS' INCOME OF BUDGETARY REALLOCATION OF FERTILIZER SUBSIDY TO IRRIGATION DEVELOPMENT

It has been shown in this chapter that higher prices of fertilizer reduce fertilizer consumption. But other factors, such as increased output prices, development of irrigation facilities, and adoption of HYVs, also increase fertilizer consumption. Thus, although fertilizer prices have increased rapidly since the early seventies, the negative pure price effect on fertilizer consumption has been outweighed by the positive effects of these other developments. This is a principal reason why fertilizer consumption has grown despite the increase in fertilizer prices, not only in absolute terms but also in relation to the prices of crop output.

The ultimate objective of Bangladesh government policy is not to increase the sale of fertilizer per se but to accelerate the growth of foodgrain production so as to achieve self-sufficiency as soon as possible. Since land is a limited factor of production, in order to accelerate growth, emphasis must be placed on expansion of modern technology, and fertilizer is only one of the inputs in this technology package. But it was also shown above that fertilizer is still a minor input with regard to its contribution to overall growth in production. The output elasticity of fertilizer consumption is only 0.1, indicating that a 10 percent increase in fertilizer sales would lead to an increase in foodgrain output of only 1 percent.

The productivity of land, however, could be raised through additional investment in irrigation, drainage, research, extension, and so forth. Since a shortage of financial resources may be a serious constraint to undertaking development projects that are necessary to raise the productivity of land or to facilitate the supply and distribution of modern inputs and the marketing of output, policymakers must explore the most effective ways of using these scarce resources.

This section attempts to quantify the effects of the withdrawal of fertilizer subsidies on budgetary savings and the effects on foodgrain production and farmers' income of the reallocation of the resources saved to the development of irrigation facilities. It has been assumed (following Ahmed's calculation) that fertilizer prices must be increased by about 30 percent over the level of 1983/84 to completely eliminate the subsidy. The quantification is based on a static partial equilibrium approach; it does not take into account the multiplier effects of the increase in price, which may be quite significant because of the strong interdependence between irrigation, HYV seeds, and fertilizer. Although the subsidy is to be phased out by the end of 1985/86, all calculations are done over the benchmark level of 1983/84 in order to avoid the problem of forecasting the relevant variables. So it is assumed that all other variables that affect fertilizer consumption will remain constant at the levels of 1983/84.

The effect of a 30 percent increase in fertilizer prices on budgetary savings and foodgrain output under alternative assumptions of the price elasticity of fertilizer demand is shown in Table 42. Using the medium estimate of the price elasticity of -0.65, a 30 percent increase in fertilizer prices would lead to a decline of fertilizer sales of 19.5 percent, that is, by 220,000 tons out of 1.13 million tons of materials. The output elasticity of fertilizer use of 0.1 implies that foodgrain production would decline by 1.95 percent, that is, by 301,000 tons out of 15.46 million tons of rice.[51] At 1983/84 prices, the government would save Tk 1,125 per ton of fertilizer as a result of the price increase. Since fertilizer consumption is expected to fall to 909,000 tons after the price increase,[52] the total budgetary saving is expected to be Tk 1,023 million, about 2.9 percent of the total allocation of resources in the Annual Development Program (ADP). The amount saved is, however, a significant proportion (10.8 percent) of the ADP allocation to agriculture and flood control. It will be noted from Table 42 that under alternative assumptions of demand elasticity, the budgetary savings do not vary significantly, although the negative effect on foodgrain production does.

If the government decides to import food with the savings, the medium estimate of the price elasticity allows for additional imports of 176,000 tons of rice at the border price of Tk 5,810 per ton (see Chapter 3, by Ahmed). This is about 41 percent less than the decline in domestic production. Even with the low estimate of price elasticity, the additional imports with the budgetary savings fall short of the decline in domestic production. Thus, a withdrawal of the fertilizer subsidy in favor of food imports is not a desirable policy for the government to follow. So long as there is a food deficit in the country requiring the government to import food, it is better to provide the fertilizer subsidy, if it is the only way of increasing food production in the country.

Of course food production can also be increased through investment in agricultural development. The answer to the question whether the fertilizer subsidy should be retained or not would then depend on the cost effectiveness of fertilizer subsidies compared to, for example, irrigation expenditures, in raising foodgrain production if resources cannot be diverted from activities outside agriculture for accelerating investment in irrigation development.

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[51]The decline in output may be less if fertilizer consumption is cut on the marginal land where the marginal response to output is less than the average.

[52]The full impact of a 30 percent increase in fertilizer prices relative to crop output prices is calculated here. Actually, portions of this required price increase were undertaken in July 1984 and January 1985 (see the chapter in this volume by Ahmed).

Table 42--Effects of a withdrawal of fertilizer subsidies on fertilizer consumption and foodgrain production

Factor	Low Estimate	Medium Estimate	High Estimate
Price elasticity of demand for fertilizer	-0.48	-0.65	-0.75
Fertilizer use in 1983/84 (1,000 metric tons of materials)	1,129	1,129	1,120
Change in fertilizer use as a result of a 30 percent price increase (1,000 metric tons)	-163	-220	-254
Fertilizer use after the price increase (1,000 metric tons)	966	909	875
Expected change in foodgrain output (1,000 metric tons of rice)[a]	-223	-301	-348
Unit of budgetary savings (Tk/metric ton of materials)	1,125	1,125	1,125
Total budgetary savings (Tk/million)	1,087	1,023	984
-- As a proportion of total development outlays (percent)	3.1	2.9	2.8
-- As a proportion of development outlays for agriculture, irrigation, and flood control (percent)	11.5	10.8	10.4
Amount of food that could be imported with the budgetary savings (1,000 metric tons)[b]	187	176	169

Note: These figures were calculated assuming that other factors remained unchanged from 1983/84.

[a]Assumes an output elasticity of fertilizer use of 0.1. This is the "pure" effect of the price increase. If other factors such as output prices, irrigation, and HYV area grow at their trend rates, this negative effect may be counterbalanced.

[b]Evaluated at a border price of Tk 5,810 per ton.

Development of irrigation facilities has been the responsibility of the government because the investments involved show limiting indivisibilities given the small and scattered nature of farm holdings. Irrigation facilities have been developed by BADC through fielding of small-scale irrigation equipment (that is, shallow [STWs] and deep tubewells [DTWs] and low lift pumps [LLPs]), and by the Bangladesh Water Development Board (BWDB) through large-scale, long-gestation-period, multipurpose projects that provide irrigation using surface water. The cost of providing irrigation differs among these projects. LLP and STW investments appear to be more cost-effective than DTW and BWDB schemes. The potential of irrigation development through alternative means should be assessed to obtain reliable estimates of the additional area that could be irrigated with the budgetary savings realized from the withdrawal of the fertilizer subsidy.

Trends in the growth of irrigation under the alternatives are shown in Figure 4. The figure illustrates that growth of irrigation through LLPs, following a rapid growth during the late sixties and early seventies, has tended to stagnate since the mid-seventies, indicating either constraints to continued development or limited potential for further expansion. Although not covered in the figure, the growth in operating capacity of shallow tubewells also reportedly declined during 1983/84,[53] following a rapid increase during the period 1977/78 - 1982/83. Only aggregate DTW capacity and that associated with the BWDB irrigation schemes are in the rising phase of the 'S' curve. So it has been assumed that future increases in irrigation will come mainly through extraction of groundwater by DTWs and development of surface water irrigation through BWDB schemes.

In order to assess the cost of alternative means of irrigation, one needs to know the capital investment requirements, operation and maintenance costs, the life of the equipment or facilities, and the areas that could be irrigated under the respective schemes. The procurement and fielding cost of a two-cusec DTW is Tk 423,000, which, according to official estimates, irrigates about 60 acres of land. In a recent microsurvey, however, the area irrigated by a DTW was estimated to be only 43 acres.[54] The Master Plan Organization (MPO) has recently estimated the cost of the BWDB type irrigation schemes for an area of 10,000 acres, which will provide irrigation to 7,500 acres of farmland (excluding the land under homestead, roads,

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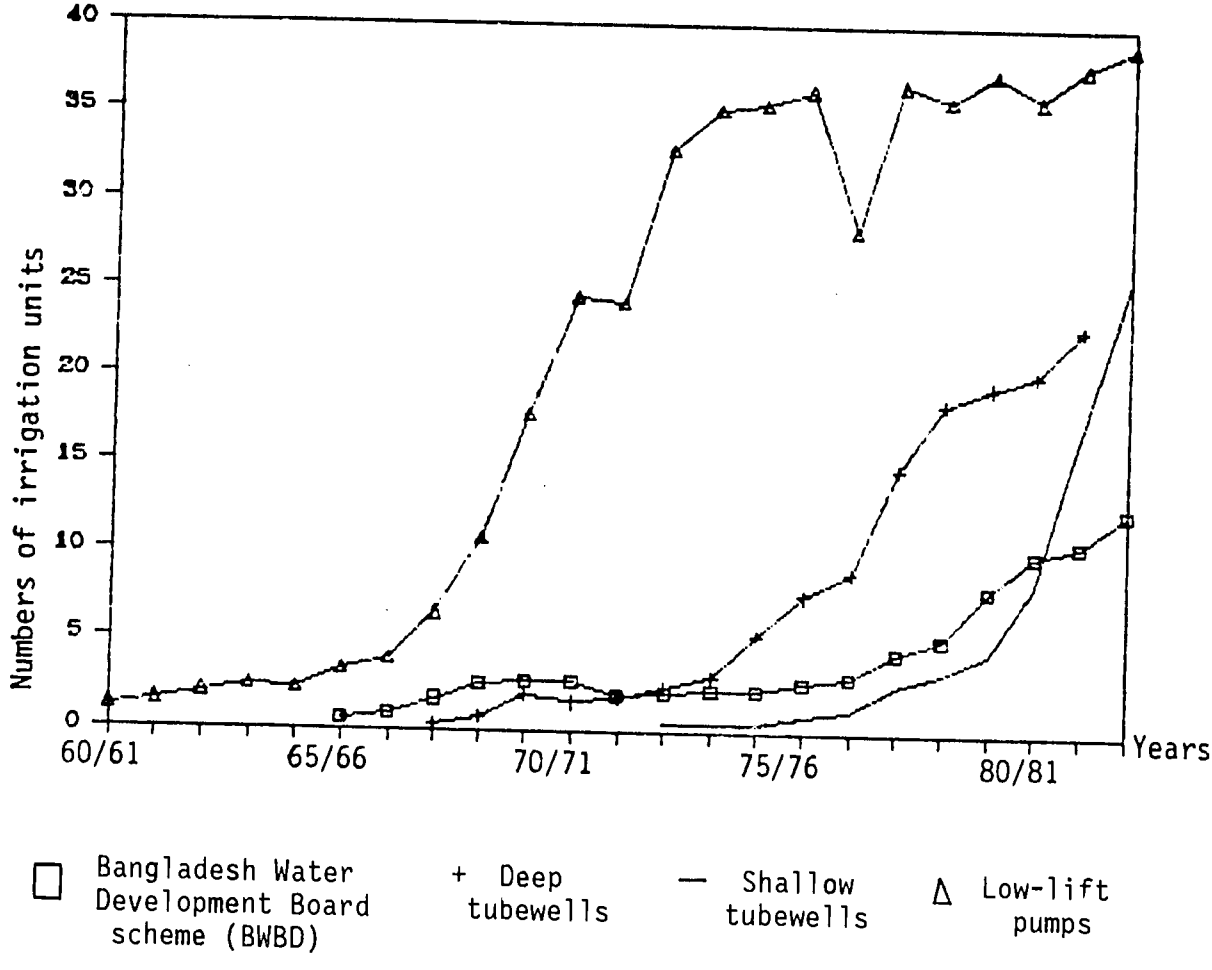
[53]Bangladesh Ministry of Finance, "Bangladesh Economic Survey, 1983/84."

[54]Md. Abul Quasem, Abul Barkat, and S. A. Khan, Impact of the New System of Distribution of Fertilizer and Irrigation Machines in Bangladesh (Dhaka: Bangladesh Institute of Development Studies, 1984).

Figure 4--Trends in approaches to irrigation development, 1960/61 to 1982/83



Note: 1 unit = 500 deep tubewells, 1,000 low-lift pumps, 2,500 shallow tubewells, or 30,000 acres covered by BWBD surface projects.

Sources: 1960s data are from Bangladesh Ministry of Agriculture, Bangladesh Agriculture in Statistics (Dhaka, 1973). 1970s data are from the Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh (Dhaka, various issues), except for the Bangladesh Water Development Board data, which are from World Bank, South Asia Programs Department, Bangladesh: Economic Trends and Development Administration, Volume II: Statistical Appendix, Report No. 4822 (Washington, D.C.: World Bank, 1984), pp. 75-78.

markets, and so forth).[55] These statistics have been used to calculate the annualized capital cost, assuming a rate of return of 15 percent on capital and a life of 15 years for DTWs and 25 years for BWDB schemes.

The BWDB project generates considerable additional employment in constructing embankments and canals. Because society would benefit from additional employment, in view of the substantial underemployment in the country, the cost at economic prices (as provided by the MPO) has also been estimated. In estimating the cost at economic prices, the MPO has assumed a shadow wage rate of 70 percent of the market wage and evaluated the tradable material inputs at border prices. For DTWs, the labor component is low, and most of the materials are imported (and consequently valued at their procurement costs). Hence, the cost at economic prices is not expected to be much different from that at market prices. For DTWs, however, two alternative estimates of area under irrigation have been assumed: a high estimate of 60 acres and a low estimate of 45. The annualized capital investment costs and the operation and maintenance costs per acre of irrigated land obtained under these assumptions are reported in Table 43.

In calculating the quantity of additional land that could be irrigated with the budgetary savings from the withdrawal of subsidies, estimates have been used of the cost for BWDB irrigation of shallow flood area, the cost of DTW irrigation (under the alternative assumptions about the area to be irrigated by a DTW), and the budgetary savings associated with the medium estimate of the price elasticity of fertilizer demand. Underutilization of irrigation capacity for out-of-order DTWs of 10 percent has been assumed, as has an inability to irrigate particularly high or low-lying farmlands within the command area of a BWDB project. It has also been assumed that the land to be irrigated will be used for growing HYV Boro paddy and will produce a yield of 1.12 tons of rice per acre (46 maunds of paddy), that fertilizer consumption after the price increase will be 234 pounds of materials per acre, that farmers within the irrigation project command area will forgo growing local broadcast Aus in favor of growing HYV Boro on the land, subsequent to irrigation, and that the government will bear only the capital costs of irrigation, while the farmers will bear the costs of operation and maintenance.

The estimated increases in irrigated area, fertilizer consumption, and rice production under these assumptions have been calculated and presented in Table 44. The increase in fertilizer consump-

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[55]Master Plan Organization, "National Water Plan Project, Second Interim Report," Annex, Ministry of Irrigation, Water Development and Flood Control, Dhaka, 1984.

Table 43--Capital investment, operation, and maintenance costs for irrigation development

Type of Irrigation	Capital Costs of Land: Over the Project Life	Capital Costs of Land: Annualized Value[a]	Annual Operation and Maintenance Costs
		(Tk/acre)	
Large-scale projects			
Nonflood area			
At market prices	10,720	1,658	334
At economic prices	6,800	1,052	294
Shallow-flood area			
At market prices	12,006	1,857	396
At economic prices	7,139	1,104	353
Medium-flood area			
At market prices	12,897	1,995	416
At economic prices	7,525	1,164	368
Deep-flood area			
At market prices	11,047	1,708	296
At economic prices	6,110	945	263
Deep tubewell irrigation			
At market prices	7,050	1,206	982
	(9,400)	(1,608)	(1,310)
At economic prices	6,701	1,145	576
	(8,934)	(1,528)	(769)

Source: Data are from the Master Plan Organization and Bangladesh Agricultural Development Corporation, 1984.

Note: Figures within parentheses are estimated on the assumption of 45 acres of land irrigated per machine.

[a]This assumes a 15 percent rate of return on capital and 25 years of project life for large-scale projects and 15 years for deep tubewells.

Table 44--Effect on foodgrain production of the reallocation of budgetary savings from fertilizer subsidy withdrawal to irrigation development

Factor	Deep Tubewell Irrigation		Large-Scale Irrigation	
	High-Capacity Utilization	Low-Capacity Utilization	At Market Price	At Shadow Price
Annualized capital cost (Tk/acre)	1,340	1,787	2,053	1,227
Additional area that could be irrigated with the budgetary savings from the withdrawal of subsidy (1,000 acres)	763	572	496	834
Increase in rice production at 1.12 tons per acre (1,000 metric tons)[a]	854	641	556	934
Increase in fertilizer consumption at 234 lbs. of materials per acre (1,000 metric tons)	81	61	53	89
Increase in rice production net of the loss due to the increase in fertilizer prices (1,000 metric tons)	553	340	255	633
Value of additional output at -- (Tk million)				
Market prices	3,603	2,215	1,662	4,125
Economic prices	3,213	1,975	1,482	3,578
Cost of production to farmers at -- (Tk million)				
Market prices	3,383	2,723	1,909	3,209
Economic prices	2,762	2,181	1,685	2,833
Cost savings as a result of lower consumption of fertilizer	854	854	854	854
Profit forgone from local Aus cultivation -- (Tk million)				
Market prices	181	136	118	198
Economic prices	234	176	152	256
Net gain from budgetary reallocation -- (Tk million)				
Market prices	893	210	489	1,572
Economic prices	1,071	472	499	1,443

[a]Net increase in production would be about 30 percent less than these figures if the production of local Aus is to be forgone on these lands. The effect on farmers' income as a result of this reallocation has been accounted for in the estimates of profit forgone and net gain given below.

tion under alternative calculations varies from 53,000-89,000 tons, which is lower than the estimated decline in consumption (220,000 tons) due to the price increase. Thus, the net effect of the withdrawal of the subsidy on fertilizer consumption is expected to be negative, regardless of fund reallocations to irrigation investment.

The effect on foodgrain production of this reallocation of funds is, however, expected to be positive. The estimated increase in production, under alternative calculations, varies from 556,000 to 934,000 tons, which, after subtracting the loss in output from the increase in fertilizer price (301 metric tons in Table 42), gives a net addition to production varying from 255,000 to 633,000 tons (1.6 to 4.1 percent of 1983/84 output). The farmers, however, would save Tk 854 million because fertilizer use would fall after the price increase.

To achieve this growth in output, the farmers would have to incur additional costs not only for purchasing modern inputs, but also for labor (since HYV Boro is a highly labor-intensive crop), and these costs would have to be deducted from the value of additional production for estimating the net effect. The costs of production in cultivation of HYV Boro paddy and the alternative crop, local broadcast Aus, have been calculated and presented in Table 45. The BARC/IFDC survey[56] gives detailed information on the use of inputs in cultivation of these crops, with the exception of seed and irrigation. The input coefficients from the BARC/IFDC survey have been used to estimate their value at 1983/84 prices. Seed costs in 1980/81 have been adopted from the author's earlier work on the Chandpur Irrigation Project and have been adjusted for the change in growers' price of paddy over the 1980/81 to 1983/84 period. The cost of irrigation has been taken from Quasem et al., which reports the water charges paid by farmers for the 1983 Boro season.[57] The cost of production at shadow prices has also been estimated, assuming no subsidy on fertilizer, a shadow wage of labor equal to 70 percent of the market wage, and an irrigation charge equal to the operation and maintenance costs reported by Quasem et al. Under these assumptions, the cost of HYV Boro cultivation is calculated to be Tk 4,762 per acre at market prices and Tk 3,813 at economic prices under DTW

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[56]BARC/IFDC, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80, and Agricultural Production, Fertilizer Use and Equity Considerations, 1980-82.

[57]Quasem et al., Impact of the New System of Distribution of Fertilizer and Irrigation Machines.

Table 45--Estimated cost of production and profit per acre associated with HYV Boro and local Aus paddy cultivation at 1982/83 prices

Items	Unit	HYV Boro		Local Aus	
		Quantity	Value	Quantity	Cost
			(Tk)		(Tk)
Seeds	Pounds	21	244[a]	62	122
Fertilizer	Pounds	290	493 (641)	33	56 (73)
Pesticides	Pounds	1.66	141	0.04	3
Irrigation	Tk	...	1,310 (769)	nil	...
Labor	Person days	103	1,854 (1,298)	60	1,080 (756)
Draft power	Days/pair		720	17	680
Total cost	...	...	4,762 (3,813)	...	1,941 (1,634)
Gross value of production	Tons of rice	1.12	7,298 (6,507)	0.334	2,178 (1,941)
Net profit	Tons of rice	...	2,536 (2,694)		237 (307)

Note: The figures in parentheses are costs at economic prices.

[a]This includes the cost of seedbed preparation.

irrigation with an effective command area of 45 acres. If the assumed capacity utilization is raised to 60 acres, the unit cost of irrigation would fall, and the cost of production would be Tk 4,434 per acre at market prices and Tk 3,620 at economic prices.

Operation and maintenance costs under BWDB schemes are substantially lower than those for deep tubewell irrigation (Table 43). Thus, the costs for farmers of HYV cultivation under BWDB irrigation is expected to be even lower. Even if farmers pay the irrigation system operation and maintenance costs that accrue to the BWDB, the cost to farmers of HYV Boro cultivation comes to Tk 3,848 at market prices and Tk 3,397 at economic prices.

The cost calculations also show that the farmers would have to forgo production of 0.33 tons of rice and a net profit of Tk 237 per acre (Tk 307 at economic prices) in the process of shifting land from local Aus to HYV Boro.

The estimated net gain after deducting the increase in the cost of cultivation and the profit forgone from local Aus cultivation has been calculated and is presented in Table 44. At market prices, the net gain is substantially positive for BWDB irrigation when capital costs are estimated at economic prices (about Tk 1,500 million). It is also positive under DTW irrigation, if capacity utilization could be raised to 60 acres. For the other two alternatives (BWDB irrigation at market prices and the lower 45-acre capacity assumption for DTWs), the net gain is small, ranging between Tk 210 and 500 million.

Finally, it must be noted that the effect of the increase in fertilizer consumption is immediate, while the gain from development of irrigation would be realized over time, following the expenditure of resources for irrigation development. There is no guarantee that savings from withdrawal of subsidy will be invested in development of irrigation. Also, if resources could be diverted from outside agriculture for both fertilizer subsidy and irrigation development, the effect on foodgrain production and farmers' income could be even higher.

SUMMARY OF FINDINGS

The use of chemical fertilizers in Bangladesh grew rapidly in a short period of time. Use of chemical fertilizers on farmers' fields was virtually insignificant in the early sixties. BADC was set up in 1961 to popularize modern agricultural inputs among farmers, and it distributed 0.3 million tons of chemical fertilizers in 1970. Distribution rose to 1.1 million tons by 1983/84.

In spite of this rapid growth, fertilizer use per acre of land remains low, about 75 pounds of materials (36 pounds of nutrients) per acre of cropped land. Extreme variation is evident in fertilizer

use per acre among different regions of the country. Application is more than 150 pounds per acre in Bogra and Chittagong, while less than 40 pounds in Patuakhali, Barisal, Khulna, Faridpur, and Sylhet. These low-consuming districts encompass about 28 percent of the arable land in the country, and consumption there is still growing slowly. If fertilizer use throughout the country were raised to the level of Bogra (in 1983/84), total consumption would increase to 2.38 million tons, more than double the present aggregate level.

There are also extreme variations in chemical fertilizer use among various crops grown in the country. Fertilizers are applied on almost all land sown with Boro and Aus HYVs, and use of fertilizer on such land is about 289 and 208 pounds per acre, respectively. On the other hand, farmers use little fertilizer on deep-water Aman, local Boro, and pulses; the highest consumption on these crops was found to have been 6, 36, and 9 pounds per acre, respectively.[58] As a result, a third to a half of the cropped land in the country remains unfertilized during the three cropping seasons.

The fertilizer prices at the farm gate increased rapidly beginning in the mid-seventies and accelerated after 1978/79. This was mainly the result of a gradual withdrawal of subsidies from a high of about 50 percent for urea and 75 percent for TSP and MP in 1975/76. Subsidies stood at about 4 percent for urea and about a third for TSP and MP in 1982/83. As a result, although the BADC procurement and distribution cost of these inputs increased by about 6 percent per year during 1975/76 - 1983/84, the prices paid by farmers increased by about 14 percent per year for urea and 17 percent for TSP and MP. This period also experienced a major change in the fertilizer distribution system in the country.

Farm-gate prices for agricultural produce increased at a slower rate than did fertilizer prices, so the fertilizer-crop price ratio became less favorable for farmers through 1982/83. The ratio of fertilizer prices relative to farm-gate prices of paddy increased steadily, from 0.91 in 1972/73 to 1.38 in 1975/76 and to 2.07 in 1982/83. It fell to 1.91 in 1983/84 and to 1.74 between July and September 1984 (despite a 10 percent increase in fertilizer prices in July), owing to the rapid increase in output prices; still, the 1983/84 ratio was higher than the 1.46 ratio in 1979/80.

The unfavorable movement in relative fertilizer-crop prices appears to have reduced fertilizer consumption, particularly after 1977/78 when fertilizer consumption reached 0.73 metric tons. In spite of the rapid increase in area under modern irrigation and HYVs

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[58]BARC/IFDC, Agricultural Production, Fertilizer Use and Equity Considerations, 1979-80.

during this period, the growth of fertilizer consumption decelerated. Fertilizer consumption per acre grew only 1-2 percent per year during the six-year period from 1977/78 to 1983/84 in two of the high-consuming districts, Chittagong and Comilla, and fell in absolute terms in the low-consuming districts of Barisal, Patuakhali, and Noakhali. It grew more than 10 percent per year in North Bengal and the Mymensingh region, which experienced rapid growth in the area under tubewell irrigation during this period. The annual growth rate for the country as a whole was 6.7 percent from 1977/78 to 1983/84.

The diffusion of fertilizer use was almost complete for HYVs by 1976/77, but there was scope for further expansion on local paddy varieties and on Rabi crops. Findings of microsurveys show that diffusion proceeded rapidly for certain Rabi crops, such as potatoes and oilseeds, but more slowly for local varieties of paddy.

The use of fertilizer per acre on different crops (as estimated by IFDC from farm-level survey data) did not, on average, increase during the period 1979/80 to 1981/82, except for the Boro season crops. For most crops, application on treated land declined in 1981/82 from 1980/81 levels. A resurvey of two villages also shows that fertilizer application rates declined over the period 1977/78-1983/84 for the fertilizer-intensive crops. All this indicates that fertilizer prices have reached a level where farmers respond to changes in the fertilizer-crop price ratio.

This is confirmed by an estimate of the price elasticity of demand from a model fitted on pooled time series (1977-83) and cross-section (district) data. The model tries to explain fertilizer demand by relating it to the price of fertilizer and paddy along with changes in other factors that might shift fertilizer demand, such as the area irrigated by modern methods or the area under HYVs. The linear form of the model fitted on 105 observations for the period 1978/79 -1982/83 explains about 85 percent of the variation in fertilizer consumption. The estimated parameters indicate that a 30 percent increase in fertilizer prices, with all other variables remaining constant, would lead to a 22.5 percent reduction in the demand for fertilizers. To offset this negative effect, the paddy price would have to be raised to Tk 206 per maund. The current procurement price of paddy is only Tk 165 per maund but the average farm-gate price (during July-September 1984) was Tk 195.

The estimated model also shows that expansion of irrigation and HYVs (paddy + wheat) is the most important factor explaining historical changes in fertilizer use in the country. Thus the negative effect of the increase in fertilizer prices on fertilizer consumption could be overcome through the expansion of irrigation facilities and HYV coverage, which are still low in most regions of the country. Fertilizer consumption could also be increased through improved drainage facilities, thereby reducing the area under deep-water Aman and local Boro, which are low-fertilizer-consuming crops.

In the event of a decline in fertilizer use, there will be some adverse effect on growth of food production. The estimate of output response to fertilizer use in different locations of the country for various crops obtained from BARI field trial data show a high response for urea and NPK for most locations with a B-C ratio higher than 3:1. Average application rates are still low enough that the marginal response has not started declining significantly. Marginal response is found to decline in some of the areas only for HYV Aus and wheat. A large variation is noted in the phosphate and potash response in different locations, often in adjacent thanas. Thus a more effective extension service, providing farmers with location-specific knowledge of fertilizer response, could increase output with the same level of application of fertilizers, thereby reducing the adverse effects of increased fertilizer prices.

The high benefit-cost ratio is obtained under experimental conditions where fertilizer is applied at the right time and the associated inputs such as water and pesticides, as well as inter-cultural operations, are applied optimally. Management conditions in the actual farmers' fields would not be as efficient, and so the output response on farmers' fields is expected to be less. IFDC studies show a much lower response of output to fertilizer use on farmers' fields and a large variation in response for the same crop across time, which is an indication that fertilizer use has a high risk. The weighted average response for all foodgrains together is estimated to be 4.3 units of paddy per unit of nutrient, compared to a 10:1 ratio under experimental conditions. The lowest average annual response that the surveyed farmers obtained from the crops gives only marginal net returns over the costs, although the three-year average response still gives a benefit-cost ratio of more than two, at the existing farm-gate prices for fertilizers and foodgrains.

The average response ratios with present fertilizer applications and foodgrain yields indicate an output elasticity of fertilizer use of 0.05 to 0.08 for local varieties and 0.16 to 0.22 for HYVs. The weighted average elasticity is estimated to be 0.1, which indicates that a 10 percent reduction in fertilizer use may reduce crop yields by only 1.0 percent.

Fertilizers, however, account for a large proportion of the cost of material inputs (29 percent). Thus the increase in fertilizer prices would have a significant effect on the cash cost of cultivation to which the small farmers may respond. Available micro-studies show that small farmers use slightly more fertilizer per acre of land than do operators of larger farms, and that they have increased fertilizer consumption by greater proportions than the large farms in spite of the increase in fertilizer prices. A resurvey of two villages conducted during the course of the study shows that this was primarily related to the diffusion of use on local paddy crops and a rapid increase in the proportion of area under fertilizer-intensive crops, such as HYV paddy, wheat, and

mustard. The small farmers reduced fertilizer application rates on these fertilizer-intensive crops proportionately more than the operators of larger farms.

Quantification of the effect of the withdrawal of fertilizer subsidy on foodgrain production and farmers' income is difficult because of the strong interdependence between irrigation, HYV seeds, and fertilizer and the competitive nature of the claims of agricultural extension, irrigation development, and input supply to the limited public resources available for agricultural development. An exercise based on the partial equilibrium approach and the parameters estimated in this study shows that a complete elimination of the subsidy, at the level of 1983/84 prices, would save government resources to the extent of about 3 percent of the allocation to ADP and 11 percent of the allocation to agriculture (including irrigation and flood control). This would, however, lead to a decline in domestic foodgrain production of about 300,000 tons, which is significantly higher than 176,000 tons of rice that the government could import with the budgetary savings. Thus, a withdrawal of the fertilizer subsidy in favor of food imports is not a desirable policy for the government to follow. However, if the budgetary saving is invested for development of irrigation facilities, it would lead to a net addition to rice production in the range of 225,000 to 633,000 tons depending on the type of irrigation development and utilization of capacity.

Table 46--Distribution of commercial fertilizer by weight, 1969/70 - 1983/84

Division/ District	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83[c]	1983/84[c]
	(1,000 long tons of materials)														
Rajshahi	64.2	71.2	43.6	66.6	79.0	68.4	104.8	131.6	190.2	195.4	234.8	264.4	252.1	304.3	390.8
Dinajpur	13.9	12.2	8.1	13.6	14.1	14.1	20.3	24.2	35.2	35.8	43.5	45.2	40.8	52.1	68.7
Rangpur	12.7	15.0	11.5	13.6	16.6	14.4	21.5	27.3	38.7	41.8	43.5	56.1	50.6	63.4	85.5
Bogra	17.3	19.7	9.8	14.2	19.3	15.9	24.4	33.7	43.0	47.4	58.3	69.8	71.1	74.2	91.4
Rajshahi	13.3	15.5	8.2	13.6	17.4	15.8	21.1	27.8	41.8	41.3	57.7	58.7	56.2	65.9	87.2
Pabna	7.0	8.8	6.0	11.5	11.6	8.1	17.5	18.6	31.6	29.1	31.8	34.8	33.4	48.7	58.0
Khulna	37.0	45.1	42.2	54.2	53.8	36.8	63.2	67.1	108.8	100.9	131.9	130.2	116.6	127.2	156.3
Kushtia	7.8	7.2	6.0	10.6	9.6	8.2	14.3	21.3	31.4	28.3	43.7	42.6	37.1	36.3	51.7
Jessore	8.3	8.1	7.6	8.0	10.6	9.2	15.3	20.9	33.3	32.9	41.3	40.7	39.6	41.2	55.2
Khulna	7.7	7.7	6.7	6.5	7.4	4.2	6.9	8.2	11.9	9.5	12.2	16.6	15.0	17.5	19.8
Barisal	10.8	14.8	16.3	23.5	21.0	12.2	20.9	13.2	25.1	22.7	25.8	24.2	20.0	25.2	24.6
Patuakhali	2.4	7.4	5.6	5.6	5.2	3.0	5.8	3.4	7.8	7.5	9.0	6.2	4.9	7.0	5.1
Dhaka	67.3	83.4	55.7	111.0	105.5	66.6	129.8	140.0	193.0	202.6	212.5	237.4	236.5	274.5	313.5
Jamalpur[a]	}30.3	}36.1	}19.8	}49.3	}49.6	}33.2	}59.5	}60.3	}91.9	}91.3	}95.6	}107.1	24.8	30.0	38.3
Mymensingh[b]													70.7	87.2	93.7
Tangail	6.1	7.5	4.6	9.2	9.8	5.8	14.7	16.0	22.5	27.5	29.3	35.2	37.7	46.2	48.5
Dhaka	27.4	35.1	23.4	45.8	39.6	23.9	50.2	54.9	65.7	69.3	69.8	80.7	87.6	91.3	108.1
Faridpur	3.5	4.8	6.8	7.0	6.5	3.7	5.4	8.8	12.9	14.6	17.8	14.4	15.7	20.0	24.9
Chittagong	108.7	104.7	102.4	152.3	141.6	107.8	159.8	173.9	227.0	242.7	259.0	243.1	224.1	262.4	268.5
Sylhet	12.7	9.6	17.6	20.9	12.8	14.6	15.5	16.5	23.7	20.2	27.4	26.5	25.8	29.7	38.0
Comilla	33.5	35.2	30.1	51.5	52.6	36.1	62.3	69.1	98.8	115.3	127.3	119.8	111.2	125.0	121.5
Noakhali	14.1	16.6	10.5	20.0	21.6	15.4	24.9	27.4	32.8	31.1	37.0	32.7	29.0	28.5	26.7
Chittagong	45.0	41.7	41.6	58.2	52.0	39.1	54.5	58.4	69.1	73.1	63.8	59.8	53.1	75.5	74.7
Chittagong Hill Tracts	3.2	1.6	2.6	1.8	2.6	2.5	2.7	2.5	2.7	3.0	3.5	4.4	5.0	3.8	7.7
Total	277.1	304.4	243.8	384.0	379.9	279.6	457.6	512.6	719.1	741.6	838.1	875.2	829.3	968.4	1,129.1

Source: Bangladesh Agricultural Development Corporation.

[a]Jamalpur was a subdivision of Mymensingh until December 26, 1978.

[b]Including Jamalpur from 1969/70 through 1980/81.

[c]Figures in metric tons.

Table 47--Fertilizer use in different seasons and locations, 1980

Location	Boro		Aus		Aman		Wheat
	Local	HYV	Local	HYV	Local	HYV	HYV
	(maunds/acre)						
Jalakathi, Barisal	...	3.79	0.02	...	0.02	...	...
Nandigram, Bogra	...	3.44	1.25	2.00	1.01	1.94	2.78
Ramu, Chittagong	...	3.65	...	2.65	0.47	1.01	2.53
Chandina, Comilla	...	...	1.73	1.95	0.28	1.09	...
Atghoria, Pabna	...	...	0.49	1.99	0.74	3.18	1.72
Balaganj, Sylhet	0.07	...	0.01	0.03	...	...	...
Modhupur, Tangail	...	3.03	0.69	1.41	0.92	1.20	2.55
Kapasia, Dhaka	0.12	2.73	0.34	1.22	0.61	1.25	...
Kurigram, Rangpur	...	...	0.27	2.43	0.36	0.96	1.23
Mirpur, Kushtia	...	...	0.11	3.39	0.81	3.12	2.43
Nagarkanda, Faridpur	...	3.65	0.02	...	...	...	...
Chiribandar, Dinajpur	...	...	0.05	0.48	0.08	...	1.03
Jhikargacha, Jessore	...	3.92	0.02	1.06	0.48	1.41	1.68
Sonagazi, Noakhali	...	...	1.25	1.51	0.86	1.54	...
Phulpur, Mymensingh	1.09	1.43	0.48	...	0.49	1.45	1.41
Fakirhat, Khulna	...	...	0.37	...	0.28	2.12	...

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 (Muscle Shoals, Ala.: IFDC, 1982).

Table 48--Fertilizer use in different seasons and locations, 1981 and 1982

Location	1981						1982				HYV	Wheat
	Aman		Boro		Aus		Boro		Aus		HYV	Wheat
	Local	HYV	Local	HYV	Local	HYV	Local	HYV	Local	HYV	1981	1982
	(maunds/acre)											
Jalakathi, Barisal	0.10	...	...	3.0	0.05	2.19	...	2.96	0.12	3.64	...	...
Nandigram, Bogra	1.23	2.14	...	...	1.32	2.52	...	...	1.40	2.91	3.14	3.80
Rangunia, Chittagong	2.29	3.08	...	...	...	...	...	3.33	0.72	1.88	...	...
Ramu, Chittagong	0.19	...	2.13	3.49	...	2.39	2.83	3.20	...	...	...	...
Chandina, Comilla	0.69	1.03	...	6.68	1.34	3.69	4.03	3.95	0.80	1.77	3.14	3.08
Chiribandar, Dinajpur	0.04	0.66	...	1.98	0.03	0.46	...	1.45	0.01	0.48	1.22	0.88
Jhikargacha, Jessore	0.53	1.01	...	3.97	0.01	0.71	...	3.81	0.01	0.88	1.89	0.84
Sonagazi, Noakhali	1.12	1.62	...	2.92	1.26	1.61	...	...	1.27	1.70	1.54	0.76
Atghoria, Pabna	1.05	2.65	...	...	0.27	2.78	...	...	0.12	2.53	1.96	1.29
Balagonj, Sylhet	0.02	2.81	0.02	1.27	0.06	2.29	0.07	2.68	0.03	...	...	...
Madabpur, Sylhet	0.82	...	...	...	...	...	2.53	4.15	1.64	...	...	...
Modhupur, Tangail	0.66	1.18	...	2.78	0.57	0.95	3.85	...	0.04	0.67	2.96	3.17
Phulpur, Mymensingh	0.51	1.40	1.48	2.41	0.51	0.99	1.97	2.58	0.30	0.49	0.79	0.72
Bajitpur, Mymensingh	1.71	2.12	...	...	...	...	1.47	3.75	0.57	...	...	1.24
Kapasia, Dhaka	0.48	0.84	0.00	2.10	0.54	1.60	0.03	1.42	0.80	2.17	1.17	...
Kurigram, Rangpur	0.27	0.57	...	...	0.05	1.89	...	...	0.11	1.69	1.33	0.93
Mirpur, Kushtia	0.60	3.93	...	...	0.15	3.71	...	...	0.10	3.51	1.61	1.40
Nagarkanda, Faridpur	0.04	...	...	1.97	...	2.10	...	...	0.02	...	0.17	0.18
Fakirhat, Khulna	0.59	1.51	...	...	...	...	...	1.87	0.30	1.92	0.58	0.72
Mohonpur, Rajshahi	0.17	1.47	...	...	...	...	2.68	2.57	0.15	2.48	...	0.86

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1980-82 (Muscle Shoals, Ala.: IFDC, 1984).

Table 49--Output response to fertilizer application, HYV Boro, 1982/83

Area	Period	Fertilizer Use	Incremental Production of Paddy			
			Urea	TSP	MP	NPK
		(lbs./acre)	(lbs./lb. of fertilizer application)			
Narsingdhi, Dhaka	1983	142	9.6	2.2	0.6	6.1
Kotwali, Pabna	1983	36	18.2	6.7	-11.7	10.1
Kotwali, Jessore	1983	151	12.0	7.7	6.5	9.9
Ullapara, Pabna	1983	104	2.3	6.6	23.0	7.8
	1982	...	7.5	11.4	12.2	9.3
Chandraghona, CHTs.	1983	57	6.2	0.8	-2.2	3.0
Naogaon, Rajshahi	1983	82	7.3	0.9	22.4	8.7
	1982	...	11.5	-0.4	6.7	7.3
Fatikchhgari, Chittagong	1983	53	14.8	6.3	-11.0	7.1
Satkania, Chittagong	1983	173	1.9	7.6	4.0	3.7
Kapasia, Dhaka	1983	36	7.6	4.8	3.7	6.3
Rupganj, Dhaka	1983	49	14.9	5.3	7.5	10.7
Kendua, Kishoreganj	1983	31	-9.8	17.3	29.4	5.5
	1982	...	6.2	12.1	2.9	7.1
Amount of paddy needed to buy one unit of fertilizer	...	...	2.2	3.0	1.7	2.4

Source: Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1982-83," Dhaka, 1984 (mimeographed).

Notes: TSP is triple superphosphate. MP is muriate of potash. NPK is nitrogen, phosphorus, and potassium.

Table 50--Output response to fertilizer application, HYV Aman, 1982/83

Area	Period	Fertilizer Use	Incremental Production of Paddy			
			Urea	TSP	MP	NPK
		(lbs./acre)	(lbs./lb. of fertilizer application)			
Kotwali, Dinajpur	1983	093	17.2	4.3	8.6	12.3
Thakurgaon, Dinajpur	1983	112	15.8	-1.6	3.7	9.2
	1982	...	13.3	3.0	6.4	9.4
Senbag, Noakhali	1983	54	9.6	9.6	-1.3	7.6
	1982	...	6.3	10.0	2.4	5.8
Chandina, Comilla	1983	116	11.9	12.6	3.3	10.6
Barura, Comilla	1983	142	15.4	3.3	9.8	11.3
	1982	...	12.1	-4.2	12.1	7.9
Pirojpur, Barisal	1983	41	11.7	6.5	7.0	9.5
Bhola, Barisal	1983	122	7.8	26.3	2.0	11.6
	1982	...	12.5	12.0	-5.5	9.2
Kotwali, Pabna	1983	36	29.0	6.9	1.2	18.4
	1982	...	22.7	4.1	0.9	13.7
Jhenaidah, Jessore	1983	64	11.6	3.6	-5.8	6.5
	1981	...	1.2	2.6	2.9	1.9
Daulatpur, Khulna	1983	12	11.1	4.1	0.4	7.4
Panchbibi, Bogra	1983	86	18.1	5.3	-2.2	11.2
Bajitpur, Kishoreganj	1983	120	12.1	1.9	0.8	7.5
	1981	...	8.1	4.3	5.5	6.6
Panchagorh, Dinajpur	1982	147	10.2	0.3	14.3	8.4
	1981	...	16.2	2.5	16.9	13.1
Kapasia, Dhaka	1982	36	8.8	12.9	1.6	8.0
	1981	...	9.8	8.4	3.5	8.1
Kahaloo, Bogra	1982	129	5.9	5.4	0.6	4.7
	1981	...	14.2	13.5	3.1	11.6

Source: Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1982-83," Dhaka, 1984 (mimeographed).

Notes: TSP is triple superphosphate. MP is muriate of potash. NPK is nitrogen, phosphorus, and potassium.

Table 51--Output response to fertilizer application, HYV Aus, 1982/83

Area	Period	Fertilizer Use	Incremental Production of Paddy			
			Urea	TSP	MP	NPK
		(lbs./acre)	(lbs./lb. of fertilizer application)			
Narsingdhi, Dhaka	1983	124	5.2	4.3	-2.3	3.7
Kotwali, Mymensingh	1983	75	5.9	4.3	1.7	4.8
Kotwali, Jamalpur	1983	83	18.3	9.7	2.0	13.3
Bajitpur, Kishoreganj	1983	120	5.5	9.0	12.4	7.6
Ghatail, Tangail	1983	44	16.9	4.3	5.2	11.6
Satkania, Chittagong	1983	173	10.4	5.3	6.1	8.4
Chandina, Comilla	1983	116	6.2	20.6	6.9	10.0
Kotwali, Bogra	1983	98	17.6	10.8	11.8	14.9
Kahaloo, Bogra	1983	129	15.9	18.9	7.5	15.3
Mithapukur, Rangpur	1983	43	7.1	14.5	1.6	7.5
Chandpur, Comilla	1982	37	7.6	0.5	-0.3	0.3
Boda, Thakurgaon	1982	17	5.1	1.1	0.41	0.7
Phulbaria, Mymensingh	1982	130	16.7	4.9	0.3	1.7

Source: Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1982-83," Dhaka, 1984 (mimeographed).

Notes: TSP is triple superphosphate. MP is muriate of potash. NPK is nitrogen, phosphorus, and potassium.

Table 52--Output response to fertilizer application, HYV wheat, 1982/83

Area	Fertilizer Use	Incremental Production of Paddy			
		Urea	TSP	MP	NPK
	(lbs./acre)	(lbs./lb. of fertilizer application)			
Bhola, Barisal	122	26.9	-1.2	3.7	13.1
Bakergonj, Barisal	029	-4.7	22.0	15.5	8.0
Rupgonj, Dhaka	049	...	20.3	8.5	8.5
Raipura, Dhaka	079	14.1	18.2	-2.2	12.8
Pakundia, Rajshahi	...	13.3	13.4	-0.1	11.1
Palashbari, Rangpur	047	8.6	11.5	...	8.1
Gabtoli, Bogra	097	10.4	4.2	13.8	8.8
Borguna, Patuakhali	078	8.0	4.6	3.6	6.1
Sadarpur, Rajshahi	...	8.1	6.9	22.3	10.0
Puthia, Rajshahi	058	7.5	4.7	-4.4	4.5
Bagerpara, Jessore	042	7.0	9.3	27.0	8.2
Sahjadpur, Pabna	105	17.2	2.7	4.5	10.0
Jhenaidah, Jessore	064	1.7	5.0	-2.0	2.5

Source: Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1982-83," Dhaka, 1984 (mimeographed).

Notes: TSP is triple superphosphate. MP is muriate of potash. NPK is nitrogen, phosphorus, and potassium.

5. AGRONOMIC AND ENVIRONMENTAL CONSTRAINTS ON FERTILIZER EFFECTIVENESS

S. M. H. Zaman

For the average farmer in Bangladesh, the use of chemical fertilizer is most effective and profitable when he possesses technical knowledge about soil conditions, pesticides, and the importance of timing and balance in fertilizer application rates. Even small deviations from proper usage and timing of fertilizer application may result in substantially lower yields. At the national level, many field demonstrations and experiments have been done that have substantially narrowed the gap in knowledge. This paper presents many of these findings.

INTERACTION BETWEEN CROPS AND FERTILIZERS IN BANGLADESH SOILS

NPK Fertilizers

Fertilizer efficiency is determined primarily by the crop's growth rate and its nutrient demand, and, to a lesser extent, by the ability of the plant to compete effectively with other processes that draw off nutrients. By selecting an appropriate growth stage of the crop, the fertilizer can be applied when its uptake will provide maximum output. In most cases, each crop has a "grand period of growth" (GPG), which under optimum field and climatic conditions will draw heavily on the soil's nutrients. If there is a lack of required nutrients in the soil during this GPG, however, crop growth and development will be adversely affected. Thus timing of fertilizer application is a crucial element for success.

In a soil with low nitrogen (N) content, application of soluble N to the roots at planting time--basal application--will be more effective than a topdressing of N. Topdressing--scattering the fertilizer on the ground around the plant--is more efficient in high N soil where applications are made at certain intervals or growth stages of the crop. Table 1 illustrates the performance of a typical rainfed, broadcast Aus rice crop (under drought stress) when N fertilizer was applied at different growth stages of the crop. Better response was found either with two split applications (one basal application at the time of transplant and another at the time of panicle initiation) or with three "splits" (one at the early tillering stage, one at maximum tillering, and another at the panicle

initiation stage). In deep-water rice (Table 2), there was practically no effect on yield due to any variation in timing or method of N application. Deep-water rice has a long life cycle (240-250 days) and thrives fairly well on the constant pool of soluble nutrients in the floodwater. Manufactured nitrogen application to rice under deep-water conditions tends to be ineffectual because the nitrogen is apt to escape in the form of ammonia gas, following conversion to ammonium bicarbonate in these typically alkaline waters. Transplanted (T.) Aman rice, on the other hand, shows variability in yield, dependent upon timing and quantity of nitrogen application (Table 3). Under wet season Boro conditions adequate N supply at the panicle initiation stage is critical in obtaining good yields (Table 4). Thus Tables 3 and 4 show that split applications of N covering the tillering and panicle initiation stages are effective. Also well established is the effect of seasonal variability on fertilizer response. Response to fertilizer is higher in the cooler but drier Rabi season, which has plenty of sunshine and fewer pests, provided there is no moisture deficit in the soil.

The crop's nutrient demands must be properly assessed in order to avoid losses. In Table 3 it seems that a much lower N dose can be applied on T. Aman rice to produce a fair yield, as revealed by treatment 7. In the case of wheat, the marginal increase in yield for each incremental increase in applied fertilizer was rather large --up to 80 kilograms per hectare--and it decreased at the highest rates (see Table 5). In Table 6, it is clear that high doses of nitrogen, phosphate, and potassium (NPK) with or without zinc (Zn) and sulfur (S) had little effect on either rainfed or irrigated wheat.

Different soil types also affect fertilizer response rates. For example, in gray and calcareous brown floodplains, wheat yields under rainfed conditions, which were given a dose of NPK of up to 60-60-0 kilograms per hectare, were only a little more than 2 tons per hectare in most locations, except at Raipura and Pakundia, where yields were higher (Table 7). When the N dosage was increased to 80-40-0 or 80-60-0, yields increased to at least 3.0 tons per hectare in three locations with gray floodplain soils and only one location with calcareous brown floodplain soils. In general, yields are distinctly lower on the calcareous soils deposited from the Ganges River alluvium. Even in the high rainfall areas of the lower Ganges Basin, soil alkalinity (pH) can be unexpectedly high. Unfortunately, alkaline soils with a pH above 7 will destabilize urea fertilization, releasing gaseous ammonia into the atmosphere. Also, if the N fertilizers are not incorporated into the soil, especially in the anaerobic zone of flooded soils, but are left on the soil surface, denitrification losses become an additional worry. Given these conditions, how much nitrogen is lost in the form of ammonia gas (volatilization) or nitrogen gas (denitrification) has not been properly assessed. Some quantitative work on nitrogen loss is presented at the end of this section.

Table 1--Effect of fertilizer application timing on yields of broadcast Aus rice

Rate and time of N application				
Basal	Early Tillering	Maximum Tillering	Panicle Initiation	Yield
(kilograms/hectare)				(tons/hectare)
30	...	...	30	2.06
...	30	...	30	1.93
...	20	20	20	2.41
Control	...	...	...	1.66

Source: Field trials, Bangladesh Rice Research Institute, Joydebpur, 1981.

Notes: The variety of Aus rice tested was BR 203-26-2. The control application rate was 0-0-0; others received 60-40-40 kilograms/hectare of N, P_2O_5, and K_2O respectively.

Table 2--Effect of timing of N application on yields of deep-water rice

Treatment	Grain Yield
	(tons/hectare)
Control	1.73
Total N = 40 kilograms/hectare	
50 percent at basal and 50 percent before flooding	1.83
50 percent at basal and 50 percent in two foliar sprays after flooding	1.79
Four foliar sprays of 10 kilograms of N/hectare after flooding	1.64

Source: Field trials, Bangladesh Rice Research Institute, Habiganj, 1981.

Notes: The variety of rice tested was Aman IV. The control application was 0-0-0; others received 40-40-40 kilograms/hectare of N, P_2O_5, and K_2O respectively.

Table 3--Effect of timing and rates of N application on T. Aman yield

Treatment	Yield			
	BRRI	Jugitola	Bariali	Mean
	(tons/hectare)			
Basal @ 20 plus 2 top-dressings each @ 20 = 60.	4.71	4.83	3.80	4.46
No basal, first top-dressing @ 20 and second topdressing @ 30 = 50.	4.52	4.50	5.73	4.92
No basal, 3 topdressings each @ 20 = 60.	4.81	4.91	4.54	4.75
Basal plus 2 topdressings each @ 30 = 90.	4.70	4.47	3.96	4.38
No basal, 2 topdressings each @ 45 = 90.	5.04	5.37	4.15	4.85
No basal, 3 topdressings each @ 30 = 90.	4.78	5.19	4.40	4.79
No basal, 2 topdressings each @ 20 = 40.	4.53	4.56	3.87	4.32
Control (0-0-0).	3.74	4.26	3.27	3.76

Source: Field trials, Bangladesh Rice Research Institute, 1981.

Notes: The variety of T. Aman rice tested here was BR4. All the plots for this experiment seem to be quite fertile, as revealed by the yield of the control plot.

Table 4--Effect of timing of N application and transplanting date on Boro rice yields

Transplantation Date	Control	N	
		50 Percent Basal, 50 Percent at Panicle Initiation	50 Percent at Mid-Tillering, 50 Percent 10 Days before Panicle Initiation
		(tons/hectare)	
January 24 (seedling age 45 days)	3.66	4.31	5.02
March 10 (seedling age 45 days)	3.50	4.22	4.74

Source: Field trials, Bangladesh Rice Research Institute, 1981.

Notes: The variety of Boro rice planted here is BR3. The application was 80-40-40 kilograms per hectare of N, P_2O_5, and K_2O respectively.

Table 5--Effect of N application rate on wheat yields

N Rate	Yield	Marginal Increase in Yield per Incremental Increase in Fertilizer
(kilograms/ hectare)	(tons/hectare)	(kilograms)
0	1.64	...
40	2.81	29
80	3.72	23
120	4.05	8
160	4.18	3

Source: Bangladesh Agricultural Research Institute, Wheat Production Manual, Agricultural Information Service and FAO/UNDP Project on Strengthening the Agricultural Extension Service (Dhaka: BARI, 1982).

Note: Estimated regression equation:

$$\text{Yield} = 1.66 + 1.35\ N - 0.18\ N^2.$$

Table 6--Wheat yield response to NPK, Zn, and S application

Nutrient Levels	Yield	
	Irrigated	Rainfed
(kilograms/hectare)	(tons /hectare)	
Control 0-0-0	2.9	1.09
(N) 60-0-0	3.4	1.26
(N) 120-0-0	3.8	1.76
(N-P) 120-80-0	4.0	2.05
120-80-60-30 (N-P-K-S)	4.0	2.16
120-80-60-30-4 (N-P-K-S-Zn)	4.1	2.29
180-80-60-30-4 (N-P-K-S-Zn)	4.2	2.48

Source: Bangladesh Agricultural Research Institute, Wheat Production Manual, Agricultural Information Service and FAO/UNDP Project on Strengthening the Agricultural Extension Service (Dhaka: BARI, 1982), p. 65.

Table 7--Wheat yield variation in different floodplains at various fertilizer doses

Soil Type/ Location	NPK Applied in Kilograms/Hectare								Least Significant Difference
	0-0-0	40-40-0	60-40-0	60-60-0	80-40-0	80-60-0	80-60-20	80-60-40	1 percent
	(yield in tons/hectare)								
Gray floodplain									
Raipura	1.57	3.63	3.71	3.83	3.92	4.04	4.12	4.22	0.67
Pakundia	1.69	3.26	3.45	3.57	3.66	3.74	3.84	3.95	1.05
Polashbari	0.89	2.00	2.08	2.28	2.28	2.40	2.52	2.50	0.83
Gabtoli	1.51	2.05	2.27	2.46	2.58	2.76	2.98	3.40	1.39
Bhola	1.06	2.36	2.36	2.62	3.48	3.68	3.19	3.64	0.45
Barguna	1.22	2.21	2.56	2.48	2.52	2.08	2.14	2.87	0.96
Mean	1.32	2.58	2.74	2.87	3.08	3.12	3.13	3.41	...
Calcareous brown floodplain									
Sadarpur	1.08	1.80	1.94	2.13	2.17	2.17	2.95	3.22	0.30
Puthia	1.82	2.18	2.30	2.91	2.87	2.56	2.65	2.56	0.59
Khulna	1.39	2.57	3.00	2.81	3.03	2.96	3.06	3.30	0.51
Bagherpara	0.62	0.70	0.75	1.52	1.16	1.14	1.69	2.48	0.38
Mean	1.23	1.81	2.00	2.34	2.31	2.21	2.59	2.89	...
General mean	1.29	2.27	2.44	2.66	2.77	2.75	2.91	3.20	...

Source: Field trials, Bangladesh Agricultural Research Institute, Agronomy Division, 1983.

Phosphate (P) is the second major plant nutrient in the NPK fertilizer grade. The quality and early maturity of grain crops and healthy rooting systems has for many years been associated with adequate phosphate levels in the soil.

In general, application of phosphatic fertilizer is done at the final stage of land preparation in Bangladesh. In a study of 1,867 T. Aman farmers, triple superphosphate was found to be the most widely used fertilizer applied to their fields before transplanting.[1] Bangladesh Rice Research Institute (BRRI) varieties received less. Approximately 10-15 percent of the soil phosphorus is available to the crop. The residual P becomes fixed, particularly in lateritic soils, and it is released slowly over time.

Fertilizer demonstrations were conducted in 1981-82 and yield responses of rice to different nutrients including phosphorus were classified into low, medium, and high on the basis of their value-cost ratio (VCR) (see Figure 1).[2] This was estimated by dividing the value of the increase in yield attributed to fertilizers by the cost of fertilizer used. Yield response of rice to phosphorus is considered low when the VCR is less than 2, medium when it is between 2 and 4, and high when it is more than 4. For instance, VCR = 4 means a return of 4 taka for each taka invested in fertilizer.

The response of rice to a balanced dose of plant nutrients has been quite high. In fact, in the presence of added nitrogen, the uptake of phosphorus is increased. The improved availability of phosphorus may be due in part to the lowering of soil pH in the vicinity of the P fertilizer due to nitrification and root exudates. Table 8 shows some of the favorable effects of applying a balanced dose of NPK. For various socioeconomic reasons, Bangladesh farmers usually cannot apply the recommended balanced doses.

Potassium (K) is the third nutrient needed to complete the balance. K usually increases lodging and disease resistance, as well as photosynthesis rates, and it improves the taste and texture of grains and fruits.

Although potassium is usually available in sufficient amounts, it is suggested that minimal doses of muriate of potash (KCl) be

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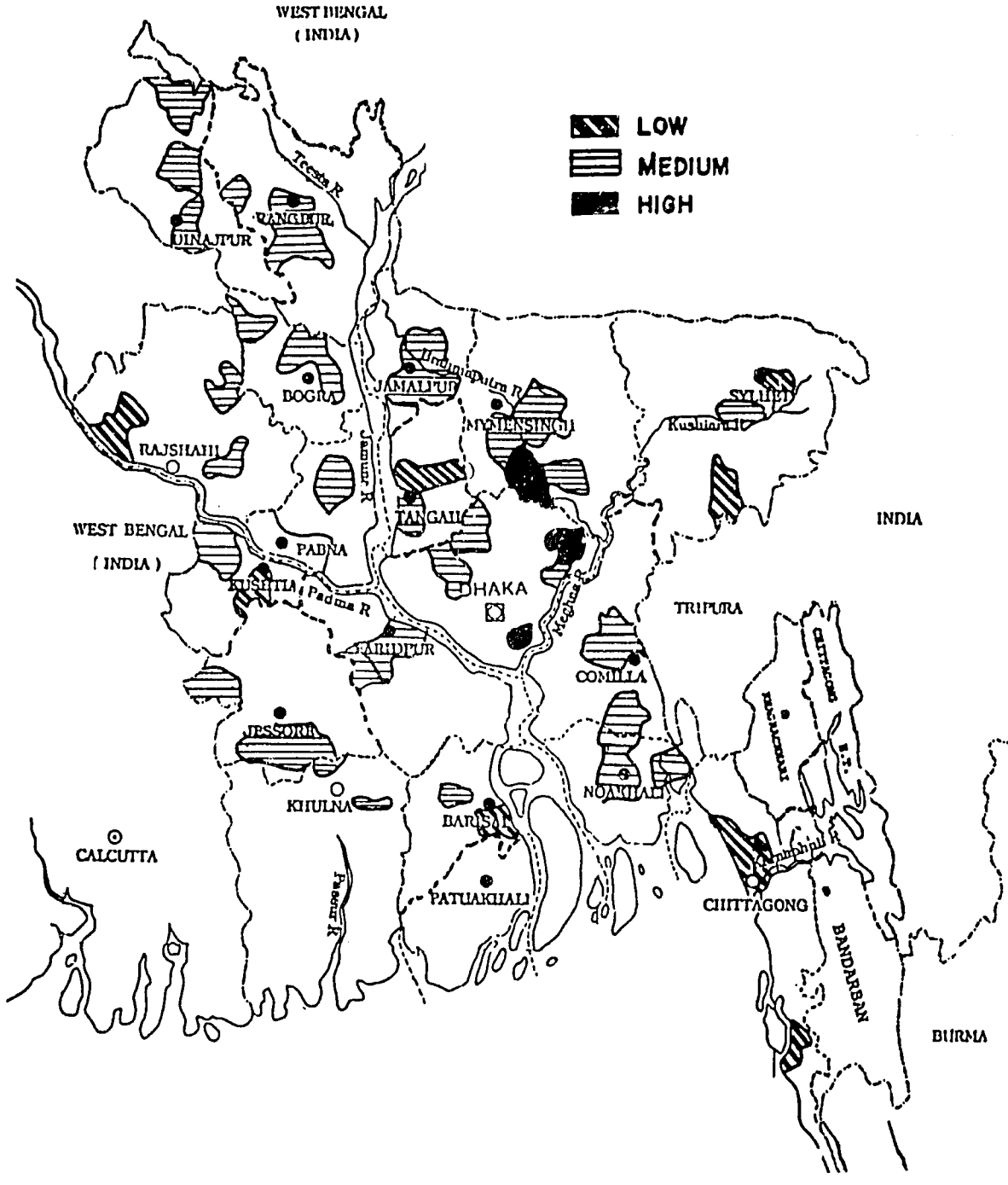
[1]M. S. Ahmad, Studies on Methodology for Forecasting the Yield of Transplanted Aman Rice Based on Dates of Seeding and Transplanting in Bangladesh, 1983-84 (Joydebpur Gazipuri, Bangladesh: Bangladesh Rice Research Institute, June 1984).

[2]Bangladesh, Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," report of the Fertilizer Demonstration and Distribution Project, BGD/80/002, Dhaka, 1984.

Figure 1--Yield response of rice to phosphorus



Source: Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," Report of the Fertilizer Demonstration and Distribution Project, BGD/80/002 (Dhaka, 1984).

Table 8--Nutrients removed from soil by rice crops

NPK Applied			Rice Yield[a]	Nutrient Removed		
N	P_2O_5	K_2O		N	P_2O_5	K_2O
			(kilograms/hectare)			
0	0	0	3,029	45.13	11.42	65.43
60	0	0	3,994	59.51	15.06	86.27
0	40	0	3,381	50.38	12.75	73.03
0	0	40	3,264	48.63	12.31	70.50
60	40	0	4,119	61.37	15.53	88.97
0	40	40	3,652	54.41	13.77	78.88
60	0	40	3,981	59.32	15.01	85.99
60	40	40	4,142	61.72	15.62	89.47

Source: Bangladesh Rice Research Institute, Soil Chemistry Division.

[a]Average of 9 experiments.

applied as a preventive measure in maintaining present levels in parts of Khulna's gray calcareous floodplains and in Jessore, Kushtia, and Barisal's nonsaline tidal floodplains. In other areas, K deficiency can pose a problem, especially in the acidic and lateritic soils of Barind, Madhupur, the Lalmai hills, and other hilly areas. The light-textured soils of nonsaline and noncalcareous floodplains, such as those found in the Teesta floodplain around Thakurgaon, Debiganj, Domar, and Nilphamari all require potash applications. Usually K is added as basal application, but in light-textured soils, K is applied as a topdressing at the panicle initiation or heading stage (where the ripening stage is longer than 30 days) to give better results. A topdressing of K on T. Aman rice in the Domar-Debiganj area at the late tillering or panicle initiation stages will eliminate black spots on the grain and increase the quality of paddy.

Although K is subject to greater leaching in sandy soils than in clay soils, higher application rates are usually required on clay soils. For example, given 150 kilograms of applied K_2O per hectare, the exchangeable K level will increase to 10-15 milligrams K_2O per 100 grams in the rhizosphere (the root area) with an increase of K concentration in the soil solution of sandy soil of 0.5 milliequivalents per liter, in contrast to an increase in soil concentration in a clay soil of only 0.05 milliequivalents per liter.

The yield response to potash is affected by soil types, as can be seen by data on rice yields in Table 9. There is significant variation from locality to locality in the response of Aman to K fertilizer, but in general a higher response is found in gray terrace valley soils and gray floodplain soils than in calcareous brown floodplain soils. Significant response is found in Rangpur, Sujanagar, Fakirhat, Madhupur, Nachol, Sherpur (Bogra), Chirirbandar, and Phulbari. One unexpected finding was the inclusion of Sujanagar as a high-response area, although there seem to be high levels of available K (100 parts per million) there in comparison to other localities. It may be assumed that K uptake has been blocked in this area by factors such as K being fixed by certain types of clay or K+ ions in competition with NH_4^+ ions.

Yield response of irrigated wheat to K is, in general, moderate and soil type does not seem to explain much of the variability (Table 10). However, a significantly higher response to K can be seen in Madhupur, Fulbaria, Sujanagar, and Fakirhat. The above explanation for Sujanagar may explain this anomaly as well.

In Bangladesh, KCl is the most commonly used K fertilizer, especially on rice and wheat. Potassium sulfate is a much better fertilizer, supplying both K and S, but this more expensive product is rarely used. However, it is recommended where sulfur deficiency is a particular problem.

In summary, it would be useful to know annual loss rates of NPK under various agroecological conditions, cultural practices, and cropping systems. Unfortunately, this kind of information is not available. Present knowledge of how to reduce loss rates on N-fertilized fields is limited to the following points.

1. Split applications instead of a single application are recommended. In fertile soil, there is no need for basal application. The required N can be applied in appropriate stages of plant growth for maximum utilization.

2. Deep placement of N fertilizers in the rhizosphere normally improves N efficiency. The broadcast method without incorporation into the soil increases N loss.

3. Slow-release N fertilizers decrease N losses. Sulfur-coated urea and "super granules" are also better than normal pelleted or granulated urea for deep placement and slow release.

4. Soils with high pH will always accelerate N loss from all manufactured fertilizers applied, including urea, ammonium sulfate, diammonium phosphate (DAP), and similar products.

Table 9--Response of T. Aman rice yields to potash application

Soil Type	Location	Control Group 0-0-0	Pounds of Potash (K_2O) Applied 0	20	40	60	80	Least Significant Difference 5 Percent	1 Percent
		(maunds/acre)							
Gray floodplain	Rangpur (44.0)	27.67	30.50	32.67	34.42	35.50	36.83	1.36	1.93
	Kaunia (17.0)	18.83	26.00	29.67	29.67	32.42	31.83	2.56	5.65
	Mean (30.5)	23.25	28.25	31.17	32.05	33.96	34.33	...	...
Calcareous brown floodplain	Sujanagar (100.0)	29.66	51.30	54.85	57.96	59.71	59.94	1.17	1.62
	Fakirhat (20.0)	20.17	20.00	27.08	33.17	24.33	29.83	3.26	4.63
	Jessore (38.0)	14.50	22.00	2[illegible].50	26.67	24.00	23.67	3.43	4.88
	Mirpur (20.0)	27.92	56.92	56.58	60.00	58.17	57.33	2.92	4.15
	Mean (44.5)	23.06	37.56	40.75	44.45	41.55	42.69	...	...
Shallow red-brown terrace soil	Madhup r (24.0)	16.88	26.88	29.50	30.75	32.63	33.50	0.98	1.36
Gray terrace and valley soil	Nachol (16.0)	39.38	47.49	52.25	54.56	56.38	59.88	1.64	2.27
	Patnitola (27.0)	25.61	32.82	33.23	34.79	35.93	36.37	0.79	1.09
	Sherpur (28.0)	19.04	28.18	32.00	33.70	35.54	36.48	2.07	2.95
	Adamdighi (34.0)	25.86	40.67	42.57	44.73	46.57	47.74	0.21	0.30
	Chirir Bandar (38.0)	23.67	42.00	46.33	49.50	49.83	56.17	0.36	0.51
	Phulbari (20.0)	22.66	36.58	37.41	37.83	37.41	37.66	0.56	0.88
	Mean (36.4)	25.48	37.96	40.80	42.72	43.91	44.50	...	...
General mean (37.0)		23.85	35.66	38.59	40.83	41.01	42.46	...	...
Percent increase over 0 pounds of K_2O		...	...	8.22	14.50	15.00	19.10	...	...
Mean K_2O response		...	...	12.01	10.60	7.32	6.97	...	...

Source: Bangladesh Agricultural Research Institute, On-Farm Research Division, in Bangladesh Agricultural Research Council, Second Annual Report: Coordinated Soil Test Crop Response Correlation Studies, 1981-82, Soils and Irrigation Publication No. 13 (Dhaka: BARC, 1983).

Notes: N application rate = 80 pounds/acre; P_2O_5 rate = 60 pounds/acre.
Figures in parentheses indicate potassium (K) level in parts per million.
1 maund = approximately 37 kilograms.

Table 10--Response of irrigated wheat yields to potash in 50 trials

Soil Type	Location	Control Group	Kilograms of Potash (K_2O) Applied per Hectare				Least Significant Difference	
			0	20	40	60	5 Percent	1 Percent
			(tons/hectare)					
Gray floodplain	Narsingdi (50.0)	1.16	2.33	2.38	2.42	2.46	0.008	0.012
	Fulbaria (36.0)	1.33	3.58	3.77	3.97	4.07	0.055	0.082
	Tangail (38.0)	1.20	2.05	2.25	2.35	2.53	0.162	0.236
	Barguna (109.0)	0.92	1.75	1.93	2.05	1.93	0.558	0.813
	Rangpur (44.0)	2.33	3.17	3.42	3.42	3.33	0.494	0.719
	Mean (55.0)	1.18	2.15	2.30	2.39	2.41	...	...
Calcareous brown floodplain	Sujanagar (190.0)	1.53	2.40	3.11	3.78	4.43	0.382	0.537
	Fakirhat (86.0)	1.26	2.47	3.04	3.28	3.17	0.205	0.298
	Jessore (121.0)	1.09	2.65	2.76	2.76	2.85	0.053	0.077
	Bheramara (96.0)	0.52	1.96	2.18	2.55	2.99	0.197	0.027
	Chuadanga (154.0)	1.12	2.00	1.91	2.17	1.82	0.568	0.827
	Mean (129.0)	1.10	2.30	2.60	2.91	3.05	...	...
Shallow red-brown terrace soil	Madhupur (33.0)	1.36	2.55	2.95	3.31	3.97	0.102	0.144
Gray terrace and valley soils	Adamdighi (24.0)	1.04	2.82	2.98	3.00	2.92	0.020	0.029
	Kahaloo (52.0)	0.96	2.73	2.83	2.94	2.85	0.047	0.069
	Parbatipur (60.0)	0.89	1.52	1.60	2.42	2.56	0.465	0.670
	Mean (42.0)	0.96	2.36	2.44	2.78	2.78	...	...
General mean (75.0)		1.20	2.41	2.62	2.86	2.95	...	...
Percent increase over 0 kilograms of K_2O		...	...	8.90	18.90	22.50	...	...
Mean K-response of kilograms of grain/kilograms K		...	...	10.75	11.38	9.05	...	...

Source: Bangladesh Agricultural Research Institute, On-Farm Research Division, in Bangladesh Agricultural Research Council, Second Annual Report: Coordinated Soil Test Crop Response Correlation Studies, 1981-82, Soils and Irrigation Publication No. 13 (Dhaka: BARC, 1983).

Notes: N application rate = 100 kilograms/hectare; P_2O_5 rate = 60 kilograms/hectare.
Figures in parentheses indicate potassium (K) level in parts per million.

5. Use of urea, ammonium sulfate, and DAP in upland conditions enhances nitrate formation and thus N loss through leaching. Band placement or plow sole application at planting time are not practiced in Bangladesh. The usual method of broadcasting urea is only about 50 percent efficient. In fact, the mean efficiency of urea N is about 30 percent under upland rainfed conditions. Under transplanting conditions with good water management, the N loss can be reduced and the efficiency of N uptake can be increased to about 50 percent.

6. A low content of organic matter in the soil also accelerates N loss.

7. Low sulfur and zinc levels decrease N uptake.

8. Continuous waterlogging seriously affects N uptake.

9. Loss of organic P exacerbates the problems of deficiency from P fertilizer fixation. Organic P loss could be decreased by recycling human and animal bones in crop fields. Instead, Moslems and Christians bury their dead in graveyards and Hindus burn their dead, throwing the ashes in rivers where they ultimately find their way to the sea. Animal bones are mostly exported. Conscious efforts to replace phosphates can help to build up reserves in the soil.

At present, quantitative information about NPK utilization from BRRI's Soil Chemistry Division has been used to develop a balance sheet for rice (Tables 11 to 13) and wheat (Table 14). For example, column 3 of Table 13 indicates that the opening balance of N, P, and K for the next crop will be 57, 79, and 61 percent, respectively, of the native nutrient stock originally present in the soil. If depletion continues at this rate, N and K will be in deficit after one more crop is harvested, and P would last for three more crops. This is only a rough estimate, and because NPK uptake is a complex process, recommendations should be based upon other factors as well.

Sulfur and Zinc Deficient Soils

Sulfur is now considered to be the fourth major element vitally needed for crop production. Unfortunately, the stress on single element fertilizers, disregarding ammonium sulfate, single and double superphosphates, and potassium sulfate has led to problems of S deficiency. Commonly used higher analysis fertilizers such as urea, triple superphosphate (TSP), and DAP, and cheap but lower analysis KCl are all devoid of sulfur. Further consideration should be given to the possibility of using sulfuric acid in phosphate fertilizer manufacturing processes to provide an adequate amount of S to soils at recommended phosphate application rates.

Table 11--Nutrients removed by rice crops, 1981/82

Rice Crop	Area	Nutrients Removed		
		N	P_2O_5	K_2O
	(1,000 hectares)	(1,000 metric tons)		
Aus				
Local	2,674	219.27	61.50	328.90
HYV	472	39.65	11.80	69.38
Subtotal	3,146	258.92	73.30	398.28
B. Aman				
Local	1,586	130.05	36.48	195.08
T. Aman				
Local	3,460	283.72	79.85	425.58
HYV	956	80.30	23.90	140.53
Subtotal	6,002	494.07	139.96	760.19
Boro				
Local	405	33.21	9.32	49.82
HYV	898	75.43	22.45	132.01
Subtotal	1,303	108.64	31.77	181.83
Total	10,451	861.63	245.03	1,340.30

Source: Bangladesh Rice Research Institute.

Table 12--Nutrients supplied to all crops, 1981/82

Fertilizer		Nutrient		
Type	Amount Applied	N	P_2O_5	K_2O
		(metric tons)		
Urea	527,000	237,193	...	...
Diammonium phosphate	80,000	14,400	33,600	...
Triple super-phosphate	211,830	...	88,969	...
Muriate of potash	45,560	...	...	27,336
Total		251,595	122,569	27,336
Ratio, $N:P_2O_5:K_2O$		9.20	4.48	1.00
75 percent of nutrients		188,696	91,927	20,502

Source: Bangladesh Rice Research Institute.

Note: The fertilizer application data in this table refer to application on all crops, most but not all of which is actually applied to paddy soils. In this table, 75 percent of fertilizers are assumed to have been applied to paddy in 1981/82. In Mahabub Hossain's paper in this volume (Table 9), estimates of 79.3 percent (1977/78) and 81.3 percent (1983/84) were made.

Table 13--NPK balance sheet for rice crops

Nutrients	Removed by the Rice Crop (1)	Native Nutrient Content in the Soil[a] (2)	Nutrients Added[b] (3)	Total Soil Stock (2+3)	Balance in the Soil (2+3)-1
		(1,000 metric tons)			
N	861.63	1,575.3	188.70	1,764.00	902.37
P_2O_5	245.03	869.5	91.93	961.43	716.40
K_2O	1,340.30	3,414.0	20.51	3,434.51	2,094.21

Source: Data obtained from Bangladesh Rice Research Institute, Soil Chemistry Division.

[a]The native nutrient content in the soil has been taken from the mean of control and others where those respective nutrients were added. The totals of N, P_2O_5, and K_2O used under such conditions without addition of N, P_2O_5, K_2O are respectively 45.22, 24.96, and 98.00. These figures represent about 30 percent of the total soil stock, as shown in Column 3.

[b]Total chemical fertilizer application (for all crops) is used for the computation; however, organic manure application has not been estimated.

Table 14--NPK balance sheet for a wheat area of 513,200 hectares

Nutrients	Nutrients Removed from the Soil	Native Nutrients in the Soil	Nutrients Added	Total	Balance
		(1,000 metric tons)			
N	48.75	52.35	56.57	108.92	60.17
P_2O_5	12.32	32.84	49.60	82.44	70.12
K_2O	70.82	92.38	91.88	184.26	113.44

Source: Data obtained from S. M. Elias and M. S. Hussain, Wheat Production in Bangladesh - Socio-economic Assessment of Improved Technology and Identification of Constraints to Higher Production (Dhaka: Bangladesh Agricultural Research Institute, Division of Agricultural Economics, 1983).

Notes: Mean fertilizer used per hectare: urea, 127 kilograms; TSP, 129 kilograms; MP, 33 kilograms; organic manure, 5,448 kilograms. These figures exceeded estimated application in all recent years.

S is a component of plant protein, and most crops need as much sulfur as phosphorus. In general, a constant proportion of N to S (15:1) is found in plant protein. The S content in field crops varies from 13 to 96 kilograms per hectare, and the percent of S removed when the crop is harvested also varies from 23 to 56 percent of S available per hectare.

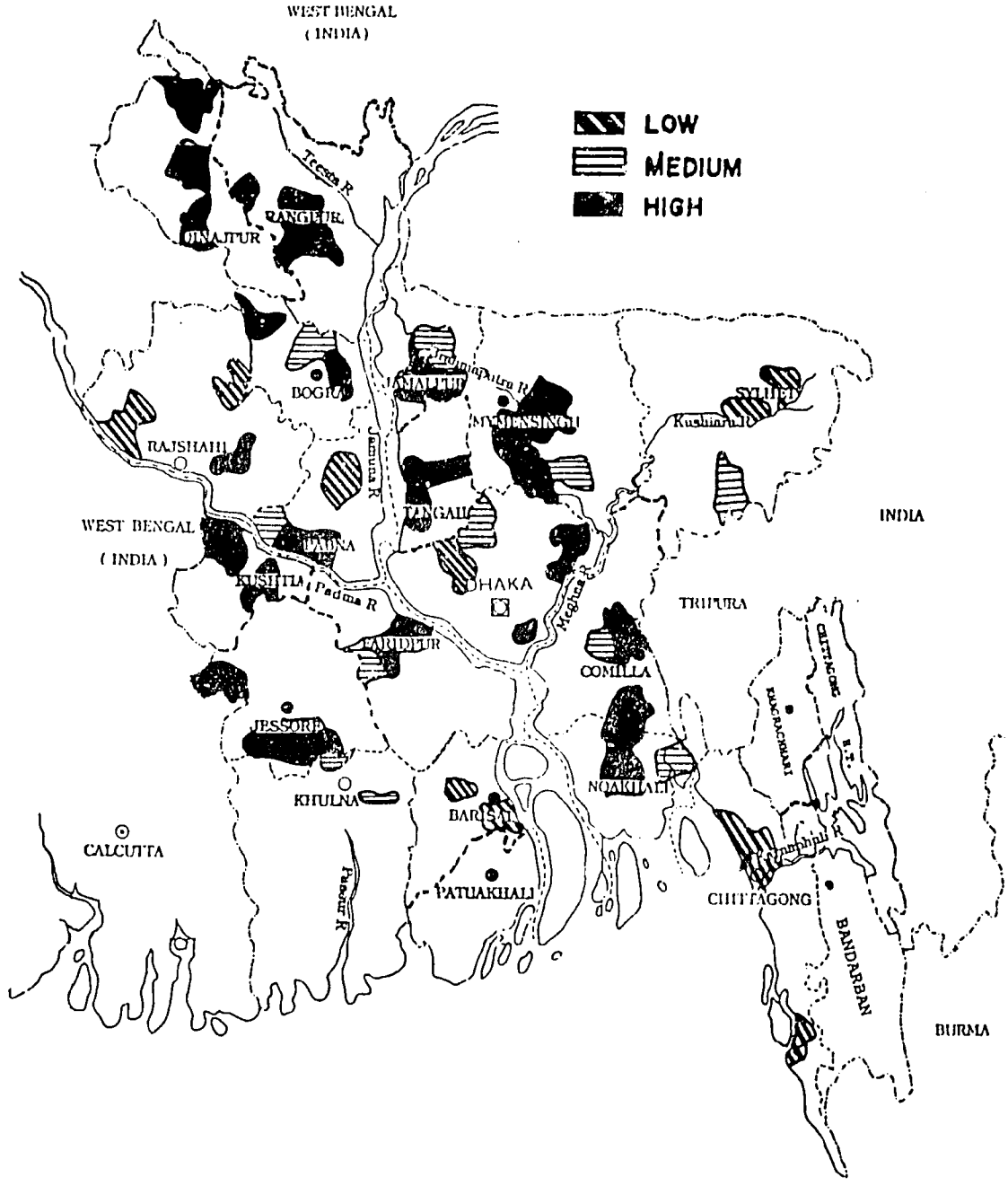
The main forms of S in the soil are the inorganic sulfates and the S in organic compounds. Sulfate in the soil solution available to plants is the product of the interaction of adsorption and leaching losses. S availability is similar to that of N. Organic S acts as a reserve. It undergoes transformation to the sulfate form by microbial action, which depends on a temperature of 40°C, soil moisture at 60 percent of field capacity, pH, numbers and types of soil organisms, and oxygen. Mineralization of S from its organic form occurs when the S content is close to 0.15 percent.

Although S deficiencies are difficult to detect with soil tests, it seems that approximately 3 million acres exhibit S deficiency (Figure 2). The heavier clay soils of the northern districts, Madhupur and Lalmai hill soils, tend to be S deficient. S deficiency is the ultimate result of improper agricultural practices and soil exploitation, such as constant removal of crops with residue where cropping intensity is high, constant loss of soil organic matter, S loss from leaching and erosion, and use of higher analysis fertilizers.

The S requirement for a crop can be estimated on the basis of either its N or P requirement. One unit of S for 5-7 units of N may be used. The standard formula is one unit of S for every three units of P_2O_5. An N:S ratio of 10 is a more reliable index when both N and P are essential. This rule of thumb would underestimate the S requirement where low rates of N and P are applied. Additional experimental trials would have to be conducted to determine the correct dosage. For crops with very high yields, the S requirement increases and the proportion of S to N may be as high as 1:5 or 1:7.

Cultural practices can be modified to deal with problems of S deficiency. In order to get the best response from S applications, especially in rice cultivation, a waterlogged soil must be avoided, particularly in the Boro season. Where a Boro crop must be grown, the date of transplanting must be shifted to late February or March so that the soil is thoroughly dried by the sun after the T. Aman harvest. In some cases such a practice improves the availability of soil S. The practice of drying the soil prior to panicle initiation is also desirable in increasing S uptake efficiency. On the other hand, when the soil is waterlogged for about 115-125 days, the S availability will decrease to an almost critical level.

Figure 2--Yield response of rice to sulfur



Source: Bangladesh Department of Agricultural Extension, Field Services Division, Results of Fertilizer Demonstrations, 1981-82, report of the Fertilizer Demonstration and Distribution Project, BGD/80/002 (Dhaka, 1984).

Note: Data were obtained from 1,182 demonstration sites in 31 thanas. The unmarked areas were not tested. Rice data were aggregated over the Aus, T. Aman, and Boro seasons on the map, but disaggregated results are presented in the report tables. Sulfur was applied in the form of gypsum.

Standard sulfate fertilizers and their S content are listed below.

Fertilizer	S Content (percent)	S (kilograms per ton)
Ammonium sulfate	23.7	243.0
Ammonium nitrate sulfate	5.0	50.0
Ammonium phosphate sulfate	15.4	155.0
Ammonium sulfate nitrate	15.1	121.0
Superphosphate	12-14	140.0
Potassium sulfate	17-18	176.0
Gypsum, $CaSO_4$ $2H_2O$	18-19	186.0
Ferrous sulfate	18-19	186.0
Poultry droppings	1.1	11.0
Zinc sulfate, 36.4 percent Zn	17.8	178.0
Urea - gypsum, $CaSO_4 + 4CO(NH_2)_2$	14.8	148.0
Urea sulfur, $CO(NH_2)_2 + S$	10.0	100.0

The last two compounds can be prepared by adding gypsum to urea or S to urea. Possible sources of S supply will be discussed at the end of this section. Oilcakes also contain S and can be used safely where the S requirement is low. They also make good organic manure for almost all crops.

The response of wheat yields to S application is shown in Tables 15 and 16. Table 15 indicates a slight response to S at an NPKS dose

Table 15--Wheat yield response to NPK, S, and Zn

Treatment	Yields With Irrigation		Yields Without Irrigation	
	Rajbari	Jessore	Rajbari	Jessore
	(tons/hectare)			
Control	1.86	1.39	1.92	1.09
N_1 (60)	3.20	2.50	2.73	1.26
N_2 (120)	3.56	2.38	3.34	1.76
N_2P (120-80)	3.71	2.50	3.40	2.05
N_2PK (120-80-60)	3.70	2.59	3.42	2.16
N_2PKS (120-80-60-30)	4.16	3.74	3.52	2.29
N_2PKSZn (120-80-60-30-4)	4.27	2.97	3.57	2.31
N_3PKSZn (180-80-60-30-4)	4.40	2.15	3.63	2.48
LSD 5%	0.93	0.43	1.02	0.25

Source: Bangladesh Agricultural Research Institute, Annual Report, 1980-81 (Joydebpur: BARI, 1982).

Notes: N_1 = 60 kilograms/hectare, N_2 = 120 kilograms/hectare, and N_3 = 180 kilograms/hectare; P = 80 kilograms/hectare; K = 60 kilograms/hectare; S = 30 kilograms/hectare; and Zn = 4 kilograms/hectare. LSD = least significant difference.

Table 16--Wheat yield response to NPKS

Floodplain Soil Type	Location	NPKS Application Rates									Least Significant Difference	
		0-0-0	60-40-0	80-40-0	100-40-0	80-60-0	100-60-0	120-60-0	100-60-0	100-60-40-30S[a]	5 Percent	1 Percent
		(yield in tons/hectare)										
Gray	Kaliganj	1.60	2.85	3.12	3.22	3.37	3.58	3.55	3.70	4.08	0.140	0.193
	Bhairab	1.97	3.49	3.53	3.59	3.53	3.60	3.61	3.65	3.70	0.035	0.048
	Chowddagram	1.42	2.21	2.32	2.43	2.63	2.71	2.78	2.89	2.97	0.130	0.180
	Mean	1.66	2.85	2.99	3.08	3.18	3.30	3.31	3.41	3.58		
Non-calcareous brown	Dinajpur (Kotwali)	1.91	3.43	3.78	5.00	3.96	3.99	3.78	4.31	3.97	0.250	0.240
	Boda	1.37	2.50	3.04	3.30	3.37	3.63	3.76	3.67	3.86	0.407	0.561
	Mean	1.64	2.97	3.41	4.15	3.67	3.81	3.77	3.99	3.92		
Calcareous brown	Kaliganj	1.56	2.44	2.97	3.07	3.67	4.00	4.12	3.94	4.50	0.157	0.216
General mean		1.64	2.82	3.13	3.43	3.42	3.59	3.60	3.69	3.85	...	...

Source: Results from Bangladesh Agricultural Research Institute, On-Farm Research Division, 1982/83.

Note: NPK application rates are given in kilograms per hectare.

[a]30 S = 30 kilograms of sulfur per hectare.

of 120-80-60-30 kilograms per hectare (with low statistical significance) at both locations under both rainfed and irrigated conditions. Where N is high, S uptake from soil usually increases. This may satisfactorily meet a plant's requirements. A similar situation is revealed by the data in Table 16.

At 80 kilograms of N per hectare, the rice yields increase to 6.04 tons per hectare for the variety BR3 but not for BR11 (Table 17). The addition of P, K, S, or Zn did not affect the yield significantly, except for BR11 where yield increased by about 0.65 tons per hectare with the application of 200 kilograms of gypsum (36-38 kilograms of S per hectare). Table 18 provides data on the effects of NPKS and Zn on rice at various locations. There was a significant yield increase with the application of S and Zn on T. Aus and Boro rice at Narsingdi and Godagari, and on T. Aus and T. Aman rice in Jessore. Research conducted by the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP) with the cooperation of BRRI and Bangladesh Agricultural Research Institute (BARI) shows a significant yield response to S on rice at different locations. Based on this research, Figure 3 identifies the location of thanas in which low, medium, and high response rates to S in rice production were recorded, with results aggregated across seasons and test sites within each thana.

Table 17--Rice yield response to NPK with and without Zn, S, and manure

Fertilizer Rate						Yield	
N	P_2O_5	K_2O	Gypsum	$ZnSO_4$	Cow Dung	BR3 (Boro)	BR11 (T. Aman)
(kilograms/hectare)						(tons/hectare)	
0	0	0	0	0	0	3.42	2.99
80	0	0	0	0	0	6.04	4.43
0	60	40	0	0	0	4.03	2.95
80	60	40	0	0	0	6.08	4.56
80	60	40	200	0	0	6.17	5.21
80	60	40	0	20	0	6.48	4.71
80	60	40	200	20	0	6.12	4.71
0	0	0	0	0	20	4.46	3.40

Source: Bangladesh Rice Research Institute, "Internal Review, Section XV," Dhaka, 1982.

Table 18--Yield response on transplanted Aus, Boro, and transplanted Aman rice crops to NPKS and Zn

Treatment	Narsingdi			Kishoreganj			Godagari			Jessore and Kotwali		
	T. Aus	Boro	T. Aman	T. Aus	Boro	T. Aman	T. Aus	Boro	T. Aman	T. Aus	Boro	T. Aman
	(tons/hectare)											
0-0-0	3.16	4.04	2.32	3.74	3.05	2.68	2.64	3.90	2.53	3.52	6.02	3.36
N_1	3.92	5.70	2.44	5.73	4.07	3.12	2.93	4.40	2.83	3.78	6.54	3.99
N_2	4.29	6.86	2.51	6.19	4.10	3.31	2.69	4.83	3.02	3.98	7.33	4.16
N_2P	4.73	7.15	2.64	6.60	4.32	3.33	2.95	5.59	3.23	4.10	7.50	4.27
N_2PK	5.14	6.98	2.75	6.81	4.76	3.69	3.41	5.91	3.52	4.24	7.77	4.46
N_2PKS	5.62	7.19	3.31	6.95	4.18	4.19	3.40	6.69	3.84	4.40	8.10	5.05
N_2PKSZn	6.28	8.08	3.15	7.08	5.12	4.34	3.58	6.86	3.70	5.39	8.39	5.48
N_3PKSZn	5.73	7.96	3.36	6.62	5.09	4.72	3.44	5.80	3.33	5.45	8.66	5.89
LSD, 5 percent[a]	0.25	1.00	0.19	0.17	0.51	0.42	0.10	0.13	0.13	0.10	0.34	0.22

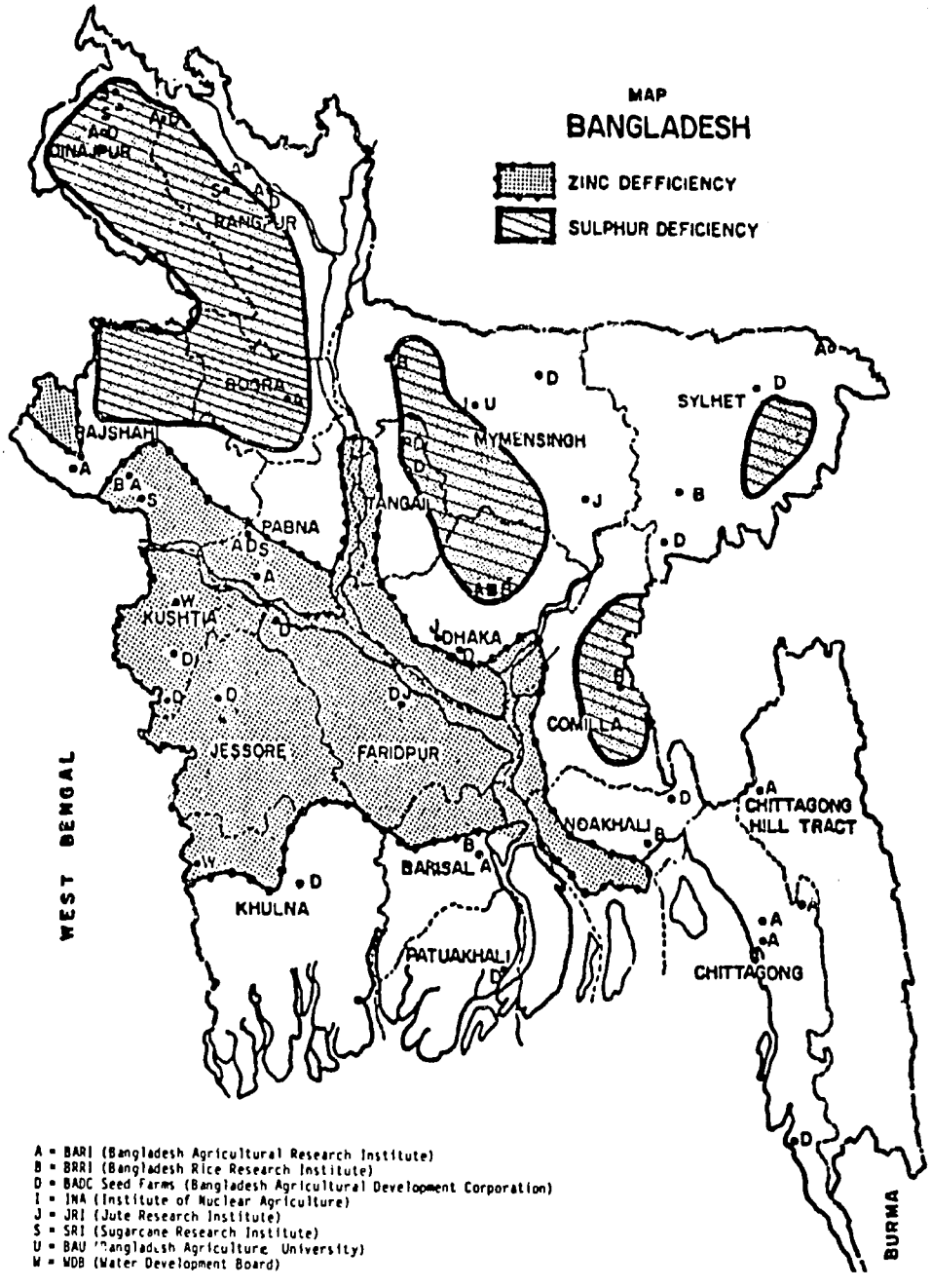
Source: Results of tests conducted by Bangladesh Agricultural Research Institute, On-Farm Research Division, 1981.

Notes: The yield responses above were obtained with the following applications of chemicals. (These are weights of active ingredients, not of the fertilizer mixture itself.) Phosphorus was applied in the form of P_2O_5 and potassium in the form of K_2O.

Chemical	On T. Aus	On Boro	On T. Aman
	(kilograms/hectare)		
N_1	60	60	45
N_2	120	120	90
N_3	135	180	135
P	80	80	80
K	60	60	60
S	30	30	30
Zn	8	8	8

[a]LSD refers to a least significant difference.

Figure 3--Zinc and sulfur deficiencies in Bangladesh



Note: Some overlap of sulfur- and zinc-deficient areas may occur and response tests prove to be positive in areas not accounted for as being deficient, as outlined on this map. This map is more general in that it shows sulfur-deficient soils in the northern and central districts rather than in the coastal areas, and zinc-deficient soils in the deeply flooded areas rather than in well-drained areas.

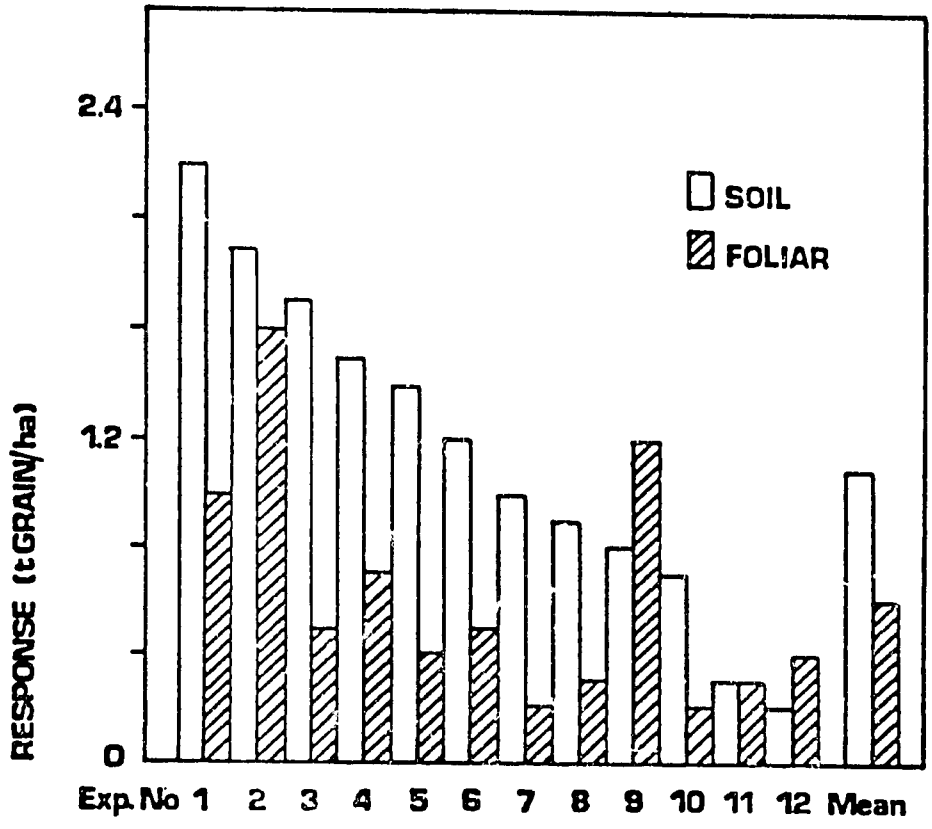
Among the micronutrients, Zn, iron (Fe), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl), and cobalt (Co) play a vital role. Under certain conditions, sodium (Na), silicon (Si), and vanadium (V) have been found to be important for some plant species. However, at present in Bangladesh, adequate survey work has only been done on Zn. Approximately 4 million acres are thought to be deficient in Zn, as shown in Figure 2. The soils of the Gangetic alluvium and those near the banks of other major rivers exhibit Zn deficiency.

Zn is not required in large amounts to meet a plant's needs, but it can become the limiting factor affecting yields. In a 10-ton rice crop (5 tons of grain and 5 tons of straw), the nitrogen content may be 105-110 kilograms whereas the Zn content may be limited to a maximum of 250 grams. This is just 0.25 percent of the nitrogen requirement. Nevertheless, if the Zn content in the soil is low (less than 20 parts per million) the plant cannot meet its Zn requirement and the yield is drastically reduced. In the case of severe Zn deficiency, the yield may be as low as zero.

Zinc availability decreases with increasing soil pH. Thus, Zn toxicity, although not common in plants, can be treated with adequate applications of lime. Other factors that affect availability include soil texture, soil moisture status, temperature, organic matter, and the interaction of other nutrients. Zn deficiency is commonly found in calcareous, alkaline, and saline soils where the pH may be greater than 6.0. Liming can retard Zn availability if it increases the soil pH above 6.0. High levels of organic matter in the soil usually increase Zn availability. Also, light-textured soils with low organic matter usually are prone to Zn deficiency. Low soil temperatures and high levels of P applications may also induce Zn deficiency, especially on calcareous soils.

The effect of Zn on wheat yields is shown in Table 15. A combination of NPKS and Zn increased wheat yields to a level of approximately 4 tons per hectare, and yet even in these Zn deficient areas the profitability of applying Zn is not totally convincing given the results shown. Large experimental error may be the cause for such results. The response of wheat to soil and foliar application of Zn (10 kilograms of Zn per hectare and 1.5 kilograms of Zn per hectare respectively) are evident in India (Figure 4). The response of rice to Zn fertilization is shown in Tables 19 and 20. Approximately 6.9 tons per hectare of BR3 could be obtained by the application of 20 kilograms of Zn per hectare. It seems that BR11 gave a lower yield for other reasons. At a high level of N (80 kilograms per hectare) rice can use Zn more efficiently. At Tebunia, Zn applications to the soil and in foliar form produced higher yields than at Gournadi (Table 19). About a 100 percent yield increase was

Figure 4--Response of wheat to soil and foliar application of zinc in India



Notes: Soil application = 10 kilograms Zn per hectare; foliar application = 1.5 kilograms Zn per hectare.

Table 19--Rice yield response to zinc

Treatment	Grain Yield: Tebunia Seed Multiplication Farm Pabna (BR3)	Grain Yield: Gournadi Barisal (IR8)
	(tons/hectare)	
Control	5.51	2.96
Root dipped in 2 percent ZnO suspension	5.93	3.29
$ZnSO_4$ 10 kilograms/hectare	7.06	3.38
$ZnSO_4$ 20 kilograms/hectare	6.89	3.48
$ZnSO_4$ 0.5 percent foliar spray	5.60	3.21
1 gallon/hectare zinc chelate spray	6.20	3.42
Coefficient of variation	9.00	10.00

Source: Bangladesh Rice Research Institute, "Internal Review, Section XV," Dhaka, 1982.

Note: BR3 and IR8 designate specific rice varieties planted for the experiment.

Table 20--Mean rice yields with and without NPK or zinc

Treatment: Zn	Treatment: NPK	Grain Yield
		(tons/hectare)
No	No	2.2
No	Yes	2.4
Yes	No	4.5
Yes	Yes	4.7

Source: J. C. Katyal and N. S. Randhawa, "Micronutrients," FAO Fertilizer and Plant Nutrition Bulletin No. 7 (Rome: FAO, 1983).

Note: This table is based on data from eight farmers' fields.

obtained for rice through Zn applications by Katyal and Randhawa (Table 20). Figure 5 shows three levels (low, medium, and high) of yield response of T. Aman rice to Zn applications among various thana in Bangladesh where tests were conducted. The economics of Zn fertilization of wheat and rice crops in India are impressive, as shown in Figure 6. The data upon which this figure is based imply an input-output ratio of 1:6. Assuming similar input prices and higher output prices in Bangladesh, the input-output ratio is expected to be even greater.

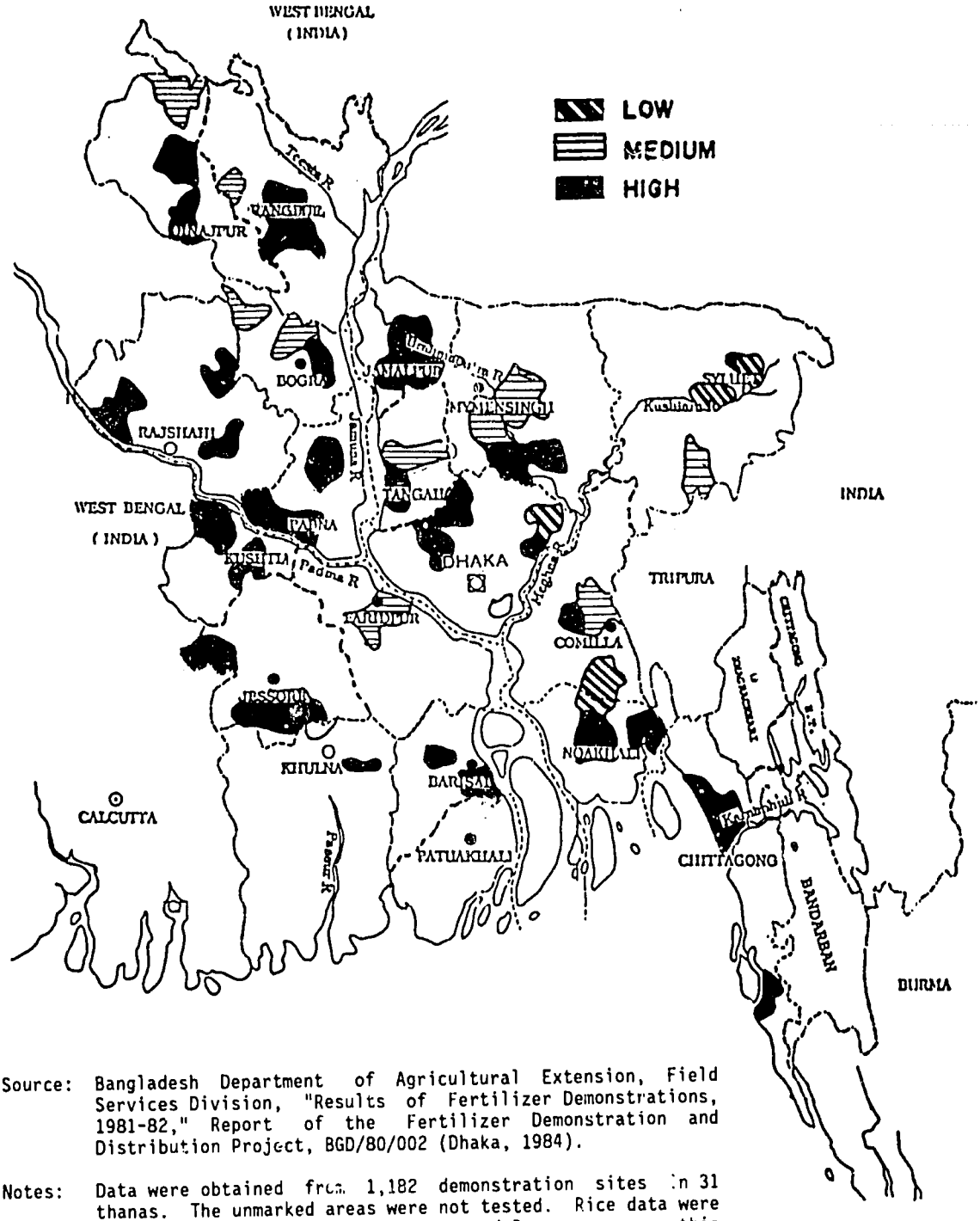
Typical Zn-containing fertilizers are listed in Table 21. Zinc sulfate may be the most effective Zn compound because it combines high analysis (36 percent Zn) with water solubility and therefore may be broadcast with reasonable effectiveness. The roots of rice seedlings can be dipped in Zn oxide. Zn oxide and Zn metallic powder can be broadcast as basal fertilizers. Because these Zn compounds are not water soluble, their effects are slower than those of water soluble ones. Foliar sprays are effective, especially synthetic chelates. The current application levels of S and Zn are not up to standard because extension and field demonstration work is inadequate. The Bangladesh Agricultural Development Corporation (BADC) needs to take a bold step to supply adequate quantities of gypsum ($CaSO_4$) and Zn compounds. The following are tentative requirements for solving the Zn-S deficiency problem.

Element	Approximate Affected Area (million acres)	Approximate Affected Area (million hectares)	Total Requirement Based on Total Area (tons)
S	3.0	1.2	180,000 gypsum
Zn	4.0	1.6	20,000 commercial $ZnSO_4$

The gypsum will be required every third year, as the residual effect of S lasts about two years.

The total gypsum estimated requirement is available at the TSP factory in Chittagong as a by-product of TSP manufacturing. Because gypsum often damages jute bags, its acid content can be reduced by subjecting it to normal rainfall, dehydrating it during winter, and then bagging it. At distribution points, the fertilizer can be stacked in heaps under an ordinary shed. Farmers can pick up the gypsum using their own containers. Used urea bags or any plastic bags will do. Gypsum, when properly used, can supply S for about two years. Therefore, every third year gypsum should be used at the rate of about 60 kilograms per acre (150 kilograms per hectare). Based on this rate, the total gypsum requirement would be about 180,000 tons every three years. At least 10 percent of this requirement should be

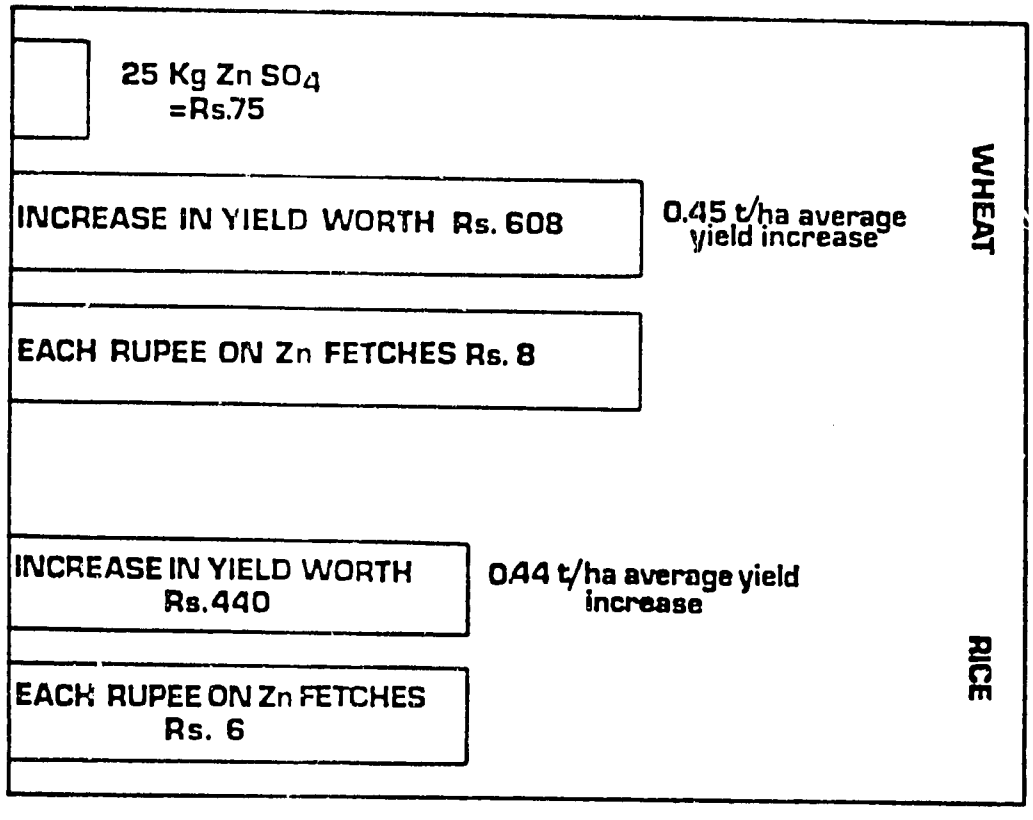
Figure 5--Yield response of rice to zinc



Source: Bangladesh Department of Agricultural Extension, Field Services Division, "Results of Fertilizer Demonstrations, 1981-82," Report of the Fertilizer Demonstration and Distribution Project, BGD/80/002 (Dhaka, 1984).

Notes: Data were obtained from 1,182 demonstration sites in 31 thanas. The unmarked areas were not tested. Rice data were aggregated over the Aus, T. Aman, and Boro season on this map, but disaggregated results are presented in the report tables. The Zn response is not totally clear because Zn was applied in the form of zinc sulfate on the T. Aman crops, which accounted for 56 percent of the demonstration sites, and thus sulfur response could have biased the results. The remaining sites applied Zn in the form of zinc oxide.

Figure 6--Economics of zinc fertilization in India, 1981



Note: U.S. $ = Rs 10.

Table 21--Fertilizers and other usable materials containing zinc

Common/Trade Name	Chemical Formula	Zinc Percentage
Zinc sulfate	$ZnSO_4 \cdot 7H_2O$	23.0
Zinc sulfate	$ZnSO_4 \cdot H_2O$	36.0
Zinc oxide	ZnO	60-80
Zinc chloride	$ZnCl_2$	45-52
Zinc carbonate	$ZnCO_3$	56.0
Zinc oxide sulfate	$ZnO \cdot ZnSO_4$	55.0
Zinc ammonium phosphate	$Zn(NH_4)PO_4$	37.0
Sphalerite	ZnS	60.0
Zinc dust	Zn	99.8
Zinc fritse	Zn	4 (variable)
Synthetic	Chelated sources	
	Na_2-Zn EDTA	14.0
	Na-Zn HEDTA	8.0
	NaZn NTA	13.0
Natural	Zn-lignin sulfonate	5.0
	Zn polyflavonoid	10.0

Source: J. C. Katyal and N. S. Randhawa, "Micronutrients," FAO Fertilizer and Plant Nutrition Bulletin No. 7 (Rome: FAO, 1983).

applied annually to severely affected areas. Based on the same assumption, the annual zinc sulfate requirement will be about 2,000 tons if only the severely affected areas are treated. The total annual Zn requirement based on total area is 20,000 tons of commercial $ZnSO_4$.

Organic Matter in the Soil

Given the low levels of organic matter in the soil in Bangladesh, it is necessary to reconsider crop production using inorganic fertilizers alone, while ignoring the role of organic matter as a source of plant nutrients and soil conditioners. Approximately 60 percent of the soils in Bangladesh have an organic matter content of less than 2 percent, which is the threshold level. In some parts of Joydebpur, Madhupur, and Barind, the organic matter content is as low as 0.8 to 1.0 percent. The organic matter content of 16 soil types and series is given in Table 22. These soils suffer from physical problems that exacerbate the ill-effects of drought and flooding. These include poor aggregation, low water-holding capacity, and increased plasticity. In addition to its physical effects, an ample supply of organic matter enhances plant growth by providing a source of slow-release nutrients, a healthy microbial population, and an increased capacity of soil to hold onto nutrients and to buffer against changes in soil pH. All these factors also lead to higher efficiency of NPK fertilizers as well as higher efficiency of S and Zn.

Use of inorganic fertilizers along with organic manure has consistently given better economic results. Experimentation, especially in the 1930s, proved this to be true, but the practice of using organic matter was not encouraged as it was considered uneconomical. This way of thinking has left soils in such poor condition that incorporation of organic matter is required in Bangladesh even at a cost much higher than would have been needed if recycling of organic matter were common practice.

A report by N. I. Bhuiyan presents the results of a BRRI study to evaluate the effectiveness of various organic materials relative to chemical fertilizer for wetland rice culture.[3] The yield response of BR4 rice to different sources and rates of organic matter are given in Figure 7. These responses are compared with yields obtained from recommended applications of fertilizers (80-60-40 N, P_2O_5, K_2O kilograms per hectare). The study clearly demonstrates that cowpea is the best source of organic matter for wetland rice, followed by Dhaincha. Adding compost, on the other hand, failed to cause an appreciable increase in grain yields.

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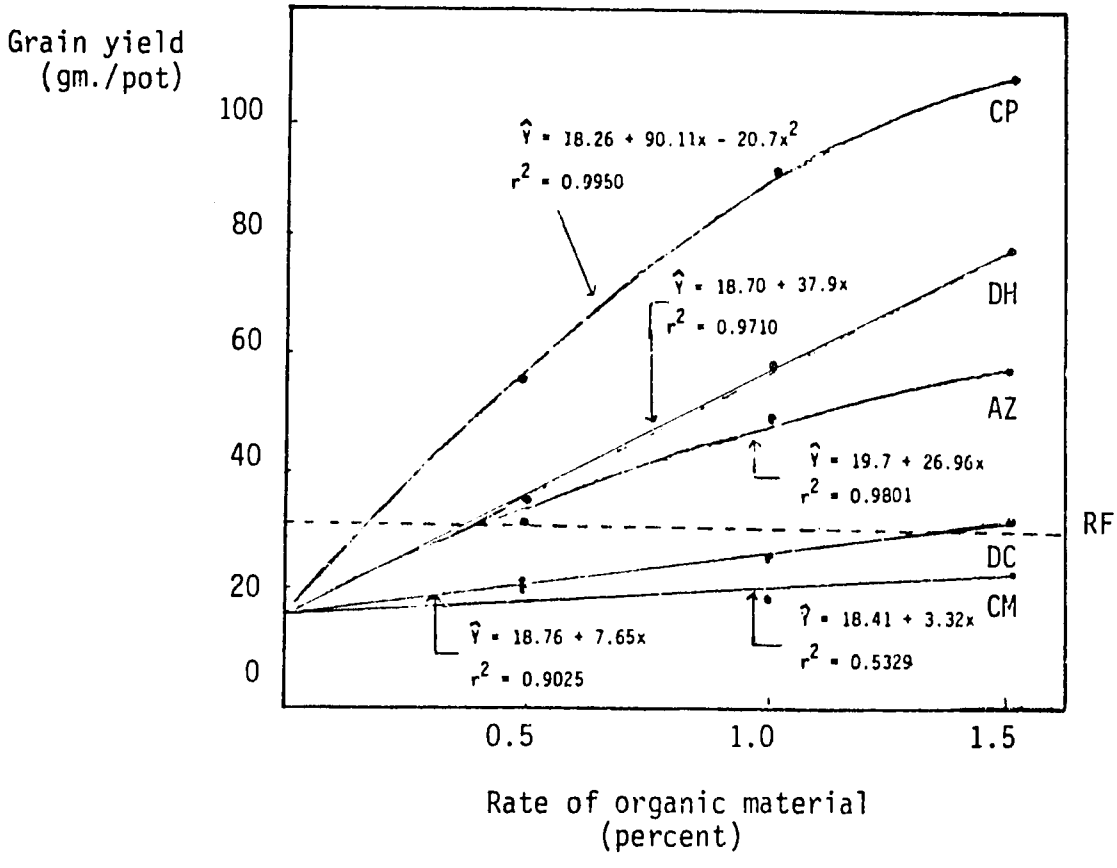
[3]N. I. Bhuiyan. "Use of Organic Materials in Crop Production," paper prepared for the Bangladesh Rice Research Institute, Dhaka, 1984.

Table 22--Percent of organic matter among different soil types and series in Bangladesh

General Soil Type	Soil Series	Organic Matter Content in Surface Soil
		(percent)
Noncalcareous alluvium	...	0.86
Calcareous alluvium	Ramgati	1.46
Gray floodplain	Sabhar Bazar	2.09
Gray piedmont	Prilimpasa	0.96
Acid basin clay	Chakla	4.00
Noncalcareous dark brown floodplain	Lokdeo	1.90
Calcareous dark gray floodplain	Ghior	6.84
Calcareous brown floodplain	Gopalpur	1.10
Noncalcareous brown floodplain	Pirgacha	1.00
Black terai	Lakhipur	2.43
Brown hill	Kulaura	1.25
Shallow red-brown terrace	Gerua	1.62
Deep red-brown	Tejgaon	2.12
Brown mottled terrace	Noadda	1.58
Gray terrace	Chhiata	1.28
Peat	Satla	30.66

Source: Z. H. Bhuiya, "Organic Matter Status of Bangladesh Soils," paper prepared for Bangladesh Agricultural University and presented to the Bangladesh Rice Research Institute, Dhaka, 1983.

Figure 7--Relationships between rice yields and application rates of organic materials



Source: Bangladesh Rice Research Institute.

Notes: Points are the experimental observations. Curves and lines are based on the adjacent regression equations. The dotted line represents grain yield with added chemical fertilizers.

CP = Cow pea
AZ = Azolla
CM = Compost

DH = Dhaincha
DC = Decomposed cow dung
RF = Recommended chemical fertilizer application

In summary, the use of organic materials of various kinds should be popularized. Use of green manures, particularly cowpeas and Dhaincha, has an immediate positive effect on crop production. Other sources such as fresh crop residues, compost, and farmyard manure do not substitute for chemical fertilizers, even when applied in large quantities. However, continuous application of reasonable quantities (say, 10 tons per hectare per year of dry matter) will surely improve the soil tilth and fertility, as well as the efficiency of added chemical fertilizers.

NON-NUTRIENT CONSTRAINTS ON FERTILIZER EFFECTIVENESS AND USE

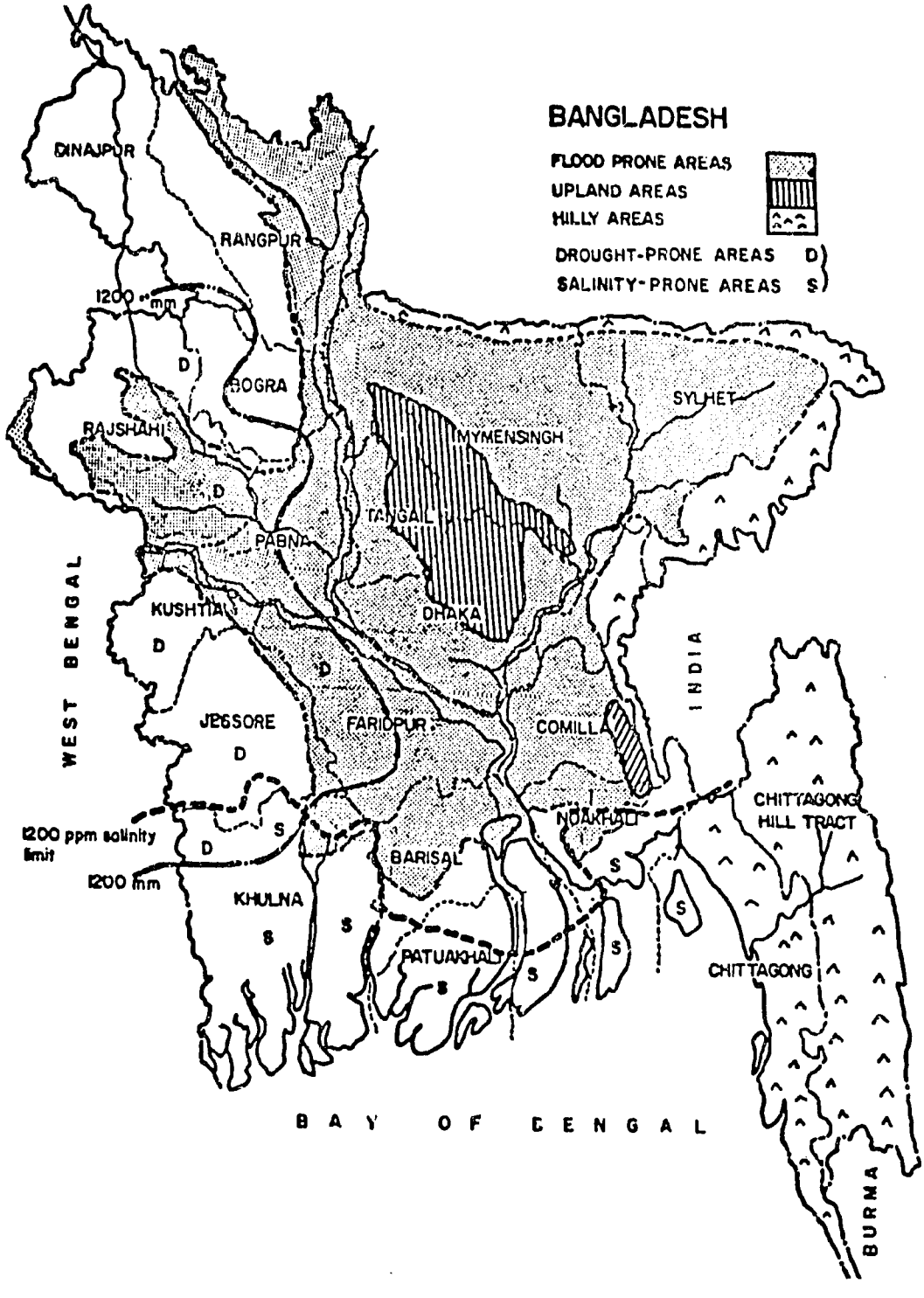
Problem Soils, Drought, and Flooding

By nature, peat soils, acid sulfate soils, fine-textured alluvial soils, and saline and sodic soils are difficult to cultivate and pose problems of water management, soil fertility, and soil conservation. In Bangladesh, the peat soils near Shahjibazar (Sylhet), Gopalganj, and some areas of Khulna may exhibit severe acidity and thus contain only low quantities of plant nutrients per unit volume. Tropical peat soils require high and recurrent inputs for their marginal use.

Acid sulfate soils have been the subject of much research mainly because of their potential suitability for growing rice and their close association with good agricultural land. In Bangladesh, acid sulfate soils are found in southern Khulna and in Cox's Bazaar areas. Cultivation of dryland crops is hampered by toxic levels of aluminum and low availability of P. Wetland rice cultivation on these soils is hampered by toxic levels of dissolved iron as well as low phosphorus availability. A main disadvantage is the risk of strong acidification during droughts when pyrite may oxidize to sulfuric acid. However, with sound agronomic practices, such as growing adapted cultivars and applying P, some acid sulfate soils are particularly suitable for rice cultivation.

Saline soil can be detrimental to the normal growth of crops, and improper usage of chemical fertilizers can compound the problem. In humid climates, such as that in Bangladesh, saline soils commonly occur in coastal areas. Figure 8 shows the salinity belt of Bangladesh delineated at 1,200 parts per million of salt. In these areas rainfall does not exceed evapotranspiration for much of the year and salts are not adequately leached from the surface soil. The salinity-prone areas of selected districts are

Figure 8--Agroecological zones of Bangladesh



District	Hectares
Khulna	192,620
Barisal	124,675
Patuakhali	128,610
Noakhali	109,503
Chittagong	8,490
Total	563,898

In the Rabi season, under rainfed conditions, khesari, chilies, wheat, barley, spinach, beets, basella, watermelons, groundnuts, and cheena-kaon are somewhat salt-tolerant and can be grown in these saline areas. The depth of the salty horizon is crucial here and because these crops have deeper rooting systems, they can escape salinity by deriving soil water from lower strata.

Drought can be harmful in itself, and it may also accentuate the problems caused by saline soil. Figure 8 delineates the drought-prone areas that receive less than 1,200 millimeters of rainfall per year. Drought that does not kill a crop can delay its life cycle. Under drought conditions IR8 rice simply "sits in" and flowers 30-40 days later than a crop not subjected to such stress. In some other crops, drought may force early reproduction, causing severe yield reductions. Drought stress at the critical early reproductive stage will do more damage than if it occurs from panicle initiation to the end of the milk stage. Moreover, the occurrence of drought during the effective nutrient utilization period (ENUP) of any field crop will adversely affect its yield by limiting nutrient uptake. In Aus crops, the ENUP for a 90-100 day variety is only 25-35 days; thus a drought that lasts for 15 days will reduce the yield by about 50 percent. Drought in September/October is dangerous for all T. Aman crops and in April for high-yielding varieties of Boro. Table 23 shows yield reductions under these conditions. One solution is to plant more drought-tolerant plants such as sorghum, smaller millets, gram, barley, and buckwheat. Under mild drought conditions fertilizer effectiveness could be affected. Assuming N fertilizer is properly placed within the anaerobic zone of the soil, mild drought can increase the zone of aeration and thus increase the losses of applied N by denitrification. Salinity problems are also worsened by drought stress.

At 1,230 parts per million of salt, rice grain becomes chalky. Beyond 2,000 parts per million of salt, rice exhibits signs of salinity injury, especially if it occurs at booting (sheath formation) and later stages. However, increased salinity after the milk stage causes negligible damage. Rice seedlings are especially susceptible even when submerged in saline water for only 10-12 hours. Tissue damage to stem and leaf sheath cells is caused by trapped saline water. Mild salinization is usually associated with increasing soil pH. At high pH levels, calcium deficiency is usually the

Table 23--Effect of drought on the yield of T. Aman and Boro HYV rice (drought in October or April)

Soil Moisture Status	Percent of Yield Loss in Crop Stages					
	Ripe	Milk	Flower	Boot	Panicle Initiation	High Tiller
Standing water, 6 cm	0	0	0	0	0	0
Saturated	0	0	0	0	20	50
Moist	0	0	10	50	80	100
Hairline crack	0	0	50	80	100	100
Open crack, soil dry	0	30	80	100	100	100
Desiccated soil	0	50	100	100	100	100

Note: It is assumed that there is no rain and no irrigation. In the event of rain and/or irrigation at any of these six stages, the score can be revised based on the moisture and growth stages.

first to occur with other micronutrient deficiencies following. It is also important to realize that soluble fertilizer salts can result in damage from toxic compounds, if placed too close to the seed. If direct contact of seed with nutrients is planned, special care must be taken to use low-salt index materials or to keep rates of nutrients low.[4]

Figure 8 also shows extensive tracts of land subjected to flooding. For lowland Aus, flooding usually occurs at its reproductive stage, when the Aus crop will fail completely if the total flood depth exceeds 1.0 meter. Mild flooding of 0.5 meter will not be detrimental and the crop will normally perform well, provided other ecological conditions remain satisfactory, including pressure from pests and parasites.

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[4]L. S. Murphy, "Plant-Soil-Fertilizer Relationships," in The Fertilizer Handbook (Washington, D.C.: The Fertilizer Institute, 1982), pp. 134-35.

T. Aman is normally not grown in flood-prone areas. However, in abnormal years such as 1954, 1955, 1974, and 1984, lower areas were affected either by flash flooding or accumulated rainwater. Lodging, especially at the booting and prebooting stage, is especially injurious to the crop.

Shallow flooding (less than 15 centimeters and close to a meter) is found in the tidal basin. Here, fertilizer placement is extremely important, especially since fertilizer application response rates were shown to be low due to leaching. Mild flood conditions should make little difference to fertilizer effectiveness if the fertilizer is applied properly. Low response rates are primarily responsible for low fertilizer consumption in southern tide-affected districts. Drainage problems and long rainy spells, producing prolonged waterlogging, contribute to the poor nutrient status of these soils. Under reduced soil conditions, soil microorganisms are forced to reduce and successfully compete for necessary plant nutrients. After oxygen and NO^3 nitrogen have been exhausted, phytotoxic concentrations of Fe^{2+} and Mn^{2+} in the soil solution become appreciable. Sulfur also follows, and in its reduced state (H_2S) it is unavailable and more toxic than in its oxidized one (SO_4^{2-}). This sulfide state may also block the uptake of calcium, magnesium, iron, zinc, and so forth, creating nutrient imbalances that disturb the normal physiological state of the rice plant.

Diseases, Pests, and Parasites

Crop losses due to diseases, pests, and parasites are substantial, and much more research needs to be done in this area. Large crop losses pose an added constraint on the economical use of fertilizers. Even if farmers were convinced of its profitability, they still might not want to invest in fertilizers given the high probability that diseases, pests, or parasites will cause severe crop losses.

Diseases. In Bangladesh one can find almost all rice crop diseases. The most important are blast, tungro, bacterial leaf blight, sheath blight, and ufra. Of less importance are sheath and stem rot, brown spot, and physiological defects due to S and Zn deficiencies. In spite of significant crop losses from these diseases, there has not been any attempt to record them.

Almost all Aus varieties, Pajam, Purbachi, and IR5 are highly susceptible to rice tungro disease. In 1970, there was a severe epidemic of rice tungro virus infecting T. Aman crops in the northern districts. The area under local Aman varieties dropped from 14,812,000 acres in 1969/70 to 12,984,500 acres (a reduction of 5.58 percent). Consequent production was 5,700,000 tons instead of 6,912,400 tons in 1969/70 (a 17.54 percent reduction loss). Another

outbreak of tungro disease infected Pajam in Chittagong, Noakhali, and the Comilla regions in 1976/77. There was a reduction of 330,000 acres sown in HYV where Pajam was included, with a production loss of 310,000 tons.

Localized yield reductions due to blast and ufra diseases in Aman crops are no less significant than drought and flood losses and yet are taken for granted. The endemic areas of ufra disease are from Goalando to the Matlab-Chandpur sectors and the Dhaka Narayanganj Drainage Project area. Ufra infestations are also prevalent in Zn deficient areas of deepwater rice. In the Demra area, incidence of this disease is increasing and may reach a serious level within the next five years if adequate protective measures are not taken. The injurious effects of blast on the scented Polao rice varieties such as Kalizeera, Chiniguri, Badshabhog, and Sakkorkhora have escaped the notice of statisticians. These varieties are highly susceptible to blast and at least 10 percent of the total crop is lost to neckblast.

Wheat in Bangladesh, especially that planted with seeds imported from India, Pakistan, or Nepal will normally contract loose smut disease, which damages 4 to 5 percent of the crop. However, the seeds of the infected crop, when planted the following year, show much less infestation, and in later generations damage eventually disappears. Leaf and stem rust diseases of wheat are less of a problem in most areas. Seedling blight, foot, and root rot diseases are common but remain below the economic threshold level.

Root-knot nematodes are on the increase and are affecting all crops. Virus diseases of tomatoes, okra, pulses, and papaya have become quite serious but as yet no losses have been assessed. The same is true of red rot in sugarcane, late blight in potatoes, stem rot in jute and sesame, and wilting and black spot in groundnuts.

Measures are being taken to control these diseases. Some of the rice diseases are being controlled by fungicides. Copper compounds are effective in controlling the Tikka disease of groundnut. Furadon, along with Zn and K fertilizers, is effective in controlling ufra and root-knot nematodes of rice.

Chemical control must be practiced at the appropriate stage of the disease in order for it to be effective. The most vulnerable stage of rice to tungro infection is the seedling stage. Sheath blight occurs from panicle initiation to booting, bacterial leaf blight at booting, stem rot at maximum tillering, and leaf scald at the flag leaf stage. Control measures should be taken at these stages. Seed treatment is effective for certain seed-borne diseases. However, toxic mercury compounds are no longer used in treating seed in Bangladesh because of the risk of accidents.

The following list includes effective cultural practices in rice disease management. Some of these are effective for crops in general. It should be mentioned that one of the main drawbacks of a list such as this is the lack of discussion of adverse consequences that may accompany these practices.

Management of water:

- Flooding the field minimizes the incidence of seedling blight in Boro seedbeds and leaf blast in the field.
- Draining water from the field may control sheath blight, bacterial blight, stem rot, and damping off in the Boro season.

Removal and destruction of stubble and weeds:

- Removal and burning of stubble in the field can control ufra, root knot, sheath blight, and stem rot.
- Alternate weed hosts of different pathogens may be removed for control of diseases such as tungro, bacterial leaf blight (BLB), blast, and brown spot.

Management of fertilizer:

- Judicious use of urea in proportion to P and K minimizes diseases such as blast, leaf scald, sheath rot, sheath blight, stem rot, BLB, and grain spotting.
- Sufficient use of potash can minimize leaf diseases such as brown spot, ufra, blast, leaf scald, sheath blight, bacterial leaf spotting, and blight.
- Nitrogen applications should be split, preferably with higher doses at later stages if the soil N content is high enough to ensure seedling survival. Otherwise basal application should be considered.
- Higher doses of N should be applied only when wider spacing is used.
- Treating Zn deficiency can reduce the intensity of diseases like ufra and root knot.

Planting practices:

- Planting dates may be delayed to avoid disease. For example, Boro seedbed sowing should be later than November to avoid tungro outbreak, and delayed sowing or transplanting of deep-water rice may help avoid ufra disease.
- Crops that are not hosts to the majority of the pathogens should be integrated judiciously into cropping patterns.
- Crops should be rotated.

Sanitation:

- Stubble should be collected and burned.
- Seeds from healthy fields should be collected and used.
- Seeds should be dried in the sun to a lower moisture content to help eliminate seed-borne diseases.

In the long run, perhaps the most important approach to pest and disease control will be the development and use of resistant varieties. Plant breeders are constantly at work improving crop varieties as new mutations of a particular disease appear and resistance breaks down. Use of resistant varieties along with prophylactic measures, balanced doses of NPK, use of organic manures, crop rotation, and water management are important aspects of an integrated system of disease control.

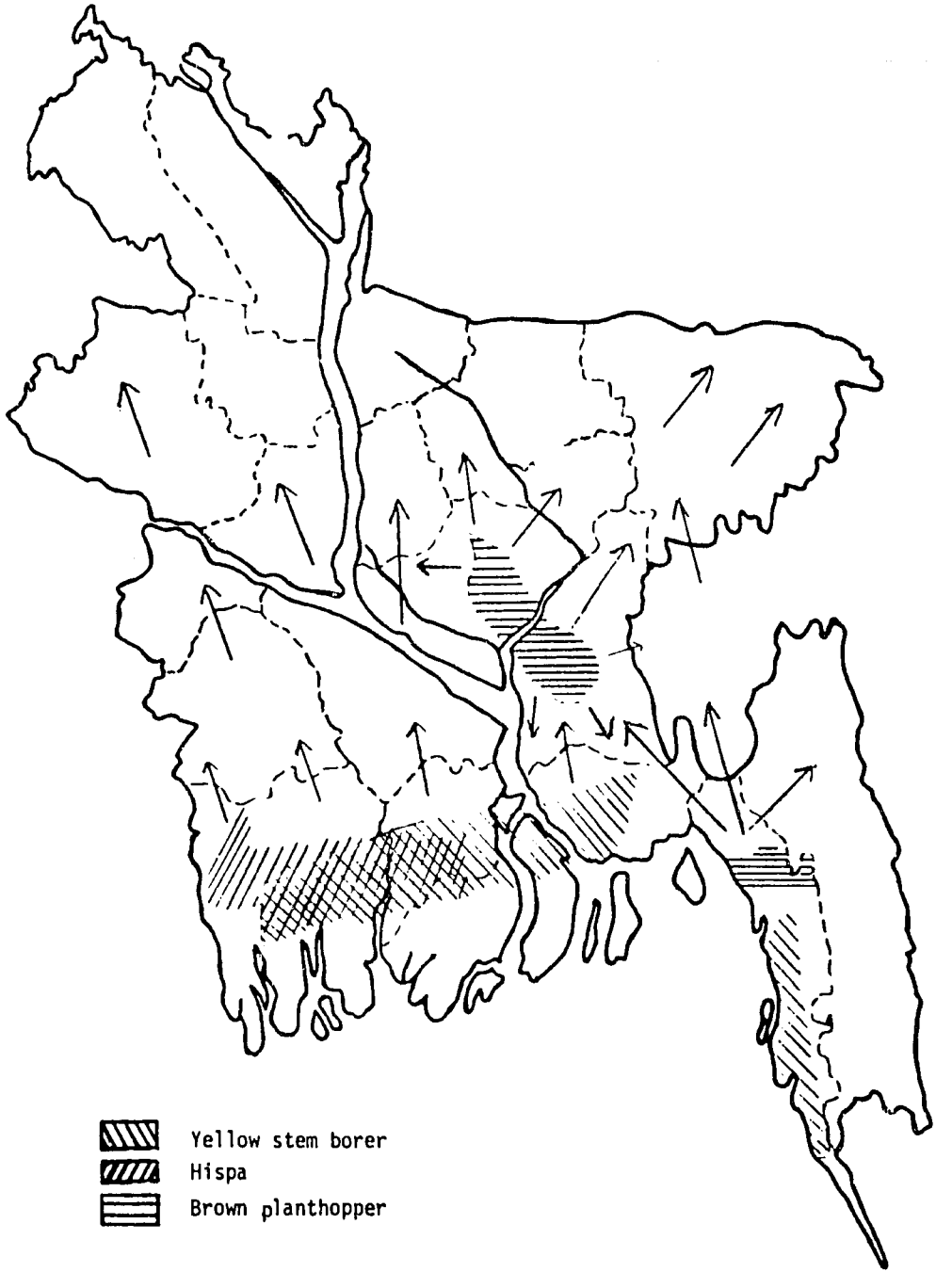
Insect Pests. Climatic conditions in Bangladesh are ideal for the breeding of insect pests. Almost all known species of rice pests are found there. The most important insect pests are stem borers, green leafhoppers, hispas, caseworms, Gandhi bugs, leafrollers and folders, army worms and ear-cutting caterpillars, brown planthoppers, gall midges, thrips, and mealy bugs. There is a higher incidence of pests in the Aus and T. Aman seasons and a lower incidence in the Boro season due to cooler temperatures.

Perhaps the most pernicious of these at present is the hispa. No rice varieties are resistant to it, and in recent years it has caused severe crop damage in Boro, Aus, and Aman crops. Deep-water and T. Aman rice can recover somewhat from an attack because of their longer life cycles. The initial population buildup of hispa occurs in the Khulna-Barisal-Patuakhali zones with the Boro crop. The population multiplies and migrates north as temperature and rainfall increase along with the planting of Aus and B. Aman (Figure 9). In some years T. Aman has been so heavily infested by hispa that farmers have simply allowed the crop to be completely destroyed: they thought control would not be economical because this late-planted crop yields only 450-550 kilograms per hectare.

The brown planthopper (BPH) is also becoming a menacing insect pest. The endemic areas are Dhaka-Comilla and the northern Chittagong zone. The population buildup starts in the Boro season, reaches a peak in March/April, and then spreads in all directions (Figure 9). During T. Aman's preflowering and flowering seasons, it is increasingly found in almost all districts.

Rice's yellow stem borer has its starting point in the Khulna, Barisal-Noakhali, and Chittagong areas during the Boro preflowering stage. It eventually spreads in a generally northerly direction (Figure 9).

Figure 9--Initial infestation areas of yellow stem borer, rice hispa, and brown planthopper



Source: S. A. Miah and A. N. M. Rezaul Karim, "Rice Pest Management Technology, A Workshop of Experience with HYV," Bangladesh Rice Research Institute, Dhaka, March 20-23, 1983.

It is interesting to note that deep-water rice (B. Aman) harbors a stem borer infestation of about 40 percent on average, but damage is still below the economic threshold level. By September, the floods begin to recede and there is a mass migration of stem borers north to the transplanted rice crop. Thus, B. Aman acts as a host for the stem borer. In winter, as temperatures drop, stem borer larvae and pupae remain in the rice crop stubble, especially in Aman, thus providing an alternate host.

Mealy bugs and thrips are associated with drought conditions. Mealy bug damage can amount to nearly 100 percent of the infested plant leaving no chance of recovery. Clearing the field of infested plants has been effective in dealing with mealy bugs. Thrips cause severe sterility if they attack rice during its flowering stage.

Ear-cutting caterpillars are prevalent in deep-water rice. The late harvest of T. Aman is an important factor in allowing this pest to do damage to the rice crop. Late planting of rice, particularly HYV, causes heavy infestation by gall midges and caseworms.

Wheat has a lower incidence of pest damage. The common pests are pink and dark-headed borers and, to a lesser extent, aphids, wireworms, and white ants. Birds also cause damage at seeding and, along with rats, cause significant damage to ripening wheat. They also cause damage during grain storage.

Aphids cause severe damage to mustard and beans, particularly late-planted mustard; the yield loss may be on the order of 50-60 percent. Semiloopers, apion beetles, and mites damage jute, and hairy caterpillars attack pulses and jute. Red ants sometimes cause severe potato damage.

Alam, Karim, and Nurullah have attempted to estimate rice crop losses due to insect pests by conducting 41 experiments in 20 crop seasons from 1970 to 1979.[5] Experimental results show that yields were reduced to 3.68 tons per hectare in untreated plots compared with 4.16 tons per hectare in protected plots. Use of insecticides increased yields by 19.04 percent in T. Aman and 18.03 percent in Boro seasons. Yield losses in T. Aman and Aus seasons were

Rice Variety/Pest	Yield Loss (tons per hectare)
T. Aman	
Stem borer	0.9 - 1.9
Gall midge	1.0
Aus	
Green leafhopper	0.52 -1.9

[5]Shamsul Alam, A. N. M. R. Karim, and C. M. Nurullah, "Insecticide Use on Rice in Bangladesh," Bangladesh Journal of Agricultural Research 6 (No. 2, 1981): 37-50.

In another study they estimated crop loss from insect pests at BRRI during 1978-79 and found it amounted to 13 percent in Boro rice, 24 percent in Aus rice, and 18 percent in T. Aman.[6] The economic aspects of insecticide use were also studied and some results are presented in Tables 24 and 25. In general the effects were beneficial, particularly in the Aus season and when applied as a curative spray.

Table 24--Effect of timing and frequency of insecticide applications on rice yield

Treatments	Number of Sprays	Yield Increase			Cost-Benefit Ratio		
		Boro	Aus	T. Aman	Boro	Aus	T. Aman
		(tons/hectare)					
Regular application at an interval of 2 weeks	5	0.40	0.50	...	1:1	1:0.48	...
At 20, 40, and 60 days after transplanting	3	0.25	0.80	0.30	1:0.40	1:1.3	1:0.48
At mid- and maximum tillering and flowering stages	3	0.40	...	0.80	1:0.64	...	1:1.8
At mid- and maximum tillering	2	0.40	0.50	0.10	1:0.97	1:1.2	1:0.24
At mid-tillering	1	...	...	0.30	...	...	1:1.45
At maximum tillering	1	0.20	0.40	0.00	1:0.97	1:1.94	1:0

Source: Shamsul Alam, A. N. M. R. Karim, and C. M. Nurullah, "Insecticide Use on Rice," Bangladesh Journal of Agricultural Research 6 (No. 2, 1981): 37-50.

[6]Shamsul Alam, A. N. M. R. Karim, and C. M. Nurullah, "Important Rice Insect Control Technologies," 8th Bangladesh Rice Research Institute Extension Workshop on Experience with HYV Rice, March 22-25, 1982.

Table 25--Effect of preventive and curative sprays on rice yield

Rice Seasons	Yield Increase		Value of Increased Yield		Cost of Insecticide		Cost-Benefit Ratio	
	P	C	P	C	P	C	P	C
	(tons/hectare)		(taka)					
Boro	0.95	0.67	2,629	1,841	3,603(6)	1,331(3)	1:0.60	1:1.38
	0.80	0.30	2,200	825	5,409(9)	195(1)	1:0.41	1:4.23
Aus	0.90	0.58	2,558	1,595	3,230(7)	1,331(3)	1:0.66	1:1.20
	1.91	1.40	5,253	3,823	2,340(6)	741(2)	1:2.20	1:5.16
	0.30	0.00	825	0	3,230(8)	425(1)	1:0.19	0
T. Aman	0.80	0.68	2,200	1,705	3,203(7)	763(2)	1:0.60	1:2.23
	0.21	0.00	573	0	2,351(6)	858(2)	1:0.24	1:0
	1.10	0.10	3,025	273	4,544(8)	852(2)	1:0.55	1:0.32

Source: Shamsul Alam, A. N. M. R. Karim, and C. M. Nurullah, "Insecticide Use on Rice," Bangladesh Journal of Agricultural Research 6 (No. 2, 1981): 37-50.

Notes: Figures in parentheses indicate number of insecticide applications. P represents preventive; C represents curative.

Twenty-five major commercial insecticides were found to be effective against the pests. The types include 17 organophosphates, 4 carbonates, and 4 others of mixed groups. They also found that Sevidol 4:4G, Ofunack 10G, and Ekalux 5G were promoting an increased population of brown planthopper and thus must not be used.

As with disease control, an integrated management program to control pests is currently being promoted, using these cultural practices.

- Infestation of green leafhoppers and subsequent tungro outbreak can be avoided by seeding the Boro crop in late December instead of November.
- Water removal from the field is effective in controlling caseworms and brown planthoppers.
- Avoiding high density and narrow spacing is recommended to ward off brown planthoppers.
- Seedbed management with thinly sown seeds can reduce green leafhopper and other hopper infestation of rice seedlings.
- Forced lodging of ripe rice crops can prevent an attack by ear-cutting caterpillars, and irrigation can destroy them.
- Clearing the field of infested plants has been successful in controlling the top shoot borer on sugarcane, smut-infested spikes of wheat, and hispa-infested sheaths of rice.

Kerosene emulsion, tobacco infusion, ashes, and light traps are also in use to temporarily ward off pests. Pyrethrum, a plant substance, is also being used because of its low toxicity. However, toxic insecticides are recommended because they are economical and effective.

Pest control in the field must be supplemented by pest control in storage. Storage losses sometimes exceed 10-15 percent for rice, wheat, and potatoes. For effective storage, the godown must be insect- and rat-proof and kept at minimum moisture levels. High humidity in storage along with more than 14 percent moisture content of stored grain results in high infestation. Clean, dry storage is essential. Storage treatments with nontoxic fumigants and grain or tuber irradiation before storage have also helped to reduce losses.

Weeds. It is very unfortunate that biologists and economists have frequently ignored the role of weeds in crop production. They rob the soil of necessary crop nutrients, necessitate one of the most labor-demanding chores in crop production, and have other deleterious effects.

Weeds, by virtue of their higher shoot and root growth, can deprive sluggish crop seedlings of sunlight, space, moisture, and nutrients, and they may act as an alternate host for many diseases and insect pests. Weeds grow faster under rainfed or residual moisture levels than the seedlings of most crops, particularly the dwarf, semidwarf, and intermediate plant types of the HYVs. This is why HYV direct-seeded rice cannot grow well in upland conditions. If weeded efficiently, HYV rice can compete, but the cost of weeding is high and farmers are reluctant to do it. Jute farmers, however, spend lots of time and money weeding their fields; without such efforts, the jute yield would be reduced by 50 percent. Agronomists usually think that if the cost of weeding exceeds 20 percent of the other costs of production, it is uneconomical to control weeds.

Tables 26 and 27 provide data on per hectare labor requirements for seeding and weeding of upland rice.[7] Because line seeding and dibbling were done by hand, more man-days per hectare were needed for these tasks than for weeding. But when seed was broadcast, man-days per hectare for weeding reached 95 percent of the total for seeding and weeding combined. Table 27 shows that 16-25 percent of total man-days per hectare are needed for weeding: thus it is very

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[7]Studies done at the Bangladesh Rice Research Institute show that dibbling--planting the seeds in small holes--was the most efficient method of seeding as compared with broadcasting and line sowing; they concluded that multirow, animal-drawn seed and fertilizer drills should be given priority in Bangladesh.

Table 26--Variation in labor needed for weeding using three rice seeding methods

Seeding Methods	Man-Days Used for Seeding			Man-Days Used for Weeding			Total Man-Days	Man-Days for Weeding as Share of Total Man-Days
	Joy-debpur	Raj-shahi	Mean	Joy-debpur	Raj-shahi	Mean		
	(man-days/hectare)							(percent)
Broad-cast	1.74	2.05	1.89	38.67	41.67	40.17	42.06	95.51
Line seeding	40.88	43.44	42.16	33.33	35.89	34.11	76.27	44.72
Dib-bling	51.88	64.58	58.23	31.25	40.52	35.89	94.18	38.11

Source: Bangladesh Rice Research Institute, Agronomy Division, "Internal Review," Dhaka, 1982.

Table 27--Comparative labor inputs for different operations of direct seeded upland rice

Operations	Man-Days Used for Seeding			Man-Days Used as a Share of Total		
	Broad-cast	Line Seeding	Dib-bling	Broad-cast	Line Seeding	Dib-bling
	(man-days/hectare)			(percent)		
Land prepa-ration	22.73	21.43	22.62	14.60	11.78	11.67
Seeding	1.74	40.88	51.88	1.12	22.48	26.76
Fertilizing	5.21	5.21	5.21	3.35	2.86	2.69
Weeding and mulching	38.67	33.33	31.25	24.83	18.33	16.12
Plant protection	2.34	3.21	3.65	1.50	1.77	1.88
Harvesting and carrying	30.90	27.52	26.04	19.84	15.13	13.43
Threshing	34.72	32.62	34.[illegible]2	22.30	17.94	17.91
Winnowing, sunning, storing	19.40	17.65	18.49	12.46	9.71	9.54
Total labor	155.71	181.85	193.86	...	...	...

Source: Bangladesh Rice Research Institute, Agronomy Division, "Internal Review," Dhaka, 1982.

expensive. The benefit-cost ratio for weed control during rice cultivation is attractive, however, as shown in Table 28. The ratio generally appears to increase with increased weeding, but tends to decline in (even efficient) weeding operations that result in more than 75 percent weed removal.

Good land preparation (usually four plowings and two ladderings) decreases the weed population. Usually a smart farmer will wait five or six days after the first spring shower to allow weed seeds to germinate. He then prepares the land, destroying about 75 percent of the weeds. Hand weeding after one raking is always an effective weed control for upland direct-seeded rice and jute.

Table 28--Costs and returns associated with weeding during rice cultivation

Number of Weedings	Labor Needed for Weeding	Cost	Gross Returns	Gross Returns Minus Weeding Costs	Benefits from Weeding	Benefit-Cost Ratio from Weeding
	(man-days/ hectare)		(taka/hectare)			
1	66.71	1,334	4,800	3,466	1,964	1.47
2	87.96	1,759	5,595	3,836	2,759	1.57
3	93.24	1,865	6,867	5,002	4,031	2.16
0 (control)	...	...	2,837	2,837	...	...
100 percent weed removal	94.48	1,890	5,955	4,065	2,363	1.25
75 percent	81.36	1,627	5,726	4,098	2,134	1.31
0 percent	...	...	3,591	3,591	...	...

Source: Bangladesh Rice Research Institute, Agronomy Division, "Internal Review," Dhaka, 1982. The benefit-cost ratios appearing in the source have been recalculated for inclusion in this table.

Note: Benefits from weeding were calculated by subtracting gross returns without weeding (control) from gross returns with weeding.

Weeds pose a constraint on the profitability of using fertilizers. Crop response to fertilizer application depends on the competition between the crop and weeds for the added nutrients. If weeds have a competitive advantage, then yield losses of 50-60 percent can be expected, as seen in direct-seeded Aus. Interesting studies on weed control have been conducted at the International Rice Research Institute (IRRI). The effect of N fertilizers on crop yields as influenced by different methods of weed control received special attention. They found that the yield response to hand weeding increases with N application and that application of more than 75 kilograms of N per hectare will decrease yields unless hand weeding is done. In summary, both the intensity of weeding and N levels must be balanced in order to get optimum yields from both inputs.[8]

In Bangladesh, where hand weeding is the most common method of weed control, the results of these studies could support Bangladesh's effort to cope with the problem of weeding and its interaction with fertilizer usage. However, it is difficult to obtain favorable conditions for both growth and weed control, which would lead to more efficient use of chemical fertilizers.

Fertilizer Storage Loss

In general, fertilizer storage losses seem to be low for Bangladesh farmers. This is because farmers in Bangladesh do not purchase fertilizer with the thought of storage in mind. They usually purchase the amount needed and use it as quickly as possible.

BADC is aware of safe storage practices, and information is available from them. The following storage problems are typical of the fertilizers used in Bangladesh.

Urea is fairly stable and has good storage life. However, under hot, humid conditions, urea may absorb moisture and become wet. Although the urea is hard and lumpy when it dries, the N content is not reduced provided bags are sealed well.

DAP is even more hygroscopic and may form a slurry-like mass in the rainy season. At that point, farmers often refuse to use it because it is difficult to handle and causes skin burns.

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[8]For more specific results, see D. T. O'Brien and E. C. Price, Interaction Between Fertilizer and Weed Control Methods in Philippine Upland Rice: Estimates from Farmers' Fields, Research Paper Series No. 97 (Los Baños, Philippines: International Rice Research Institute, 1983).

TSP also absorbs moisture and can become lumpy. The phosphoric acid used to treat the phosphate rock may undergo unfavorable changes in chemical composition. Under such conditions TSP is not a good fertilizer and can cause chlorosis in a plant. Several years ago, BADC had to discard a quantity of TSP that had become hard and lumpy.

KCl is a stable product and under normal storage conditions has the least chance of storage loss.

Ammonium sulfate is also hygroscopic and may suffer severe loss of N under hot, humid conditions due to gaseous ammonium losses to the atmosphere.

Scope for Further Expansion of HYV Areas

HYVs of rice (excluding deep-water rice), wheat, potatoes, and mustard have made a significant contribution in Bangladesh. Starting in the early 1960s with a few hectares sown with Taipei 177/1, Yabani and 36 Norin varieties in Taiwan, area sown in HYVs expanded to approximately 500 hectares of IR8 in 1966/67. Thereafter, area sown with HYVs of Aus, T. Aman, and Boro crops expanded.

With improved irrigation facilities, good climatic conditions, and a low incidence of pests and disease in the Boro season, HYV sown area increased to about 70 percent of the total Boro rice area. Further expansion in Haor areas, home of the endemic species of Boro rice, should be controlled in order to prevent genetic erosion. This locality should remain planted with the local germplasm to maintain a biological balance. Nonendemic Boro areas may be sown with additional HYVs without worry about genetic deterioration. Further expansion is possible in the Boro season, given planned improvement in irrigation and drainage facilities, bringing the estimated potential for modern Boro area to 2.4 million hectares.

Areas of expansion under Aus are limited to areas that are not flood-prone. Approximately 37 percent of all Aus areas (2.8 - 3.0 million hectares) lie in lowlands subject to flooding and are risky for even the local tall Aus varieties. Hence there is no current scope for expansion of HYVs of rice in these areas (1.04 - 1.11 million hectares). Of the remainder (1.76 - 1.89 million hectares), approximately 0.8 million hectares are now sown with transplanted Aus HYVs. Future expansion may bring the total Aus acreage under HYVs to 1.2 million hectares.

In parts of Noakhali and the offshore islands, HYVs of rice are dibbled. When seedlings reach 10-15 centimeters in height, rainwater is ponded to effect a transplanted field condition. In the uplands of Madhupur, Barind, Lalmai, and other hilly areas, HYVs cannot be cultivated as there are no suitable direct-seeded HYVs of rice. However, attempts are being made to accelerate research for development of faster growing varieties that have a life span of 90-100

days, appreciable drought tolerance, and high seed dormancy. It is expected that a prototype may be available by the end of the third five-year plan. Once this is available, about 50 percent of Aus area could be under HYVs by 1995.

It is possible that the Boro rice area could expand to 2.4 million hectares at the cost of Aus or jute. As modern Boro rice and wheat areas increase, there is a corresponding decrease in Aman and Aus deep-water rice areas. Because growing Aus rice is risky in its seedling and early growth stages and jute is a low cash crop, farmers are likely to make the change. Farmers may even be more reluctant to plant their traditional low-yielding Aus crop once wheat has been planted, because rice following wheat requires much larger amounts of fertilizer.

Within the next five years there will be practically no change in the B. Aman rice area. One new medium yield variety of B. Aman, with a yield range of 3-4 tons per hectare) is in the field-testing stage. Its impact will probably be limited unless it is suitable at a flood level of 1-3 meters, which is typical in the floodplains.

There is great scope for expansion of HYVs in the T. Aman season with 2.0 - 2.4 million hectares of land suitable for modern varieties. The areas of T. Aman under different agroecological zones are given in Table 29. The entire drought-prone areas of Khulna and Rajshahi may be brought under HYVs. This amounts to 20-22 percent of the drought area. At least 50 percent of the total nondrought/flooded areas may also be brought under HYVs for a total of 56-58 percent of total T. Aman areas suitable for expansion.

The optimum period for transplanting will be July 15 - August 15 in order to avoid an October drought. However, one supplemental irrigation (5 - 7.5 centimeters) will be essential to compensate for the severe October drought. A large part of the T. Aman crop will be planted in saline areas and therefore the necessity for planting saline-tolerant varieties is increased. At the moment BR10 seems to be performing well under normal rainfall conditions.

The areas suitable for HYVs with and without irrigation amount to 5.6 - 6.0 million hectares. Of this total, 75 percent is expected to be irrigated and 25 percent rainfed. Aus and T. Aman will be approximately 75 percent rainfed and 25 percent supplemented with irrigation. Overall, judicious management of inputs and services including credit, water, marketing, processing, and storage will be needed--horizontal expansion is not enough.

Despite rapid expansion to a peak of 0.58 million hectares in 1981, wheat area never reached the expected level of 1.6 million hectares. Several surveys were conducted to find reasons for this plateau. About a dozen constraints have been identified, including low market prices, nonavailability of seeds and their high cost,

Table 29--Area sown with T. Aman rice in different agroecological zones

Location/ Types of Rice	DP	FP	DP and FP	Not DP or FP	Total
		(1,000 hectares)			
Dhaka					
Local varieties	...	83.57	14.42	426.23	524.22
Modern	...	...	2.66	215.56	218.22
Local and modern total	...	83.57	17.08	641.79	742.44
Chittagong					
Local varieties	...	...	...	662.30	662.30
Modern	...	...	...	269.19	269.19
Local and modern total	...	...	...	931.49	931.49
Khulna					
Local varieties	413.83	...	...	512.25	926.08
Modern	51.31	...	...	37.26	88.57
Local and modern total	465.14	...	...	549.51	1,014.65
Rajshahi					
Local varieties	435.26	...	80.44	770.79	1,286.49
Modern	10.76	...	9.41	81.99	102.16
Local and modern total	446.02	...	89.85	852.78	1,388.65
Bangladesh					
Local varieties	849.09	83.57	94.86	2,371.57	3,399.09
Modern	62.07	...	12.07	604.00	678.14
Local and modern total	911.16	83.57	106.93	2,975.57	4,077.23
Local and modern total as a percent of total area sown with T. Aman rice	22.35	2.05	2.62	72.98	100.00

Source: S. M. H. Zaman, "Current Status and Prospects for Rainfed Foodgrain Production in Bangladesh," a paper prepared for FAO's Expert Group Consultation, Bangkok, November 28-December 2, 1983.

Note: DP = drought-prone; FP = flood-prone.

threshing difficulty, and lack of irrigation facilities. These reasons, along with a higher preference for rice and loss of soil fertility due to wheat, are likely causes. With time, these constraints can be solved, and wheat area and production will ultimately expand to the estimated level.

Other crops have their own sets of constraints. The area under sugarcane seems to have reached a saturation point because of faulty policy on the part of the Sugar Corporation. There is also no improved variety for gur production. Extension work is nonexistent outside the sugarmill zones. Until recently, no attempt was made to manufacture khandeswari sugar (semiwhite powdered sugar) in the nonmill areas. Manufacture of this product, which now only takes place in the Kishoreganj area, should be expanded. Instead Bangladesh is importing sugar at high prices.

Area planted with pulses is unlikely to expand due to a lack of improved varieties and, particularly, of technology for the production of Rhizobium-inoculated seed. Wheat and potato acreage is also affecting pulse production. Mustard yields average 2 tons per hectare with irrigation, high doses of NPK, and pest management. Mustard area is not increasing at this time because soybean oil is being imported liberally at low prices. Groundnuts, another popular crop, has not received appropriate state support for its processing.

So far, no attempt has been made to investigate farmers' work schedules after a long, busy period of cultivating jute/Aus and T. Aman crops. About 40 percent of all arable land is under various Rabi crops, and thus lack of irrigation may not be a limiting factor. Expansion and improvement of irrigation and drainage facilities would promote the production of Boro rice, wheat, potatoes, onions, chilies, other vegetables, and oilseeds, and it would also minimize the risk for B. Aman, Aus, and jute seedlings.

Limited Availability of HYV Seed

The problem of limited HYV seed supply has improved to some extent for rice, wheat, jute, sugarcane (in mill areas), and vegetables, along with the shift toward greater reliance on domestic sources.

The total seed requirements for rice by type are given here.

Rice Type	Seed Requirements (tons)
Aus	
A. Broadcast	185,190
B. Transplanted	18,520
B. Aman	148,150
T. Aman	97,220
Boro Transplanted	32,410
Total	481,490

To fill this need, BADC supplied only 8,253 tons of rice seeds in 1974, and by 1977, the amount supplied had decreased to 1,028 tons (Table 30). By 1982 the amount supplied by BADC increased to only 1,935 tons--about 0.4 percent of the net requirement for rice seed. The remainder has been provided by local seed merchants and farmer-to-farmer exchange. However, the multiplier effect of BADC's seemingly inadequate contribution is great. An injection of approximately 1 percent of new varieties of rice seeds should enable the entire system to supply sufficient improved seed.

Because wheat requires more seed and seed storage is more difficult, wheat seed requirements are higher than those for rice. BADC supplements its own seed supply with imports, raising the total supply to 40-50 percent of the market. Farmer-to-farmer exchange and farmers selling seed in the local market also contribute to the seed supply.

Both rice and wheat are self-pollinated crops; thus genetic degeneration does not occur with subsequent plantings. Nonetheless, varietal mixtures as the result of carelessness, diseased grain from poor handling, and lower germination rates for seeds all contribute to yield reductions. Varietal degeneration occurs in the case of mustard and other cross-pollinated crops, however. When hybrid status is uncontrolled, yields may vary from year to year. In potatoes, yield declines from year to year because seed tubers become contaminated with virus and other diseases when grown in such a warm

Table 30--Quantity of improved seeds supplied by the Bangladesh Agricultural Development Corporation, 1974-82

Year	Seeds		
	Total Rice	Wheat	Potato
		(tons)	
1974	8,253	1,439	2,727
1975	3,429	675	3,278
1976	2,002	4,777	4,321
1977	1,028	1,782	1,942
1978	1,576	3,490	2,411
1979	1,324	4,867	2,775
1980	2,039	14,024	3,711
1981	1,260	14,146	3,322
1982	1,935	11,075	3,[illegible]56

Source: Bangladesh Agricultural Development Corporation.

country. Farmers will not hesitate to buy expensive freshly imported seed potatoes from Europe knowing yields will be about 50 percent greater.

Improved jute seed is produced by the Jute Research Institute, but there is not enough to meet total requirements. Supply sources of pure sugarcane seed are also limited. Most seed for "English" vegetables, such as cauliflower, cabbage, and carrots, are imported, and hence of higher quality.

In the short run, BADC should look to producing more locally grown wheat seed rather than importing about 50 percent of supply as it is doing presently. Work should also be done to improve mustard, potato, and pulses seed. And finally, research should be undertaken to promote new rice varieties and to incorporate them along with some older varieties. In the long run the private sector should be brought into other areas of seed marketing, especially processing, grading, and storage.

CURRENT PROGRAMS AND RESEARCH PRIORITIES

In Bangladesh the problem of food deficiency required immediate action, which took the form of promoting HYV varieties, improving fertilizer and cultural practices, and managing water and pest problems. Research of this nature, when done hurriedly, may ignore other factors that can have destabilizing or adverse effects on crop production. Some of the consequences of increased use of HYVs and increased cropping intensity with irrigation are summarized here.

First, soil fertility may be lost as the result of improper use of HYVs and related technology. Only about 10 percent of the farmers use the correct dosage of fertilizer, which is roughly in the ratio of 2:2:1 (N, P_2O_5, K_2O), and apply good cultural practices and water management. Failure to apply fertilizers at the right time in appropriate doses and with proper placement leads to unbalanced uptake of nutrients and fertility problems.

Most of these problems are being addressed at the country's research institutes. Research has been undertaken to increase and stabilize soil fertility through proper application of nutrients such as NPK, S, and Zn, along with organic recycling and attention to a cropping systems approach. More emphasis is now given to increased fertilizer efficiency, appropriate cultural practices, and water management, so that reductions in yields are not inevitable. Research is incorporating more and more yield stabilizing factors into the projects.

Second, HYV technology, when not properly applied, greatly exacerbates pest hazards. Evolution of new mutants of fungi and new insect biotypes, both with increased resistance, are the result of

misuse of pesticides, thus complicating the research effort. Increased use of N without appropriate P and K balances is responsible for the creation of predisposing factors that lead the way to higher incidence of pests and diseases. Research on the interrelationships among varieties, fertilizer, cultural practices, cropping patterns, and pest and disease infestation now receives special attention. New varieties have a wider spectrum of resistance, but these are problems that require long-term research efforts. Research on the use of biological and other nontoxic pesticides is also in progress.

Third, research to reduce loss from drought, salinity, flooding, cold injury, and soil toxicity and deficiency is going on. These are difficult multidisciplinary areas, and more time is needed for the development of appropriate technology.

Fourth, research on economical aspects of crop production vis-à-vis farmers' conditions is being pursued. Some problems have been identified but, in most cases, the present administrative infrastructures and local institutions are not capable of handling their resolution.

Fifth, the problems associated with subsidies on inputs, price supports, and credit are still being debated and have not been resolved.

Finally, manpower improvement and creation of leadership for the coming century, when tougher and more complicated production problems may develop, need immediate attention. Without a strong program, critical future research will be inadequately addressed.

Both short- and long-term research priorities have been identified and recorded in a recent publication, "National Agricultural Research Plan, 1984-1989," by the Bangladesh Agricultural Research Council. The government is now preparing a third five-year plan to incorporate these research priorities.

6. NATIONAL FERTILIZER SUPPLY AND SUPPLY ADJUSTMENT PLANNING IN BANGLADESH

A. Samad

THE FERTILIZER MARKET

The use of chemical fertilizers in crop production is a comparatively recent practice in Bangladesh. In 1951/52, the earliest year for which any data are available, about 10,000 tons of ammonium sulfate were used, almost entirely on tea gardens; use of chemical fertilizers by ordinary farmers was practically unknown. Records indicate that in 1949/50, the government drew up a scheme to distribute annually for five years about 24,000 tons of ammonium sulfate, 18,000 tons of oil cakes, 15,000 tons of lime, 30,000 tons of bonemeal and superphosphate, and 7,000 tons of seed for green manure crops. Progress was insignificant because of farmers' ignorance about the benefits of fertilizer use, lack of a vigorous promotion effort by the government, and almost total absence of a marketing infrastructure. Though some progress was made during the 1955-60 Five-Year Plan under the Grow-More-Food campaign, fertilizer consumption was no more than 50,000 tons in 1959/60.

Several factors combined to bring about a change during the next decade. First, population growth had already overtaken increases in cereal production; rising foodgrain import bills required to meet the needs of the rapidly growing population forced the government to give serious attention to agriculture. Second, the government acknowledged the critical role of fertilizer in achieving higher yields. This is evident from a report of the Food and Agriculture Commission.[1]

> Unless the plant nutrient content of the soil is adequate, other factors of increased production like better seeds, water or better land preparation cannot bring about the desired results. The use of fertilizer is, therefore, taken to be a prime factor in production. It can give a large and immediate increase in yield and hence receives top priority in all agricultural development programs.

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[1]Pakistan, Ministry of Agriculture, Report of the Food and Agriculture Commission (Karachi: Government Press, 1960).

Third, fertilizer trials on farmers' fields conducted with the assistance of the Food and Agriculture Organization of the United Nations during 1957-59 established beyond doubt the high responsiveness of paddy crops to fertilizer. These trials also enabled the development of balanced application rates for different soil-climatic zones that extension workers could recommend with some confidence. Finally, inadequacies of the marketing and distribution system were recognized and the Bangladesh Agricultural Development Corporation (BADC) was established with the specific objective of ensuring easy availability of inputs to farmers. These changes, combined with liberal price subsidies for fertilizer, resulted in steady growth during the 1960s. By 1969/70 consumption had risen to 275,000 tons.

Table 1 presents growth of fertilizer sales during the 15-year period 1969/70-1983/84. For the period as a whole, fertilizer consumption increased at an annual rate of nearly 10 percent. However, this growth was highly erratic: there was negative growth in 4 of the 15 years, but in one particular year, 1977/78, sales jumped by more than 40 percent over peak year 1976/77. Overall, fertilizer sales have remained far below levels necessary to meet foodgrain production targets. Specifically, by 1977/78, the terminal year of the First Five-Year Plan, fertilizer consumption was only 60 percent of the Plan target. If the current sales target, 1.2 million metric tons for 1984/85, is realized, this will still represent a mere 60 percent of the Second Five-Year Plan target. Two factors contributed to this lag. Fertilizer sales were severely disrupted during and immediately after the War of Liberation and in 1974/75 when the Ghorasal Urea Factory broke down. Although fertilizer prices were kept unchanged throughout the 1960s, prices were raised 12 times between 1972 and 1984. The price increases have been quite drastic: from Tk 20 per maund of urea in 1972 to Tk 160 per maund in 1984.

SOURCES OF FERTILIZER

Chemical fertilizers sold in Bangladesh come from both domestic factories and imports (Table 2). Currently, almost all the urea and some of the triple superphosphate (TSP) applied in Bangladesh are locally produced. The entire quantity of diammonium phosphate (DAP) and muriate of potash (MP), as well as most of the TSP, is imported. Ensuring adequate national supplies thus depends on steady production in domestic factories and timely arrival of imports.

Fertilizer imports averaged 323,000 tons annually during the 1974/75-1978/79 period and 412,000 tons annually during the five years ending in June 1984. Had domestic fertilizer factories performed near capacity, the total volume of imports would have declined and Bangladesh would have achieved self-sufficiency in urea.

Table 1--Annual fertilizer sales, 1969/70-1983/84

Year	Urea	TSP/DAP	MP	Other	Total
		(metric tons)			
1969/70	196,463	65,535	15,109	...	277,107
1970/71	212,358	74,900	17,112	...	304,370
1971/72	169,771	60,139	13,932	...	243,842
1972/73	276,280	88,914	18,468	...	383,662
1973/74	267,628	93,821	18,392	...	379,841
1974/75	174,195	75,175	17,509	12,690	279,569
1975/76	311,926	109,915	22,112	13,832	457,785
1976/77	353,230	125,585	22,380	11,405	512,600
1977/78	479,846	192,036	41,230	5,941	719,053
1978/79	473,985	206,711	44,708	8,353	733,757
1979/80	533,405	246,780	46,331	11,594	838,110
1980/81	560,255	255,302	45,145	13,411	874,113
1981/82	518,776	256,391	44,915	8,716	828,798
1982/83	629,058	279,160	50,420	9,780	968,418
1983/84	708,070	354,561	63,222	3,207	1,129,060

Source: Bangladesh Agricultural Development Corporation.

Notes: TSP/DAP is the sum of sales of triple superphosphate and diammonium phosphate. MP is muriate of potash. All fertilizer data in this and other tables in this paper are in gross weight of the specified fertilizers. For nutrient weight data, see Chapter 1, by Gunvant Desai.

Table 2--BADC fertilizer procurement from domestic and foreign sources, 1974/75 - 1983/84

Year	Domestic		Imported						Total
	Urea	TSP	Urea	DAP	TSP	MP	Other	Total	
				(1,000 metric tons)					
1974/75	82	24	140	...	48	7	30	225	331
1975/76	280	39	72	...	223	37	2	334	653
1976/77	270	43	11	...	21	10	...	42	355
1977/78	226	38	260	...	115	13	...	388	652
1978/79	275	59	349	84	104	77	12	626	960
1979/80	304	58	286	42	174	60	11	573	935
1980/81	351	68	64	45	192	43	20	364	783
1981/82	413	65	254	37	147	26	...	464	942
1982/83	427	66	43	72	136	44	9	304	798
1983/84	640	75	93	76	124	60	3	355	1,070

Source: Bangladesh Agricultural Development Corporation.

Notes: TSP is triple superphosphate, DAP is diammonium phosphate, and MP is muriate of potash.

This did not happen, and urea imports tied up funds that could have been used for importing other types of fertilizer. Efficient operation of domestic factories is also likely to be an important determinant of future fertilizer availability in Bangladesh.

During the 10-year period from 1974/75 through 1983/84, a total of 3.6 million tons of fertilizer was imported, mostly financed by bilateral grants or concessional loans. The largest contributors in recent years were the foreign assistance agencies of the United States (USAID), the Netherlands, Canada, Saudi Arabia, Norway, Denmark, the Federal Republic of Germany, and the Oil-Producing and Exporting Countries (OPEC), as well as international organizations such as the International Development Agency, the Asian Development Bank, and the International Fund for Agricultural Development (Table 3). Some fertilizers were imported under barter arrangements with East European socialist states, but Bangladesh resorted to cash purchase with its own funds (accounting for less than 2 percent of total imports) only in crisis situations.

FIVE-YEAR PLAN TARGETS, ANNUAL FERTILIZER SALES TARGETS, AND PROCUREMENT PLANNING

The government's strategy for agricultural growth relies heavily on seed-fertilizer-irrigation-based technology. Annual fertilizer sales targets have thus figured prominently in all Plan documents (the First Five-Year Plan, the Two-Year Plan, and the Second Five-Year Plan) and have constituted a key element of agricultural sector targets. The original annual sales targets for the Second Five-Year Plan period appear in Table 4.

Although Plan stipulations provide a useful background, actual sales targets are fixed after consultation of representatives of BADC, the Ministry of Agriculture, the Ministry of Finance, and the Planning Commission. BADC prepares an initial sales projection based on past sales trends, targeted expansion of irrigation, anticipated area under various crops, the size of agricultural credit programs, and other relevant factors. The proposal is then discussed and finalized, taking into consideration its various implications for mobilization of foreign exchange for imports, the availability of sufficient budgetary funds to cover subsidy requirements, and so forth. The annual sales targets that have been fixed from year to year, as well as actual sales achieved, have lagged considerably behind Plan stipulations (Tables 4 and 5).

BADC starts the procurement planning process with a lead time of 4-6 months. The initial sales projection for the coming year and necessary procurement actions to effect these sales are usually worked out and circulated by BADC by the month of December. The

Table 3--Imports of fertilizers by source, 1981/82 - 1983/84

Year/Fertilizer Source	Urea	TSP	DAP	MP	Others	Total
		(1,000 metric tons)				
1981/82						
Netherlands	46.9	72.3	...	...	...	119.2
Saudi Arabia	74.8	...	...	...	...	74.8
OPEC	50.3	2.0	...	...	...	52.3
IDA	35.6	15.1	...	...	...	50.7
Norway	10.1	15.7	9.4	...	...	35.2
Germany	...	16.6	14.4	...	...	31.0
IFAD	14.5	...	13.1	...	...	27.6
CIDA	...	...	...	26.0	...	26.0
Bulgaria	22.2	...	...	...	...	22.2
Denmark	...	15.5	...	...	...	15.5
ADB	...	9.9	...	...	...	9.9
Total	254.4	147.1	36.9	26.0	...	464.4
1982/83						
USAID	...	...	71.7	...	...	71.7
Netherlands	...	65.2	...	...	...	65.2
CIDA	...	...	...	44.0	...	44.0
Denmark	...	40.1	...	...	...	40.1
Saudi Arabia	33.1	...	...	...	...	33.1
Bulgaria	...	22.0	...	...	...	22.0
Japan	9.9	8.8	...	...	...	18.7
Norway	...	...	...	...	9.4	9.4
Total	43.0	136.1	71.7	44.0	9.4	304.2
1983/84						
USAID	50.0	...	25.0	...	1.5	76.5
Canada	...	...	...	60.0	...	60.0
Denmark	...	45.0	...	...	...	45.0
Netherlands	...	30.0	...	...	...	30.0
NORAD	...	17.5	6.0	...	...	23.5
Saudi Arabia	14.0	...	...	...	...	14.0
West Germany	...	9.0	...	...	...	9.0
ADB	...	8.5	...	...	...	8.5
IFAD	...	8.5	...	...	...	8.5
United Kingdom	...	5.0	...	...	...	5.0
Japan	...	...	...	...	1.0	1.0
Bulgaria	...	...	25.0	...	...	25.0
Czechoslovakia	...	...	20.0	...	...	20.0
Cash	29.0	...	...	...	...	29.0
Total	93.0	123.5	76.0	60.0	2.5	355.0

Source: Bangladesh Agricultural Development Corporation.

Notes: OPEC is the Oil Producing and Exporting Countries, IDA is the International Development Agency, IFAD is the International Fund for Agricultural Development, CIDA is the Canadian International Development Agency, ADB is the Asian Development Bank, USAID is the U.S. Agency for International Development, and NORAD is the Norwegian Agency for International Development.

TSP is triple superphosphate, DAP is diammonium phosphate, and MP is muriate of potash.

Table 4--Second Five-Year Plan target fertilizer sales, 1980/81-1984/85

Year	Urea	TSP/DAP	MP	Total
		(1,000 long tons)		
1980/81	625	375	120	1,120
1981/82	650	450	150	1,250
1982/83	680	525	200	1,405
1983/84	735	580	250	1,565
1984/85	830	710	360	1,900

Source: Bangladesh Agricultural Development Corporation.

Notes: TSP/DAP is the sum of sales of triple superphosphate and diammonium phosphate; MP is muriate of potash. A long ton is approximately 1.6 percent heavier than a metric ton.

Table 5--Annual fertilizer sales targets and actual sales, 1980/81 - 1983/84

	Annual Targets				Sales Achieved				
Year	Urea	TSP/DAP	MP	Total	Urea	TSP/DAP	MP	Other	Total
				(1,000 tons)					
1980/81	690	345	115	1,150	560	256	45	14	875
1981/82	620	310	50	980	519	257	45	8	829
1982/83	650	320	55	1,025	629	279	50	10	968
1983/84	700	295	55	1,050	708	354	63	3	1,129

Source: Bangladesh Agricultural Development Corporation.

Notes: TSP/DAP is the sum of sales of triple superphosphate and diammonium phosphate; MP is muriate of potash. The 1982/83 and 1983/84 figures are specified in metric tons. Earlier targets and sales figures are specified in long tons. A long ton is approximately 1.6 percent heavier than a metric ton.

format used for this procedure appears in Table 6. Subsidy requirements are discussed in detail during preparation of the Annual Development Program (ADP) in March or April. The Bangladesh Chemical Industries Corporation (BCIC) confirms its supply schedule by April or May. The foreign exchange requirements are finalized in July when the External Resources Division holds meetings on allocation and lines up foreign economic assistance. The import schedule may be changed during the year depending on fertilizer consumption trends and shortfalls in domestic production.

Planned stocks constitute a key element of the procurement planning process. Stock levels that are too high incur avoidable working capital costs and additional storage charges. On the other hand, a stock level that is too low jeopardizes smooth delivery of supplies to farmers when there are import schedule slippages or disruptions in local production, neither of which are infrequent. BADC has typically worked on the basis of five-month stocks for TSP, DAP, and MP, which are largely imported, and three-month stocks for urea, which are procured primarily from domestic factories. In 1984, BADC was asked to reduce its planned stocks of urea to two-months' supply in order to cut costs, a questionable decision.

SUPPLY ADJUSTMENT PLANNING

BADC has detailed data on fertilizer consumption by region and by cropping season. The data extend from the mid-1960s to the present and provide a basis for sales forecasts. Before the beginning of each fiscal year, the BADC works out detailed monthly sales targets by district for each fertilizer product and prepares a program for moving fertilizer supplies to the primary distribution points (PDPs). The supply division of BADC is responsible for monitoring stocks at PDPs every month and making adjustments in the movement programs depending on the extent to which actual sales have exceeded or fallen short of targeted levels. At the same time, PDP officials submit orders for any additional stocks they feel are needed. Because movement programs are prepared on a monthly basis, some adjustments are made automatically.

Past experience shows that these forecasts, based on the simple method of adding a few percentage points to previous sales in the corresponding months (to allow for growth), have been reasonably accurate. Urea sales have three seasonal peaks--in March, June, and September--whereas TSP sales are highest in October and November (Figure 1). There could be a shift in this pattern by a month or so from one year to another due to shifts in rainfall or weather, but the net effect is usually predictable. Sudden spurts in sales in any

Table 6--Requirements and availability of fertilizer, 1983/84

Requirement/ Availability	Urea	TSP	DAP	MP	Others	Total
			(metric tons)			
Requirement						
Sales target[a]	708	261	94	63	3	1,129
Operational stock	175	120	45	30	...	370
Total requirement	883	381	139	93	3	1,499
Availability						
Actual opening stock on July 1, 1983	90	120	22	29	...	261
Local production	640	75	...	...	...	715
ZFCL (379)	379	...	...	...	...	...
UFFG (195)	195	...	...	...	...	...
NGFF (66)	66	...	...	...	...	...
TSPC (75)	75	...	...	...	...	...
Imports already arranged						
United States (AID)	51	...	25	...	...	76
Saudi Arabia	14	...	...	...	...	14
Denmark	...	45	...	...	...	45
Netherlands	...	30	...	...	...	30
Norway (NORAD)	...	17	6	...	...	23
IFAD	...	8	...	...	...	8
ADB	...	9	...	...	...	9
Bulgaria (barter)	...	...	25	...	...	25
Federal Republic of Germany (KFW)	...	9	...	...	...	9
Canada (CIDA)	...	...	...	60	...	60
United Kingdom	...	5	...	...	...	5
Czechoslovakia (barter)	...	...	21	...	...	21
Cash	29	...	...	...	...	29
Total imports	94	123	77	60	...	354
Total available	824	318	99	89	...	1,330
Shortfall	59	63	40	4	...	192

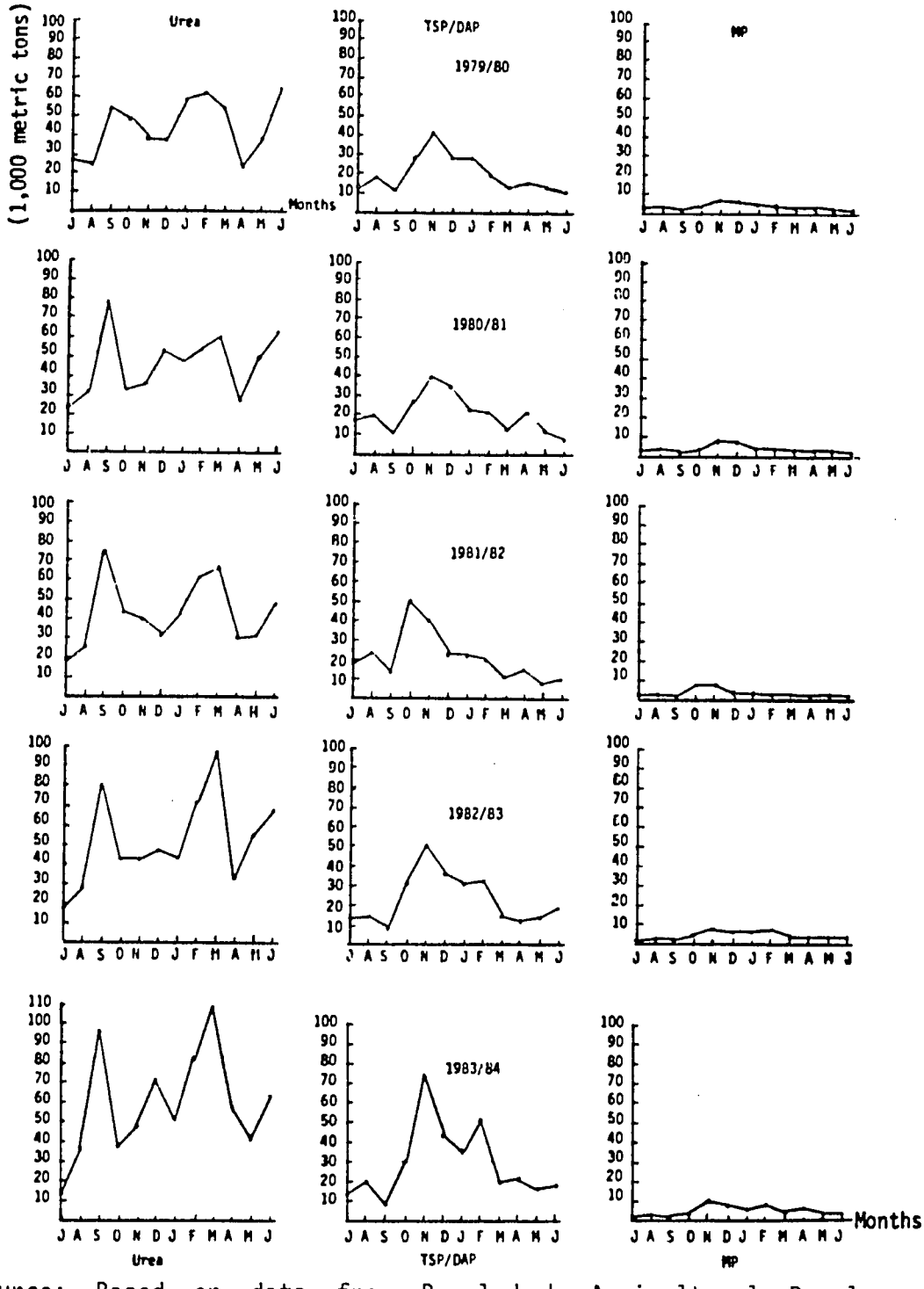
Source: Bangladesh Agricultural Development Corporation.

Notes: Acronyms refer to the Zia Fertilizer Company at Ashuganj (ZFCL), the Urea Fertilizer Factory at Ghorasal (UFFG), the National Gas Fertilizer Factory at Fenchuganj (NGFF), the TSP factory at Chittagong (TSPC), the U.S. Agency for International Development (AID), the Norwegian Agency for Development (NORAD), the International Fund for Agricultural Development (IFAD), the Asian Development Bank (ADB), the German Credit Institute for Reconstruction (KFW), and the Canadian International Development Agency (CIDA).

TSP is triple superphosphate, DAP is diammonium phosphate, and MP is muriate of potash.

[a]The figures used here for sales target are actual sales.

Figure 1--Seasonal variation in fertilizer sales, 1979/80 - 1983/84



Source: Based on data from Bangladesh Agricultural Development Corporation.

Notes: TSP/DAP is the sum of sales of triple superphosphate and diammonium phosphate; MP is muriate of potash. The agricultural year runs from July to June.

season or even in a year could be easily tackled if enough security stocks are maintained. If this is done, BADC's ability to keep the market supplied with adequate quantities of fertilizer would then depend on proper stock planning and close monitoring of the procurement program.

Implementation of the procurement programs has, however, not always been satisfactory. As may be seen in Figures 2 and 3, stock levels have fluctuated sharply, leading to shortages in some periods and oversupply in others. BADC faced severe scarcity in 1974/75 and in the winter season of 1981/82. The figures also show that there is limited correlation between stocks and sales. Stocks are necessary to execute any sales, but plentiful stocks do not necessarily lead to high sales. Stock levels were high in 1978/79 and in 1980/81, but sales grew only slightly. During the fall of 1984 Bangladesh experienced a severe fertilizer shortage for complex reasons.

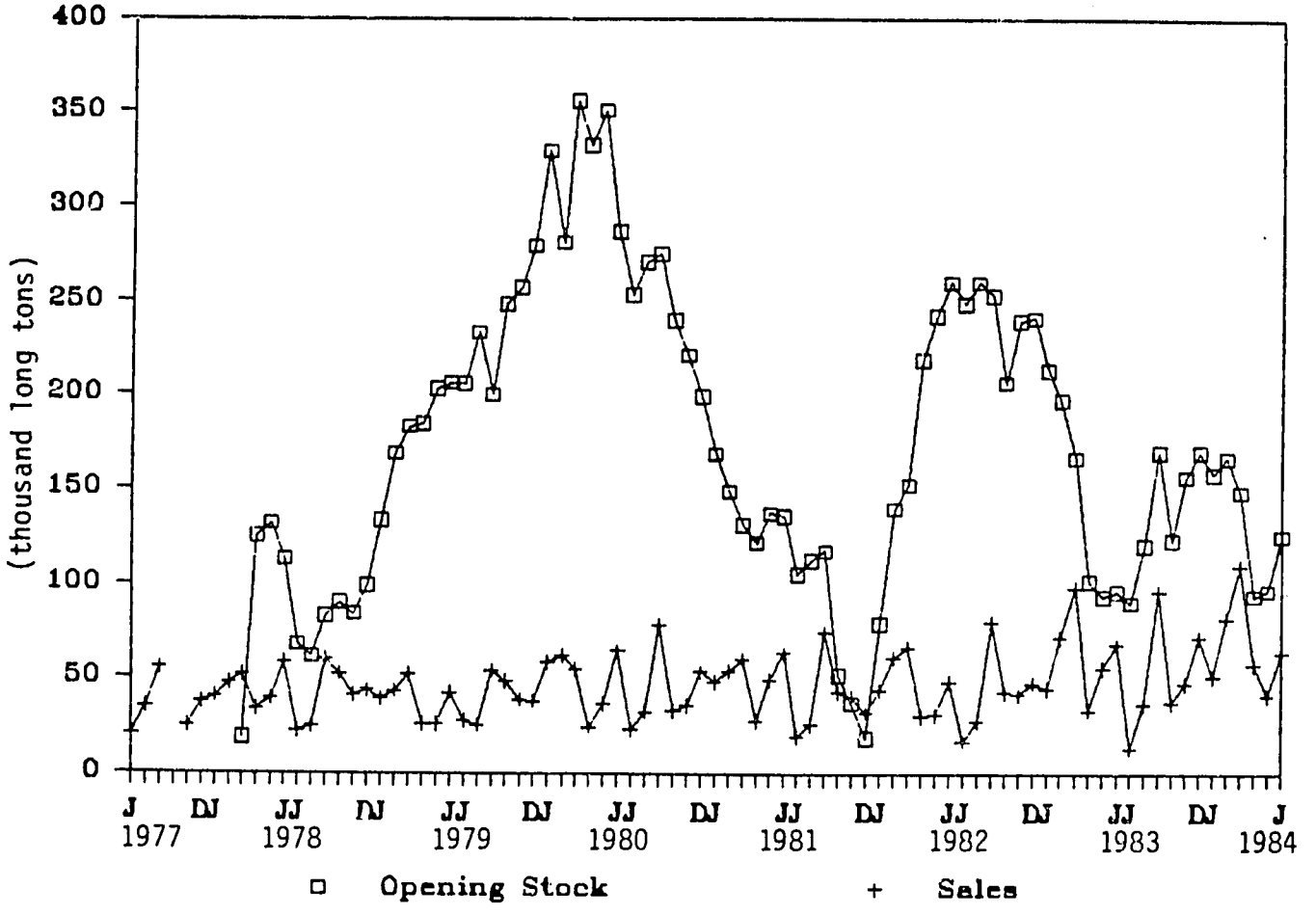
GENESIS OF THE FALL 1984 FERTILIZER CRISIS

During the fertilizer crisis in the second half of 1984, shortages hit some parts of the country as early as August and became severe throughout the country by October. The crisis reached its peak in November when, according to some reports, farmers were paying prices 60-100 percent higher than normal. The one-ton ceiling placed on removal from PDPs by dealers and restrictions on interdistrict movement of fertilizer that were imposed dislocated the distribution system and may actually have intensified the crisis. The situation eased somewhat toward the end of December when substantial imports arrived.

The Ministry of Agriculture put together a high-level committee to determine the causes of the scarcity. They found three fundamental reasons for the crisis: first, BADC started with low stocks in 1984/85; second, planned procurement allowed for almost no growth; and third, actual procurement fell far short of planned levels.

BADC finalized its sales targets and procurement plan for 1984/85 in early April 1984. This exercise should have been completed by the preceding December to allow sufficient time for programming imports. Moreover, some of the stock figures used in the projection were overestimated. For example, expected opening stocks of concentrated phosphate fertilizers on July 1, 1984 were recorded as 145,000 tons. In fact, TSP/DAP stocks were only 77,000 tons on April 1, 1984 when the projection was made, and there was no reason to expect these to double within the next three months. Actual opening TSP/DAP stocks on July 1 totaled only 62,000 tons. Thus stock levels were already down by 40 percent for urea and 60 percent for TSP/DAP when the 1984/85 fiscal year began.

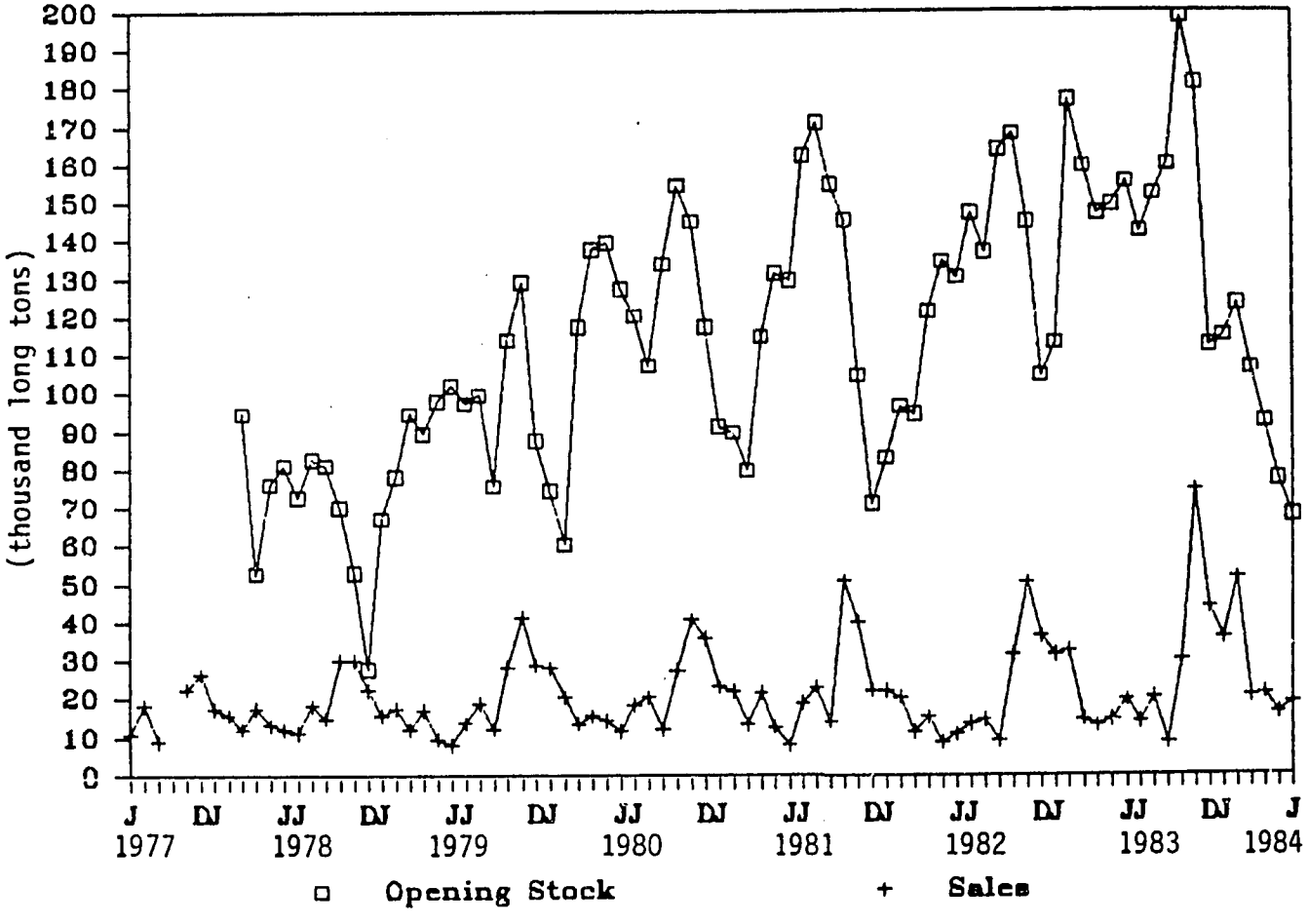
Figure 2--Monthly opening stock levels and sales of urea, 1977-84



Source: Based on data from Bangladesh Agricultural Development Corporation.

Note: The figure is plotted on a monthly basis. DJ represents December and January. JJ represents June and July.

Figure 3--Monthly opening stock levels and sales of TSP/DAP, 1977-84



Source: Based on data from Bangladesh Agricultural Development Corporation.

Notes: TSP/DAP is the sum of sales of triple superphosphate and diammonium phosphate. The figure is plotted on a monthly basis. DJ represents December and January. JJ represents June and July.

It has been suggested that the shortage was caused by sales that considerably exceeded expectations. Fertilizer sales for the six months beginning April 1984, the month in which BADC prepared and circulated its program for 1984/85, are presented in Table 7. It is clear that, except for some monthly variations, total sales more or less followed BADC projections for these months. It is therefore difficult to accept the contention that BADC's troubles arose from excess sales. BADC did face high demands in October and November, but this may have been partly due to speculative hoarding by wholesalers, dealers, and others who were taking advantage of the emerging crisis.

In 1982/83 fertilizer sales increased substantially over previous peaks, falling only 57,000 tons short of the 1982/83 sales target of 1,025 million tons. Yet the sales target for 1983/84 was only 1,050 million tons. It is not known why such a small increase was targeted, but this underestimation contributed to lower procurement and eventually to lower year-end stocks.

Slippages in the procurement program are presented in Tables 8 and 9. During the July-November period, urea picked up from domestic factories fell short by 75,000 tons and TSP pick-ups by 23,000 tons. The shortfall for urea actually totaled 81,500 tons for July-September. TSP imports available for distribution during the same period fell short by about 140,000 tons. It is difficult to say without a case-by-case study why the program failed and where the lapses occurred. Late action and procedural delays seem to have been the principal factors. In addition, BADC was overly optimistic in estimating arrival times. For example, the June newsletter (published in August) showed heavy TSP arrivals in September and October (13,000 tons from CIP I; 50,000 tons from CIP III; and 70,000 tons from the European Community[2]). The actual procurement actions were extremely late, and there were no grounds for such projections as shown by selected BADC import tenders and contract closures for May-October.

Source	Tender Floated	Contract Signed	Quantity (metric tons)
CIP III	May 23, 1984	September 24, 1984	30,000
	October 3, 1984	November 1984	20,000
EC	July 12, 1984	October 14, 1984	unavailable

[2]CIP I and III are projects financed by the Asian Development Bank.

Table 7--Projected and actual fertilizer sales, April-September 1984

Month	Target			Actual Sales		
	Urea	TSP/DAP	MP	Urea	TSP/DAP	MP
	(1,000 metric tons)					
April	40.0	13.0	4.0	57.4	21.2	5.6
May	58.0	16.0	4.0	41.3	16.0	4.2
June	70.0	19.0	3.0	63.9	18.6	4.4
July	24.0	19.0	1.5	29.3	18.0	3.0
August	40.0	23.0	3.0	50.8	16.8	3.0
September	110.0	10.0	1.5	96.3	14.3	2.1
Total	342.0	100.0	17.0	339.0	104.9	22.3

Source: Bangladesh Agricultural Development Corporation.

Notes: TSP/DAP is the sum of sales of triple superphosphate and diammonium phosphate; MP is muriate of potash.

Table 8--Urea procurement slippages, 1984/85

Month	Expected Procurement Indicated in BADC's June Newsletter			Actual Procurement		
	Local	Import	Total	Local	Import	Total
	(1,000 metric tons)					
July	113.0	...	113.0	56	...	56
August	66.0	...	66.0	58	...	58
September	66.5	...	66.5	50	...	50
October	34.5	30.0 (Netherlands)	64.5	62	...	62
November	51.0	...	51.0	60	...	60

Source: Bangladesh Agricultural Development Corporation.

Note: The net shortfall from July through November 1984 was 75,000 tons.

Table 9--TSP procurement slippages, 1984/85

Month	Expected Procurement Indicated in BADC's June Newsletter			Actual Procurement		
	Local	Import	Total	Local	Import	Total
	(1,000 metric tons)					
July	11.0	32.0 (Netherlands) 20.0 (Rumania)	63.0	3.0	31.0 (Netherlands) 15.0 (Rumania)	49.0
August	11.0	...	11.0	3.1	10.7 (CIP I)	13.7
September	11.0	13.0 (CIP I) 20.0 (CIP III) 40.0 (EC)	84.0	6.8	5.5 (Rumania) 11.5 (NORAD)	23.8
October	11.0	30.0 (CIP III) 40.0 (EC)	81.0	7.1	...	7.1
November	11.0	40.0 (Denmark) 30.0 (EC) 18.0 (NWRDP) 7.0 (KFW)	106.0	12.0	50.7 (CIP III) 13.9 (CIP I) 15.0 (EC)	91.6

Source: Bangladesh Agricultural Development Corporation.

Notes: Parenthesized acronyms indicate funding source. CIP and NWRDP are projects financed by the Asian Development Bank, EC refers to the European Community, KFW is the German Credit Institute for Reconstruction, and NORAD is the Norwegian Agency for Development.

TSP is triple superphosphate.

Whatever the reasons, BADC's stock situation deteriorated rapidly, and supplies of urea and TSP were extremely short during the August-November period (Figures 4 and 5). Stocks of MP also fluctuated but were within manageable limits. The impact of the shortage on farmers was especially severe because 25-30 percent of available stocks were tied up in port sheds or in transit during the fall and thus unavailable for farmer purchase.

It is of particular interest that sizable stocks of fertilizer remained at the domestic factories during the entire period. Factories held 57,000 tons of urea and 13,000 tons of TSP in November 1984, more than twice the usual levels. Distribution of these quantities could have helped ease the scarcity situation.

The supply shortage in the fall of 1984 provides some important lessons for supply adjustment planning. Three areas appear to be most in need of attention: shortfalls in deliveries from domestic factories, slippages in import schedules, and standard procedures for emergency purchases.

BCIC and BADC Targets

BCIC usually draws up ambitious production targets to keep pressure on factory managers. These figures are used by BADC in drawing up its procurement program. When production lags behind targets, BADC has to line up alternate sources of supply, which may be a time-consuming and expensive affair. The establishment of a firm contractual relationship between BCIC and BADC, stipulating penalties for failure of BCIC to supply and for BADC to distribute, could improve the situation by eliminating avoidable uncertainties and tightening performance discipline.

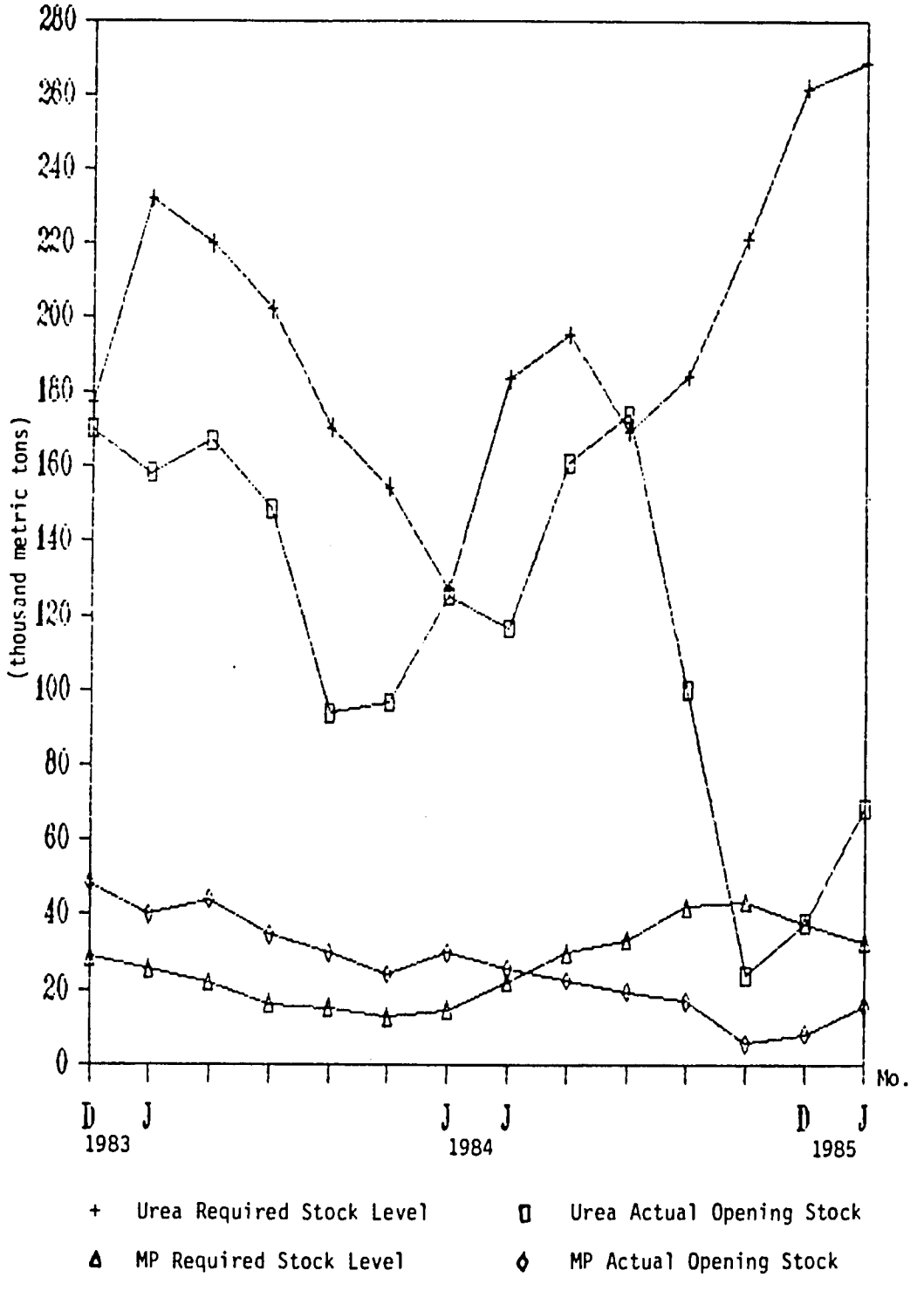
Slippages in Import Schedules

Depending on the source of financing and the procedural formalities associated with various loans and grants, implicit import lead times vary from three months to more than a year. Shortages have often resulted because these variable import lead times are not taken into consideration when drawing up the procurement program. Even now, BADC fertilizer newsletters provide a revised import forecast every month. If these forecasts are formulated with care, slippages could be easily monitored and timely corrective action taken.

Emergency Purchases

Even with good planning, emergency purchases may sometimes become necessary. BADC made two such purchases in 1984. In both

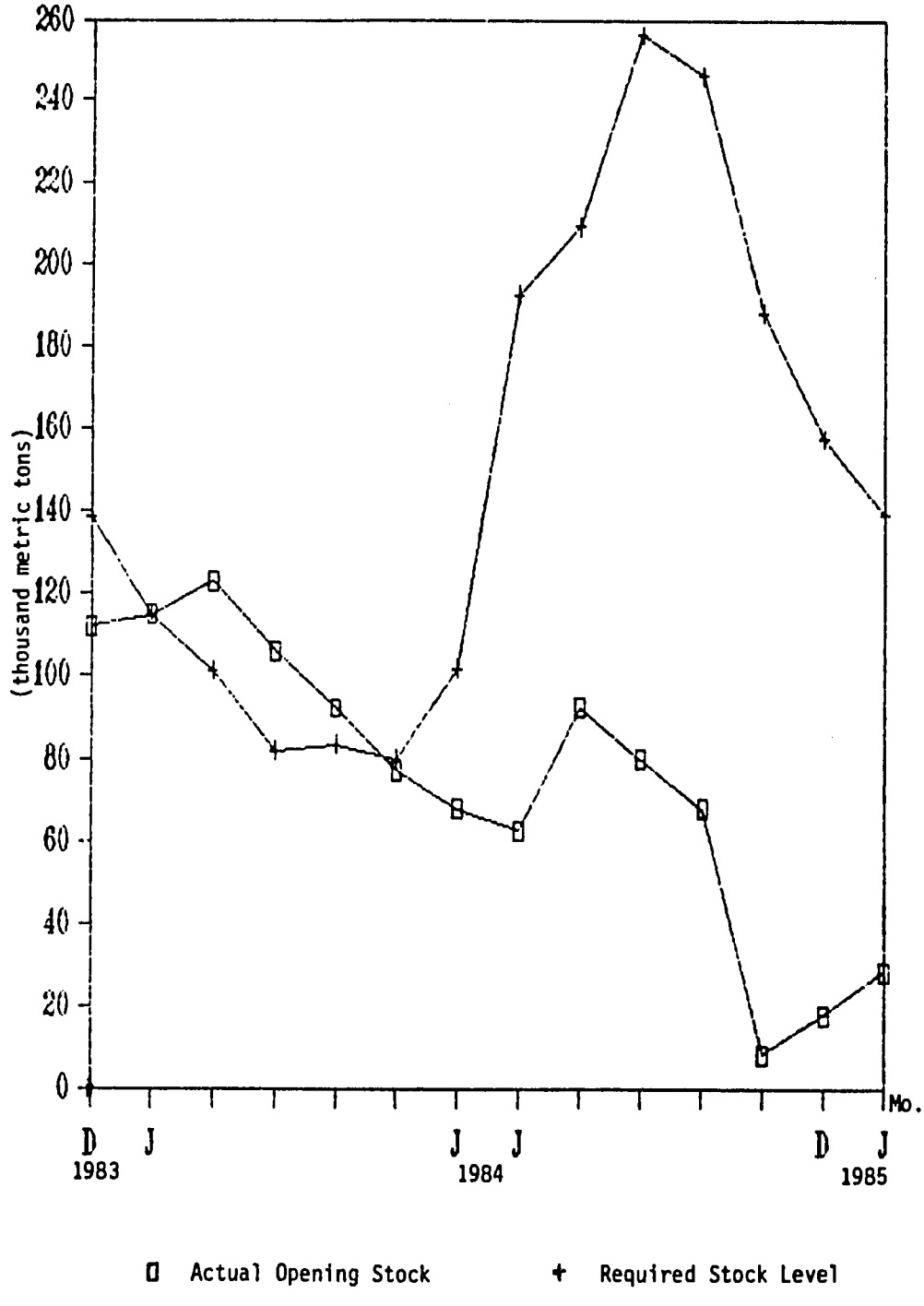
Figure 4--Required and actual monthly opening stocks of urea and MP, December 1983 - January 1985



Source: Based on data from Bangladesh Agricultural Development Corporation.

Note: MP is muriate of potash.

Figure 5--Required and actual monthly opening stocks of TSP/DAP, December 1983 - January 1985



Source: Based on data from Bangladesh Agricultural Development Corporation.

Note: TSP/DAP is the sum of triple superphosphate and diammonium phosphate stocks.

cases, procedural formalities delayed timely action. Existence of standard procedures for such purchases would enable prompt response to shortages in the future. Above all, there is no substitute for good planning and careful implementation. Careful attention to details would enable BADC's management to maintain adequate supplies at the PDPs at all times.

FERTILIZER EXPORTS

Since 1980/81, Bangladesh has occasionally exported small quantities of urea. Because fertilizer exports, however small, affect total national availability, they must be considered briefly. Urea exports by BCIC are presented in Table 10. It may be noted that exports were undertaken even though there was no overall surplus of urea. Thus compensatory imports were subsequently required. Urea exports have been justified on two grounds: first, exports relieve congestion in domestic factories due to BADC's failure to move fertilizers promptly; and second, exporting activities develop links with urea importers in other countries, which may facilitate future sales from the planned Chittagong Urea Factory, the output of which is intended primarily for the export market. Although both arguments may have some validity, past exports appear to be unjustified from a financial point of view because subsequent imports were made at even higher prices (Table 11).

Table 10--Urea exports by the Bangladesh Chemical Industries Corporation

Year or Date of Export	Quantity Exported	Purchasing Country	Price and Terms of Export	Amount of Freight Paid When Sales Are on c&f/ c.i.f Basis
	(metric tons)		(in U.S. $)	
1980/81				
October 4, 1980	20,000	Pakistan	266.50 c&f/ f.o.b.	25.0 per ton
October 15, 1980	20,000	Sri Lanka	270.00 c&f/ f.o.b.	32.0 per ton
1982/83				
October 24, 1982	45,500	Indonesia	140.26 f.o.b.	...
November 9, 1982	15,000	Nepal	175.00 c.i.f. Birol	...
December 13, 1982	4,300	Nepal	172.00 c.i.f. Calcutta	Tk 430 per ton
December 20, 1982	25,825	China	149.00 f.o.b.	...
February 23, 1983	1,000	Burma	150.00 f.o.b.	...
1983/84				
November 3, 1983	30,000	Nepal	163.00 c.i.f. Birol	...
May 25, 1984	7,000	Nepal	170.00 c.i.f. Birol	...

Source: Bangladesh Chemical Industries Corporation.

Table 11--Urea import prices, 1982/83 and 1983/84

Year	Source of Financing	Price per Ton, c&f
		(U.S. $)
1982/83	Saudi grant	225.00 205.00
	Japanese grant	252.81
1983/84	Saudi grant	205.00
	USAID	210.25 241.96 242.77
	Cash	183.00

Source: Bangladesh Agricultural Development Corporation.

7. SUPPLY AND DISTRIBUTION OF FERTILIZERS IN BANGLADESH

Md. Abul Quasem

The availability of fertilizers "at the right time, in the right quantity, and at the right places" is considered crucial to expanding agricultural production through increasing fertilizer use. Even if farmers are aware of the benefits of fertilizer application, they would not be able to use fertilizers without adequate availability at their usual marketplaces when application to particular crops is most propitious. The critical nature of timely availability is compounded by the inability of farmers, for a variety of reasons, to store chemical fertilizers for more than a few days.

The quantities of the various kinds of fertilizers that are required depend upon the specific locations and cropping seasons. These requirements have to be met by transporting fertilizers from domestic and foreign sources to the farms. Certain quantities of fertilizer have to be maintained as stocks, so that the flows in the pipeline do not suddenly dry up when delays or disruptions in supply occur. The marketing agents performing these functions, be they public or private, are guided by a framework of rules and standard conduct. This code of operation ultimately affects the prices of fertilizers at the farm gate, even if official prices are nominally fixed.

Issues related to the chain of supply are the main subjects addressed in this paper. A number of demand factors are also examined, but only to the extent that this examination informs the discussion of efficient supply management of fertilizers.

PROCUREMENT AND AGGREGATE SUPPLY OF FERTILIZERS

Farmers in Bangladesh have long been using urea, triple superphosphate (TSP), and muriate of potash (MP) as fertilizers. In recent years, diammonium phosphate (DAP), zinc sulfate, and NPK (compound fertilizers combining nitrogen, phosphate, and potash) have been used as well, but their share is small (6.8 percent of total 1983-84 sales). Ammonium sulfate is used only on tea plantations.

Most of the urea and a portion of the TSP used in the country is produced in local factories, but the remaining fertilizers, including the entire amount of applied MP, are imported. The share of imports

in the total volume of consumption gradually declined to 32 percent in 1983/84 (Table 1). This decline is particularly attributable to the increasing domestic production of urea.

The Bangladesh Agricultural Development Corporation (BADC) is responsible for the procurement of all fertilizers, both domestic and imported. In that sense BADC holds a monopsony in fertilizers acquired for distribution to the Bangladesh market. BADC is also the sole fertilizer distribution agent to 95 primary distribution points (PDPs) located in principal markets, generally at the level of the newly created districts. That means that the smooth flow of fertilizers in the country depends on BADC's performance. Any dislocation in aggregate supply may affect the entire system of distribution. BADC is aware of the critical nature of this responsibility and endeavors to maintain adequate stocks at all times through a combination of domestic procurement and imports.

Procurement from Domestic Factories

All the country's fertilizer factories are managed by the Bangladesh Chemical Industries Corporation (BCIC) of the Ministry of Industries. Prices are usually negotiated between the Ministry of Agriculture and the BCIC, although the final prices have, on occasion, been decided by the cabinet.

Urea, whose main ingredient is natural gas, is produced at three factories: the Urea Fertilizer Factory at Ghorasal, the Zia Fertilizer Company (ZFCL) at Ashuganj, and the Fenchuganj Natural Gas

Table 1--Share of imports among fertilizers used in Bangladesh, 1978/79 - 1983/84

Year	Urea	TSP	MP	Total for All Fertilizers
		(percent)		
1978/79	55.56	75.86	100.0	64.48
1979/80	48.06	78.50	100.0	60.85
1980/81	15.15	71.71	100.0	44.73
1981/82	38.11	68.95	100.0	48.88
1982/83	9.29	67.00	100.0	38.15
1983/84	8.48	58.19	100.0	31.68

Source: Bangladesh Agricultural Development Corporation.

Fertilizer Factory. Ghorasal was the largest supplier until 1983/84, when ZFCL took over that distinction by supplying about 48 percent of all urea procured by BADC (both domestic and imported). Two more factories, with annual design capacities of 562,000 tons and 95,000 tons of urea, are under construction.

At present, only about 9 percent of available urea is imported (Table 2), and Bangladesh is soon expected to be a net exporter of urea, provided that domestic plant capacities are efficiently utilized. Unfortunately, present capacity utilization is low and erratic (Table 3), particularly at ZFCL, which nevertheless reached 72 percent of capacity in 1983/84. This underutilization was most serious at the country's only TSP complex, at Chittagong, where operational efficiency has never reached 54 percent. This factory typically uses imported rock phosphate to produce a powdered form of TSP.

According to BCIC, full utilization of installed capacity is not possible: the attainable operational efficiency may be 95 percent for ZFCL but only around 66 percent for the TSP complex. A full discussion of such a low attainable capacity and its causes falls outside the focus of this paper, yet would seem to be a matter of considerable interest when formulating overall policy about future supplies.

Procurement from Abroad

Imported fertilizers consist primarily of granular TSP and MP. In recent years DAP, zinc sulfate, and NPK have also been imported. Their share in total fertilizer procurement is small, however. The imports are financed through grants, credit and loan arrangements, or purchased with cash or foreign exchange. During the last decade (1972/73 to 1981/82), the average proportions of total imports purchased under each of these categories of procurement were estimated to be 47, 46, and 7 percent, respectively. During the last three years of the period, imports obtained with grants have been increasing, reaching 93 percent in 1981/82. This short-term trend is mainly due to DAP imports from the United States, which were eventually discontinued in 1984/85.

From 1972/73 through 1981/82, the countries supplying the most fertilizer to Bangladesh under grants were Canada, Norway, Saudi Arabia, the United Kingdom, and Holland. The United States supplied only a small amount during most of the period. But the United States is the principal supplier under credit, contributing around 86 percent of total fertilizer import credits, funded mainly through the United States Agency for International Development (USAID) and the International Development Agency (IDA). Fertilizer is also purchased with credits provided by Norway, the United Kingdom, and Japan.

Table 2--Annual procurement of urea from domestic factories and imports, 1975/76 to 1983/84

Year	Fenchuganj Natural Gas Fertilizer Factory	Ghorasal Urea Fertilizer Factory	Zia Fertilizer Company Ltd. at Ashuganj	Imported from Abroad	Total Quantity Procured
	(percent)				(1,000 metric tons)
1975/76	13.27	66.48	...	20.24	351.7
1976/77	25.00	71.14	...	3.85	280.7
1977/78	15.46	31.43	...	53.11	282.4
1978/79	7.98	36.46	...	55.56	617.4
1979/80	14.11	37.82	...	48.06	586.1
1980/81	26.45	58.40	...	15.15	415.1
1981/82	16.83	35.92	9.13	38.11	667.2
1982/83	18.30	47.28	25.12	9.29	462.6
1983/84	11.57	32.17	47.78	8.48	743.0

Source: Bangladesh Agricultural Development Corporation.

Table 3--Capacity utilization among domestic factories, 1975/76 to 1983/84

Year	Percentage of Production Capacity Utilized[a]			
	Fenchuganj	Ghorasal	ZFCL	TSP Complex
1975/76	50.28	67.32	...	31.30
1976/77	73.02	61.20	...	29.23
1977/78	57.92	44.41	...	31.77
1978/79	51.51	69.44	...	47.92
1979/80	98.68	75.47	...	54.69
1980/81	93.58	72.20	...	54.69
1981/82	87.26	74.41	23.92	44.54
1982/83	82.26	83.23	26.48	51.77
1983/84	83.02	75.64	71.79	53.45

Source: Bangladesh Agricultural Development Corporation.

[a]Installed production capacities at Fenchuganj, Ghorasal, Zia, and the TSP Complex are 106,000, 340,000, 520,000, and 130,000 metric tons respectively. According to Bangladesh Chemical Industries Corporation (BCIC), 100 percent capacity utilization is not possible, and the attainable rates are 95 percent for Zia, 80 percent for Ghorasal, and only 66 percent for the TSP Complex.

All grants except those from Holland were "tied"; that is, the sources and the supplying agencies were required to be from the same donor country. Imports may sometimes be shipped on Bangladeshi vessels, however, if the bidding rates are competitive.

Credits available for the purchase of fertilizers are less likely to be tied, so imports under credit are usually initiated by floating international tenders. The only tied loans are those extended by USAID, and thus procurement prices of imported fertilizers associated with these loans are apt to be higher.

Import prices vary widely, depending on procurement conditions and the sources of funding. Prices of fertilizers purchased under credit are always higher than those acquired with grants or cash. This price difference per ton of urea has been around U.S. $30.00; for TSP it is much more. For example, in 1983/84, the lowest c.i.f. price per ton for urea was U.S. $183.00 procured with cash; the highest was U.S. $242.00, imported with USAID assistance. For TSP the lowest price was U.S. $134.00 (U.K. assistance) and the highest was U.S. $203.00 (Danish assistance). If procurement arrangements could be made to take advantage of the lowest available fertilizer prices, considerable procurement cost savings could be realized.

National Availability

The use of fertilizer in Bangladesh is increasing, mainly due to development of irrigation, diffusion of high-yielding varieties (HYVs) of paddy and wheat, and rapidly expanding application on other crops, such as mustard and tobacco. Fertilizer must remain readily available to encourage further use.

Aggregate availability for a particular year is based on the opening stock and procurement from factories in Bangladesh and abroad. Problems at any of these points may affect aggregate availability, so timely and careful supply planning based on realistic and updated estimates of demand are of the utmost importance. This is particularly so for imports, which require up to several months to arrange foreign exchange and to finalize procedures for floating international tenders, procurement, and shipping. Time is also needed for unloading at ports, as well as for packing and transport to PDPs.

According to information from BADC for 1983 and early 1984, the average time between the date of tender and the date of arrival was eight months, within which the average period between the dates of contract and arrival was four months. This time lag implies that the stock of imported fertilizers should be no less than five months, even if procurement funding has already been arranged.

Proper management of supplementary stocks from domestic factories is primarily a matter of distributing the stock smoothly throughout the country. BADC usually tries to maintain three months' stock, spread along the chains of supply from transit warehouses to PDP godowns. Stocks equivalent to a minimum of a month's anticipated sales are maintained at each PDP with the objective of meeting the immediate demand. For regular replenishment of PDPs, another month's stock is required. BADC acts as a security reserve, maintaining certain stock quantities against unforeseen disruptive events such as factory breakdowns, strikes, transport difficulties, and so forth. If BADC could depend on factories functioning on schedule and on no disruptions in fertilizer movements, then stocks associated with supplies from domestic factories could be reduced to two months' sales on the basis that transport of urea from the factory to even distant markets, such as Rangpur and Dinajpur, should not take more than a fortnight.

Difficulties sometimes arise in scheduling transport to PDPs, especially when there are shortages of railway cars and barges, which may be needed elsewhere for emergency distribution of foodgrains.[1] These competitive operations, however, are generally within the jurisdiction of BADC.

Because so much time is needed to acquire fertilizer, adequate quantities of opening stocks must be available at the beginning of each year. This is particularly important when the amounts supplied by domestic factories are not predictable. The minimum required opening stock is currently a matter of some debate. BADC has normally determined that it should be three months' consumption for domestically produced fertilizers and five months' for imported ones. This averages to more than 25 percent of the previous year's sales, since sales are expected to be higher in the current year.

The statistics for the period from 1975/76 to 1984/85, presented in Table 4, indicate that opening stocks were below normal in 1978/79, 1983/84, and 1984/85. See also Figures 1 and 2 for the last two years. In 1978/79 sales may not have been severely affected despite lower opening stocks of fertilizer, because of unusually rapid procurement. This may have been made possible by unusually early completion of foreign exchange funding arrangements. Procurement in 1982/83 and 1983/84 was not adequate, and this resulted in lower opening stocks in 1983/84 and 1984/85.

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[1]Unpublished note from the Division of Agriculture and Forests, Bangladesh Ministry of Agriculture, Dhaka, January 1, 1985.

Table 4--Opening stocks and availability of fertilizers, 1975/76 to 1984/85

Year	Opening Stocks: Estimated[a]	Opening Stocks: Share of Sales in Current Year	Opening Stocks: BADC Statistics	Procurement: Domestic	Procurement: Imported	Total Quantity Available	Total Sales
	(1,000 long tons)	(percent)		(1,000 long tons)			
1975/76	200	44	200	320	327	847	458
1976/77	389	76	381	313	41	743	513
1977/78	230	32	206	265	388	883	713
1978/79	170	23	149	333	626	1,129	734
1979/80	395	47	335	363	564	1,322	838
1980/81	484	55	434	425	346	1,255	875
1981/82	380	46	323	486	464	1,330	829
1982/83	501	52	426	487	298	1,286	955
1983/84	331	30	256	705	350	1,376	1,111
1984/85	265[b]	24[b]	200	756[c]	619[c]	...	...

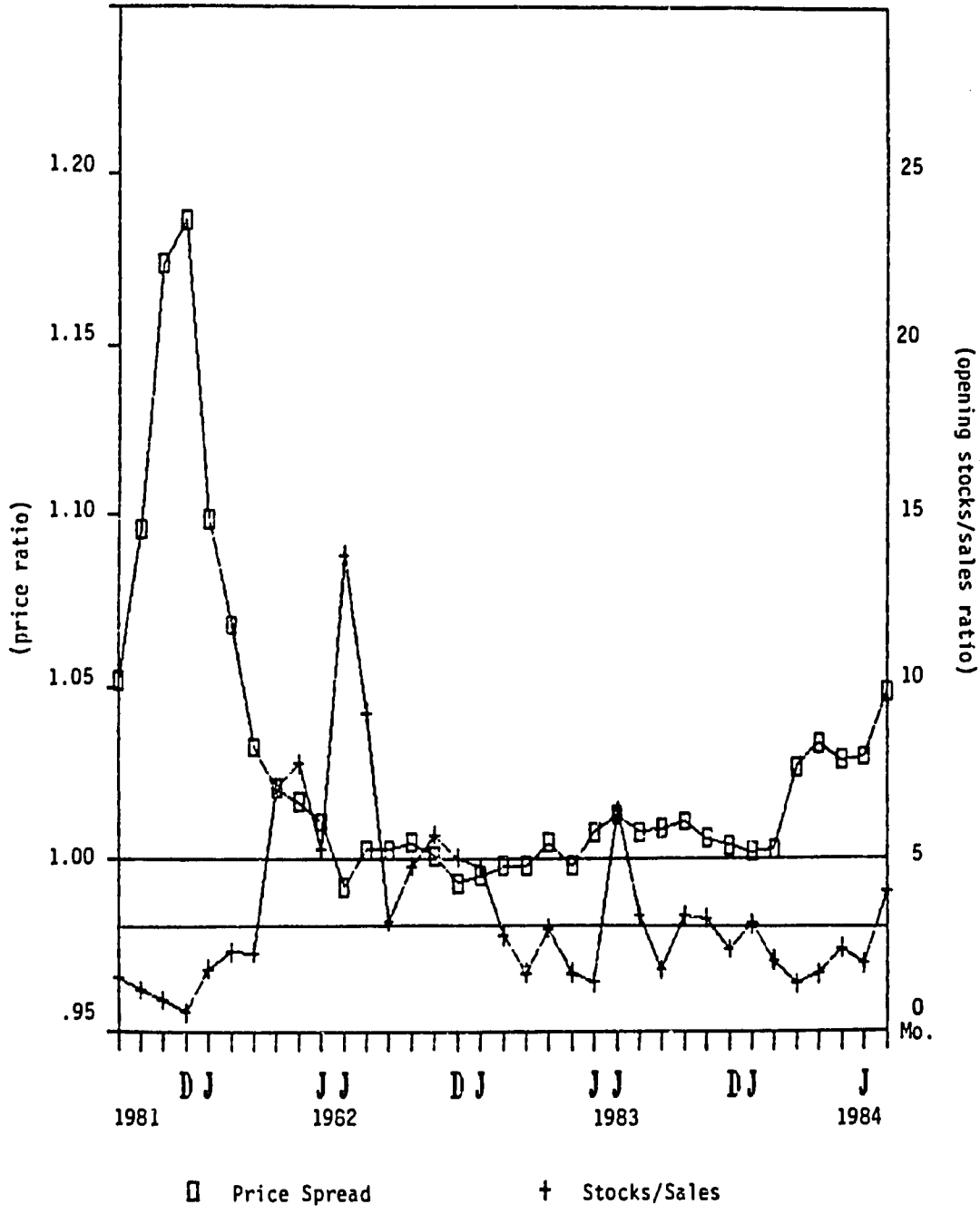
Note: The figures are for fertilizer material, not nutrients.

[a]The opening stock statistics supplied by the Bangladesh Agricultural Development Corporation (BADC) are difficult to reconcile with the estimated stocks listed above (beginning stocks plus procurement minus sales) because, according to the Bangladesh Bureau of Statistics (BBS), imports in 1977/78 and 1978/79 totaled 812,000 and 1,140,000 tons, respectively, whereas BADC records them as 388,000 tons for 1977/78 and 626,000 tons for 1978/79 (see Chapter 6 by A. Samad). In recent years BADC stock figures have been consistently less than those of BBS.

[b]This figure is based on 1983/84 sales.

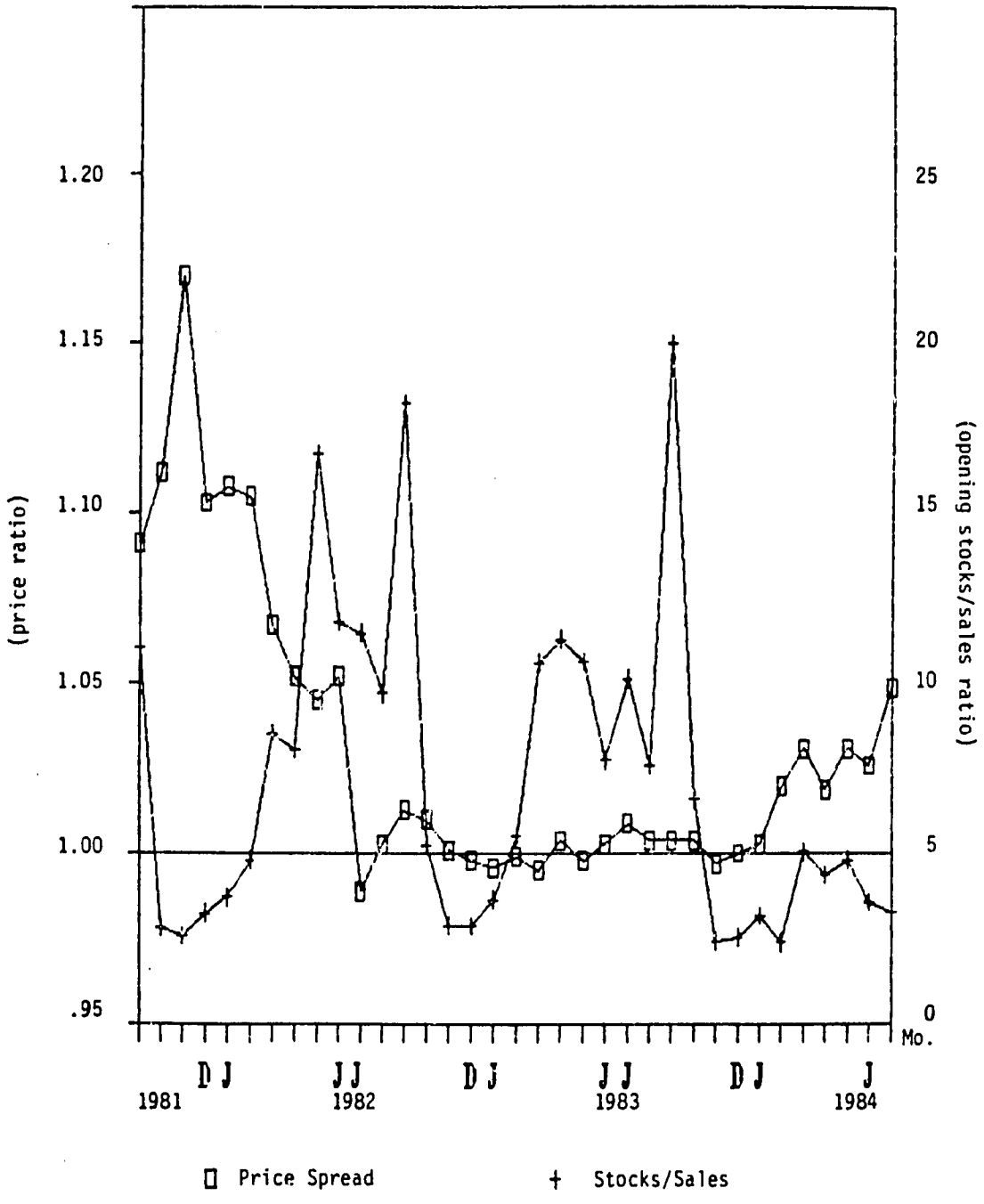
[c]This is a projection by BADC.

Figure 1--Monthly ratios of farm-gate to ex-PDP prices and opening stocks to sales for urea, 1981-84



Note: The lower horizontal line (below the unit price ratio line) indicates BADC's historic stock target equal to three times monthly sales.

Figure 2--Monthly ratios of farm-gate to ex-PDP prices and opening stocks to sales for TSP/DAP, 1981-84



Note: The horizontal line delineates both the unit price ratio and BADC's historic stock target of five times monthly sales.

The most striking instance of depleted stocks was for TSP in 1984/85 (only 48 percent of the amount required by BADC). Efforts were taken to procure TSP immediately, and large amounts reached Bangladesh by November-December.

Programming and Monitoring of Aggregate Supply

Fertilizer supply plans as incorporated into the agricultural production plans are generally prepared for five-year periods in Bangladesh. These plans are kept under constant review and necessary adjustments are made annually, depending upon economic and political circumstances.

Factors usually taken into consideration in the process of planning for annual fertilizer consumption are changes in food production strategy, specific crop production projects, input and output price policies, and institutional supports. Planning for the annual fertilizer supply plan actually extends over some 22 months. Planning exercises are supposed to start at least 7 months before the beginning of the fiscal year (see Chapter 6 in this volume by A. Samad). This annual plan should allow for reserves large enough for at least the first quarter of the succeeding year. That means planners must prepare detailed plans for monthly consumption, as well as for the expected flow of supplies, for a 15-month period commencing several months hence. This is difficult, especially owing to substantial variability in weather conditions and, consequently, the use of fertilizers on crops. Yet efficient fertilizer use depends on timing; thus BADC must conduct accurate planning exercises and make necessary arrangements for adequate stocks and smooth replenishment at all PDPs.

Regular as well as extraordinary replenishment is conducted primarily on the basis of field reports. These are monitored by assistant managers posted at the subdivisions. On occasion, if stock and local demand require it, movement between PDPs is also undertaken by BADC. Senior officers from headquarters at Dhaka and the divisions also make regular local visits to monitor the situation and make appropriate decisions to smooth the distribution of fertilizers.

It must be emphasized that when distribution to the farms was entirely the responsibility of BADC, occasional supply crises (and hence farm-level price increases) could still be diffused equitably by a form of informal rationing (union-by-union allocations and sales restriction to PDP dealers). With the new marketing system this is not possible, and the efficiency and equity of the entire distribution system would hinge on keeping adequate supply at the PDPs. Therefore, present stock requirements may need to be somewhat larger than those adopted in the past. One might argue that the recent decision to keep two months' urea stock rather than three months' stock as in the past seems to be unreasonable.

As indicated in Figures 3 and 4, the ex-PDP-to-farm-gate price spreads seem to widen when national stocks fall below three months for urea and five months for TSP.[2] However, quarterly stock/sales ratios were high in some periods and low in others, and there was variation from one district to another depending on their peak and slack periods of sales. The relation between farm-level fertilizer prices and stock/sales ratios could provide some indication of appropriate stocks at the PDPs. Such guides cannot claim to provide optimal solutions, but they can be treated as rough guidelines. Stock requirements, however, depend at least partly on the speed with which stocks are replenished. Supply flows to PDPs thus become another important consideration.

The flows of fertilizers to PDPs can generally be maintained without a serious bottleneck if there is enough stock available in the transit and central godowns or in the factories. The movements of district price spreads have been found to follow, in rough fashion, national trends, but the range of the fluctuations has not been uniform. Fluctuations were sharper for TSP. Efficient programming and monitoring at the PDPs thus appears to be vital for maintaining the flow of fertilizers to farmers. At present, programming and monitoring activities are being systematized with technical assistance from the International Fertilizer Development Center (IFDC). It is imperative that BADC organize a highly efficient programming and monitoring unit to do this if IFDC's assistance is no longer available.

DISTRIBUTION OF FERTILIZERS

Efficient distribution and timely supply of fertilizer may facilitate diffusion of use since the input would then be available when needed at reasonable prices. It is most important that procurement and distribution to the PDPs are handled by a single agency, that is, by BADC. But any failure on its part can damage the whole agricultural production program of the country.

Distribution Systems

From 1962 to 1978 there was almost no free trading, and BADC distributed fertilizers through its own appointed dealers. The dealers acquired fertilizer from thana sales centers (TSCs). This method of distribution is called the old marketing system (OMS). Later on, some changes were gradually introduced to allow free

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[2]Ex-PDP prices are those at which fertilizers are sold from PDPs primarily to wholesalers or other large traders and dealers.

Figure 3--Monthly opening stocks, total availability, and farm-gate to ex-PDP price ratios for urea, 1981-84

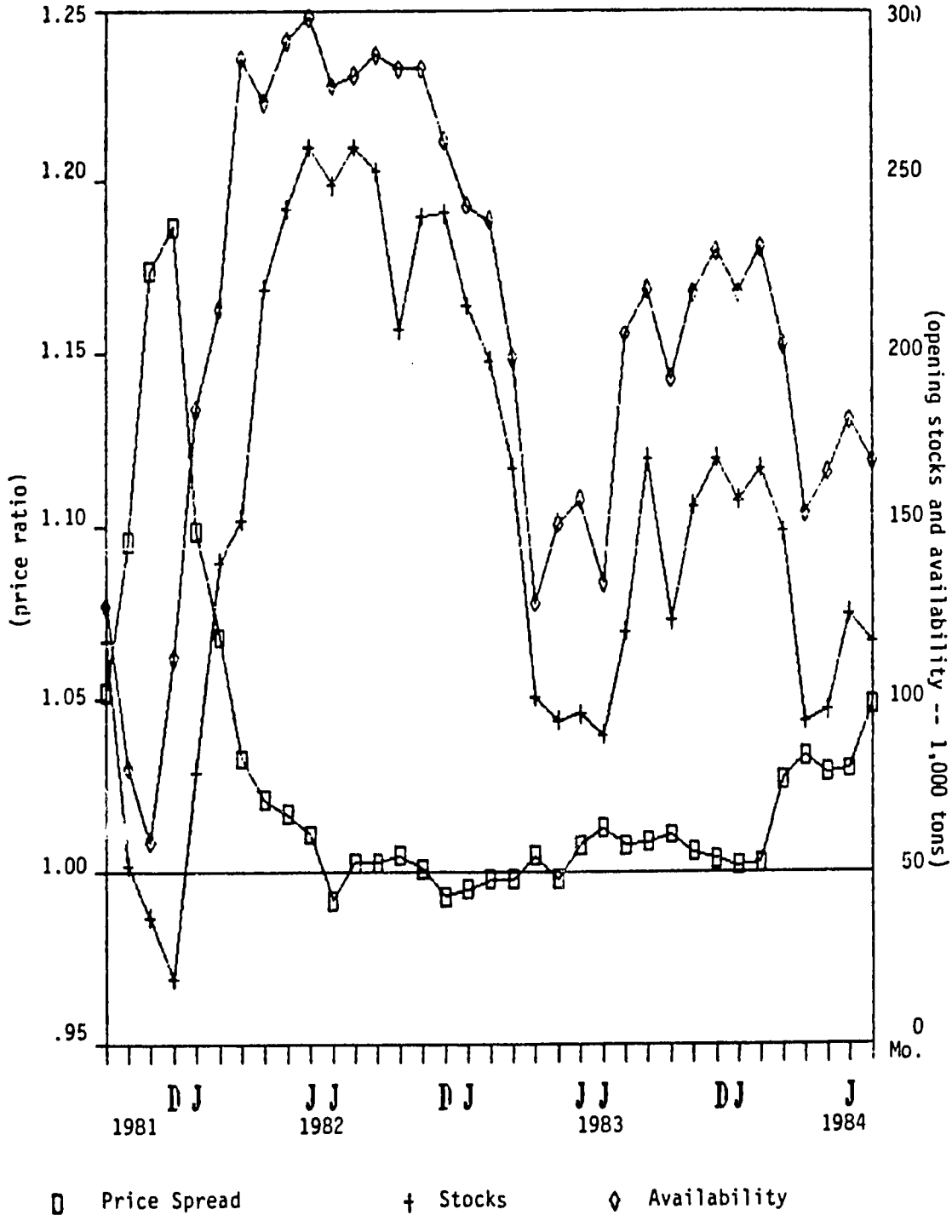
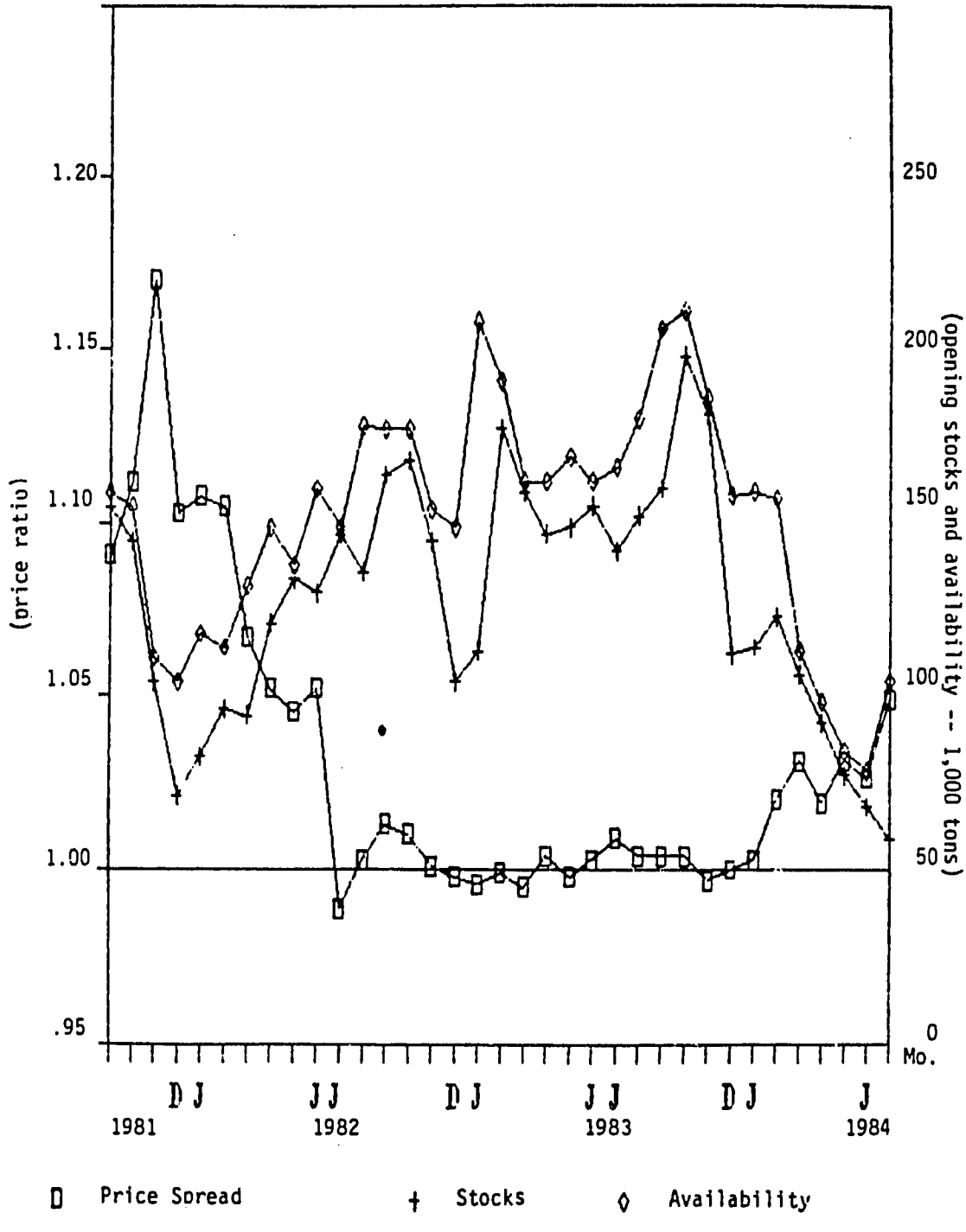


Figure 4--Monthly opening stocks, total availability, and farm-gate to fertilizer price ratios for TSP/DAP, 1981-84



private trading between PDPs and farmers.[3] Under this new marketing system (NMS), BADC still has the monopsony in procurement for Bangladesh and monopoly in distribution of fertilizers to PDPs. The OMS and NMS are schematically presented in Figures 5 and 6.

Under the OMS, BADC dealers were appointed for each union and were assigned to sell within a specified market. They were not allowed to sell outside the defined area. Dealers would procure fertilizers from specified TSCs and sell at prices fixed by the government. They would be paid a commission based on the distance from the TSC to the operation center. They were required to maintain registers which were subject to inspection by BADC officers. Prices of fertilizers were supposed to be uniform throughout the country.

Under the NMS, free trading below PDPs is allowed. Traders can get fertilizer from any PDP at which they have registered. They receive a commission based on the implicit state control prices for farm sales, although in practice, prices were decontrolled in April 1983 throughout the country. A trader must pick up at least 3 metric tons of fertilizer at any lifting from a PDP.

BADC and Its Involvement with Primary Distribution Points and Thana Sales Centers

BADC is the agency solely responsible for procurement and distribution of fertilizer to PDPs. This part of BADC's activity is assigned to its supply wing, which takes care of all procurement, clearance at port, internal movement, and storage and sale of fertilizer, including construction of fertilizer godowns. BADC maintains a fleet of about 65 trucks and several barges, which can be used during emergencies.

The BADC headquarters is in Dhaka, but to ensure efficient distribution, staff members are assigned to all administrative units through subdivision levels. These staff members constantly monitor the requirements and availability of fertilizer. Internal movement to or within a district is contracted-out on the basis of open bidding conducted every year (more recently, every two years). This procedure, along with modification of the tendering system, has helped bring down the cost of transportation.

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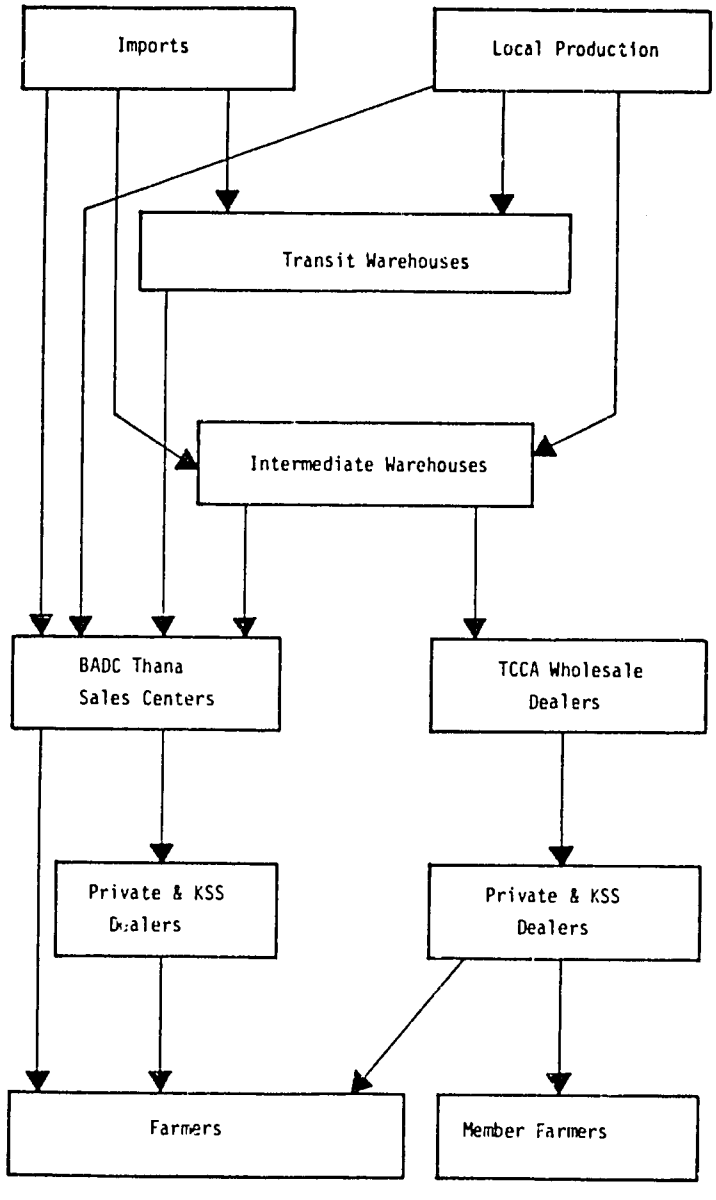
[3]Private trading below the PDP was first formally introduced in the Chittagong Division in December 1978, expanded to include the Khulna and Dhaka Divisions in January 1980, and brought to the Rajshahi Division in July 1980.

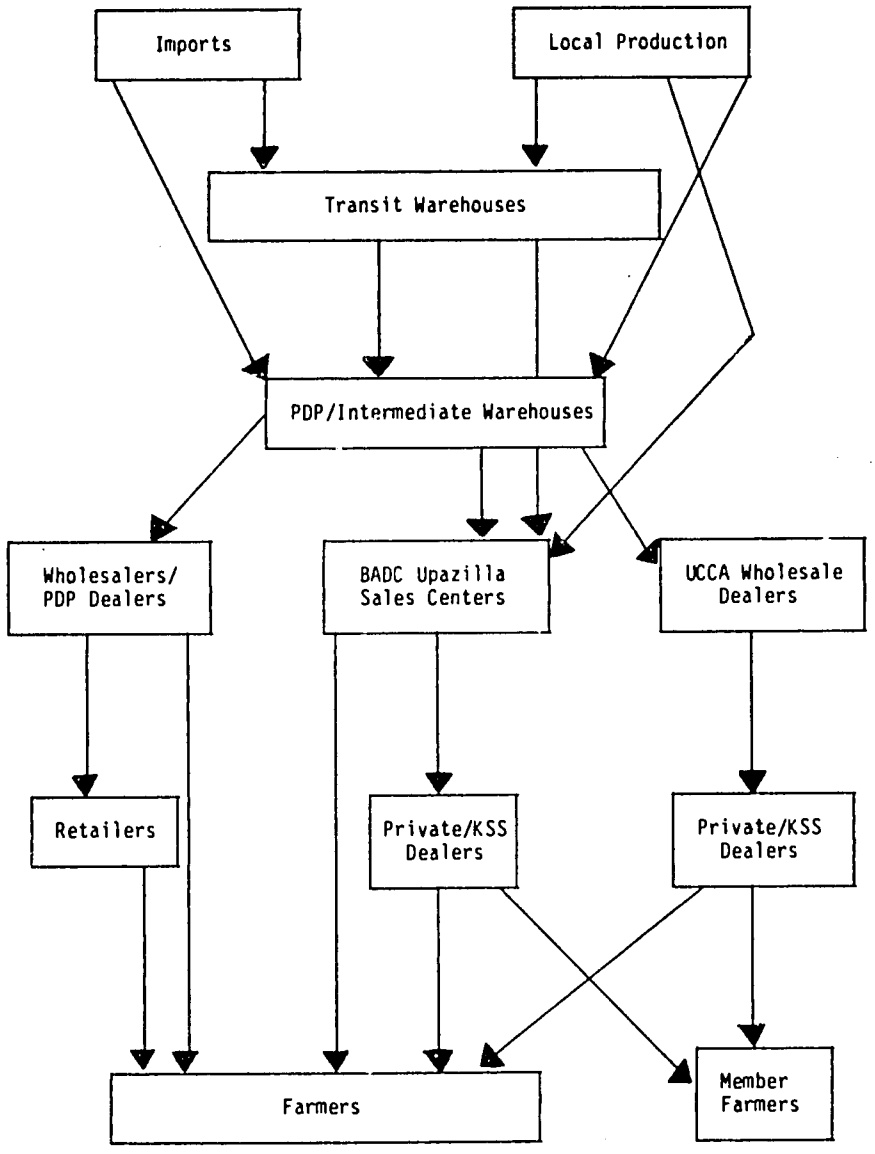
Figure 5--Fertilizer distribution under the old marketing system, 1977/78



Source: International Fertilizer Development Center, Third Evaluation of the New Marketing System (Muscle Shoals, Ala.: IFDC, April 1982).

Notes: TCCA = Thana Central Cooperative Association; KSS = Kishi Samabaya Samity (Agricultural Cooperative Society). A thana is an administrative unit smaller than a district. In the early 1980s, the term "thana" was changed to upazilla.

Figure 6--Fertilizer distribution under the new marketing system, 1983/84



Source: International Fertilizer Development Center, Third Evaluation of the New Marketing System (Muscle Shoals, Ala.: IFDC, April 1982).

Notes: UCCA = Upazilla Central Cooperative Association; KSS = Kishi Samabaya Samity (Agricultural Cooperative Society). An upazilla is an administrative unit smaller than a district (previously called a "thana").

The cost-saving modification of the tendering system is essentially an adjustment in the tender evaluation procedure. Previously, BADC calculated a simple average of the rates quoted for different routes in a district, awarding the work to the lowest bidder. But the unit cost of transport varies considerably for different routes, depending on transport conditions over the route and the volume of fertilizers to be transported. Contractors often refused to transport fertilizers to destinations in high cost routes after accepting an entire package of work. This induced BADC to adopt a payment scheme based on weighted averages, taking into account the actual unit cost of transport as estimated by BADC for different routes for comparison with the rates quoted by the bidders. Distribution has now become fairly smooth, but problems sometimes arise when contractors demand rates that are higher than those originally negotiated, either because of transport scarcity or because extraordinary increases in fertilizer prices at the farm gate alert contractors to the abnormal profits being made by traders or dealers.

To maintain adequate stocks, BADC has both leased and purchased godowns of various capacities. Initially BADC had to depend largely on rented godowns, but it has eventually built its own with USAID and IDA financial assistance. This year, most rented godowns were released. The ratio of owned to hired storage facilities is presently 5.4 to 1, while in April 1983 it was 0.8 to 1. Hired storage capacity has been cut from 240,000 tons to 58,000 tons, while owned storage capacity has increased from 182,000 tons to 318,000 tons. BADC has allowed total storage capacity to decline by 11 percent, however, in spite of the recent increase in fertilizer sales. Wholesalers are expected to compensate by maintaining stocks of their own, but so far it appears that wholesalers typically do not.

BADC is still responsible for distributing fertilizer to the remote upazillas of the country, where private dealers are less interested in operating because of risk and higher transport costs. In these areas, private dealers are also allowed to operate, and may pick up fertilizer from upazilla centers, from PDPs, or from both. So in these localities, both private traders and BADC-appointed dealers may be operating locally.

It is expected that local distribution of fertilizers by BADC will be more equitable when supplies are short. Private traders typically capitalize on short supplies by raising prices as they did in the fall of 1984 (Table 5). When scarce supplies are not allocated by higher prices, equity performance depends all the more upon how and to whom public sector dealers distribute the fertilizers.

Table 5--Farm-gate fertilizer prices, November 1983 and November 1984

Area of study	Implicit Official Farm-gate Price		Actual Farm-gate Price		Farm-gate Price Compared to the Implicit Official Price	
	Nov. 84	Nov. 83	Nov. 84	Nov. 83	Nov. 84	Nov. 83
	(taka per maund)				(percent)	
Urea						
Munshiganj, Dhaka	162	148	200	151	23	2
Chandra, Dhaka	162	148	203	176	25	19
Banguri, Dhaka	162	148	198	160	22	8
Khankhanapur, Faridpur	162	148	178	151	10	2
Gangi, Kushtia	162	148	170	145	05	-2
Patuakhali	162	148	175	150	08	1
TSP (G)						
Munshiganj, Dhaka	121(powder)	110	210	130	76	18
Chandra, Dhaka	154	140	235	155	53	11
Banguri, Dhaka	154	140	221	153	44	9
Khankhanapur, Faridpur	154	140	283	168	84	20
Gangi, Kushtia	154	140	236	140	53	0

Source: Bangladesh Institute of Development Studies survey.

Note: Official farm-gate prices are designated as "implicit" because farm-gate prices have been formally decontrolled throughout the country. Before decontrol (but under the new marketing system), private dealers were expected to sell fertilizers to farmers at the ex-PDP (official) price at which they purchased the fertilizer. They were awarded a commission to cover their costs and a normal return for their service. These commissions remain despite price decontrol. Hence, the ex-PDP price is an implicit official farm-gate price even though dealers are now free to set their own prices to retailers and farmers.

FERTILIZER USE, STOCK, AND PRICES: ANALYSIS OF DISTRICT DATA

This section examines fertilizer use in the districts and tries to explain the variation among districts. Under the OMS, trade regulation dictated the public availability of records throughout the chain of supply, even including data for each upazilla. Since the NMS allows free trading, however, analysis below the districts cannot be based on such records because complete, area-specific fertilizer sales can no longer be recorded by BADC. Data are not wholly correct even for the districts because of the possibility of private movement of fertilizers between districts. A reasonable indication of fertilizer sales by district can be obtained from PDP data, however, inasmuch as the location of PDPs within each district was carefully considered when they were established and because the basic allocation of supply among PDPs is strongly influenced by past sales.

Fertilizer Use

An average of 115 pounds of fertilizer materials was applied on each acre of net cultivated land in Bangladesh in 1983/84. The average cropping intensity was 154 percent, so average use per acre of cropped area was 76 pounds.[4]

There were wide variations in use of fertilizer among the districts, with figures ranging from 16 to 277 pounds per acre. Within districts, there was also much variation, even in the high-consuming districts, as estimated on the basis of 1979 fertilizer data (see Table 6).

Districts can be broadly classified into three groups according to average intensity of application: Group A--more than 150 pounds per acre, Group B--80-150 pounds per acre, and Group C--less than 80 pounds per acre (Table 7). Within Group C, there was a gradual

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[4]The total cultivated area was 21.28 million acres and the quantity of fertilizer products used was 1.11 million metric tons. The cropping intensity data are for 1982/83, but the change in 1983/84 is unlikely to be significant for more than a few districts (Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983), Table 5.23, p. 206). There are interdistrict variations in cropping intensities. The intensity was higher in the districts of Tangail (194), Rangpur (185), Mymensingh (182), and Comilla (172). This variation in intensity can partly explain the difference in fertilizer use but higher intensity sometimes results from more extensive cultivation of minor crops, on which less fertilizer is typically applied.

Table 6--Highest and lowest fertilizer-consuming upazillas within high-consuming districts

District	Fertilizer Use in Highest-Consuming Upazillas		Fertilizer Use in Lowest-Consuming Upazillas	
	(kilograms/cultivated acre)			
Dhaka	Munshiganj	148	Daulatpur	5
Chittagong	Double Mooring	437	Fatikchari	23
Comilla	Chandina	103	Chandpur	17
Bogra	Adamdighi	85	Sariakandi	21
Kushtia	Damurhuda	66	Kumarkhali	21

Source: Bangladesh Bureau of Statistics, Thana Statistics, Vol. I, Basic Information, Land Utilization and Irrigation (Dhaka: BBS, December 1981).

Note: Since 1979, there have been important changes in several areas, such as tubewell installation and construction of embankments, and consequent changes in cropping patterns and fertilizer use.

decline in Noakhali and Patuakhali and virtual stagnation in Faridpur, Barisal, and Sylhet from 1979/80 to 1982/83.[5] In districts falling within Groups A and B, there has been continuous increase in use, with the exception of two districts--Comilla and Chittagong. In these two high-consuming districts, fertilizer use has remained almost the same as in 1979/80. Such dissimilar trends can be explained in terms of underlying demand and supply.

This section focuses on supply as a determinant of differences in the rates of growth in fertilizer use, particularly the adequacy of stock at PDPs and participation by private traders below PDPs. Demand is examined comprehensively in the paper by Hossain and is treated briefly in the latter part of this section.

[5]These trends continued in 1983/84 for three of the five districts mentioned. Faridpur and Sylhet, however, experienced rapid growth in sales in that year.

Table 7--Per acre use of fertilizer by district, 1978/79 to 1983/84

District	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
			(pounds/acre)			
Group A						
Tangail	100.33	107.72	126.92	136.69	164.24	172.26
Kushtia	101.27	153.92	152.37	133.11	127.65	181.59
Dhaka	123.08	125.15	143.69	155.82	159.72	189.03
Comilla	208.61	229.86	209.98	194.12	214.61	208.60
Chittagong	231.40	199.47	192.39	168.51	233.00	230.62
Pabna	147.61	181.28	216.08	219.07	225.08	277.15
Group B						
Chittagong Hill Tracts	37.60	66.82	58.47	63.66	45.41	92.49
Jessore	59.16	74.08	72.78	68.69	72.48	97.11
Rangpur	55.41	57.44	74.43	67.41	83.01	111.96
Rajshahi	54.48	76.43	78.80	67.07	86.26	114.47
Mymensingh	89.37	93.06	101.61	90.46	51.80	57.11
Kishoreganj	...	...	...	...	197.93	225.29
Dinajpur	69.29	84.04	82.21	74.45	93.46	123.21
Pabna	70.78	78.07	83.91	81.19	116.24	138.28
Group C						
Patuakhali	26.23	29.86	19.66	15.62	21.92	15.98
Khulna	20.63	26.22	34.86	31.50	36.09	40.84
Faridpur	26.67	32.96	27.14	28.90	35.97	44.91
Barisal	43.53	49.35	46.28	38.45	47.59	46.49
Sylhet	30.07	39.48	35.07	34.11	38.58	49.29
Noakhali	79.09	93.84	85.92	76.59	76.47	68.88
Bangladesh	79.86	89.94	92.60	87.57	100.33	116.97

Source: Calculated from Bangladesh Agricultural Development Corporation sales data and Bangladesh Bureau of Statistics data on cultivated area by district.

Supply of Fertilizers at PDPs

BADC tries to maintain stocks adequate to fulfill local demand at all PDPs. It regularly replenishes PDP stocks on the basis of information monitored by PDP warehouse managers.

Replenishment is a continuous process and depends on storage capacity as well as sales. In the peak period, replenishment is undertaken more frequently in order to maintain adequate flows. Fertilizer is transported by trucks, railway cars and barges, depending on the type of connecting routes. According to a report prepared by the Planning Commission, about 42 percent of all fertilizer moving between districts in 1979/80 was transported by road and 37 percent by rail.[6] Movement within each district is the responsibility of the BADC district manager. Road transportation accounts for about 60 percent of intradistrict fertilizer movement under BADC jurisdiction.

BADC attempts to maintain a monthly opening stock of fertilizer that would meet normal demand during the following 3 to 5 months. The opening stock is thus one appropriate measure of effective availability, although stocks may be replenished during the period, depending on the deviation of actual demand from the normal pattern. In order to investigate the possibility of supply constraints, several categories of data have been examined: average monthly stocks during the year, total availability by quarter, and total sales by quarter. Relations between stocks and sales have also been estimated. All these exercises are limited to the four-year period from 1980/81 to 1983/84.

Table 8 shows that stocks have consistently been much higher relative to sales in low-consuming districts than in high-consuming districts. However, stock positions in both low- and high-consuming districts gradually deteriorated over the period. Quarterly availability (net stocks plus replenishment during the period), also indicates that PDP supplies were better in low-consuming districts than in high-consuming districts (Table 9). The same conclusion can be drawn from the relationship between quarterly stocks and sales in Table 10.[7]

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[6]Bangladesh Planning Commission, "Statistics Relating to Fertilizers, Irrigation Seeds, Pesticides and Climate," Dhaka, April 1983, p. 7.

[7]A linear relationship between opening stock and sales was estimated using regression techniques on monthly data for the period 1981-84 for different types of fertilizers for low- and high-consuming districts. The regression coefficients were positive only in high-consuming districts for urea and TSP, and actually negative in low-consuming districts.

Table 8--Average monthly fertilizer sales and opening stocks as percentages of monthly sales in various low- and high-consuming districts, 1980/81 through 1983/84

District	1980/81		1981/82		1982/83		1983/84	
	Sales (ton)	Stock as Share of Sales (percent)	Sales (ton)	Stock as Share of Sales (percent)	Sales (ton)	Stock as Share of Sales (percent)	Sales (ton)	Stock as Share of Sales (percent)
Patuakhali	514	946	409	766	575	469	419	560
Noakhali	2,723	476	2,413	322	2,334	447	2,188	362
Barisal	2,011	690	1,667	633	2,064	493	2,017	412
Faridpur	1,207	848	1,308	502	1,637	639	2,044	396
Bogra	5,844	221	5,925	195	6,087	305	7,496	174
Chittagong	4,960	316	4,426	230	6,189	228	6,126	255
Dhaka	6,730	264	7,298	164	7,486	220	8,861	158
Comilla	9,983	101	9,268	111	10,252	145	9,964	130

Source: Calculated from Bangladesh Agricultural Development Corporation data on fertilizer sales and opening stocks.

It is possible that the low-consuming districts might have faced a crisis in supply during the peak season that might not have been captured in the previous exercises. In order to understand this seasonality in supply, normal peak sales were estimated for the 1980/81 to 1983/84 period, on the basis of the three peak months (that is, the average of 12 peak months over the four-year period). These normal peak sales were then related to opening stocks for the corresponding peak months for the selected years (Table 11). This comparison indicates that even in peak months, opening PDP stocks in low-consuming districts were plentiful relative to sales. They generally averaged 200 percent of sales or more in the peak months, while the high-consuming districts such as Comilla and Dhaka held stock as low as 100 percent of sales in most of the peak months, and often less.

Improved supply management in the low-consuming districts appears to have been facilitated by an increase in the abundance of storage facilities relative to the volume of sales (Table 12). Lower

Table 9--Ratio of quarterly availability to quarterly sales of fertilizer by district, 1980/81 to 1983/84

District	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
	(ratio of availability to sales)			
1980/81				
Faridpur	11.1	3.5	3.2	2.1
Sylhet	5.3	3.4	1.8	2.5
Patuakhali	4.0	9.8	5.1	2.5
Noakhali	1.9	4.1	2.1	2.1
Tangail	2.8	1.2	1.2	2.2
Chittagong	1.8	4.4	1.2	1.3
Comilla	1.5	1.2	1.2	1.3
Dhaka	3.6	1.3	1.7	2.2
1981/82				
Faridpur	9.1	1.4	3.1	3.2
Sylhet	4.0	1.5	2.3	3.3
Patuakhali	4.5	3.8	3.3	2.9
Noakhali	1.9	1.5	2.6	3.7
Tangail	2.2	1.4	1.4	3.0
Chittagong	1.5	1.6	1.7	3.2
Comilla	1.4	1.2	1.4	1.7
Dhaka	2.1	1.1	1.5	2.7
1982/83				
Faridpur	14.3	2.6	3.6	1.9
Sylhet	5.0	2.6	1.9	2.5
Patuakhali	3.8	5.9	2.2	1.5
Noakhali	2.5	2.9	2.1	2.3
Tangail	3.2	1.5	1.3	2.0
Chittagong	1.3	2.6	1.6	1.5
Comilla	2.2	1.4	1.3	1.5
Dhaka	3.4	6.7	1.6	2.0
1983/84				
Faridpur	16.7	2.3	1.5	1.5
Sylhet	5.3	8.3	1.4	1.9
Patuakhali	2.9	5.3	4.5	1.6
Noakhali	2.3	2.7	1.7	1.8
Tangail	2.9	1.4	1.1	1.6
Chittagong	1.7	2.7	1.3	1.7
Comilla	2.6	1.2	1.2	1.4
Dhaka	3.2	1.2	1.4	1.6

Source: Calculated from Bangladesh Agricultural Development Corporation data on fertilizer sales, opening stocks, and stock replenishment.

Note: The first quarter is July to September, the second quarter is October to December, the third quarter is January to March, and the fourth quarter is April to June.

Table 10--Ratio of quarterly stocks to quarterly sales of fertilizer by district, 1980/81 to 1983/84

District	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
		(ratio of stocks to sales)		
1980/81				
Faridpur	9.39	2.82	2.39	1.82
Sylhet	3.13	2.49	1.18	1.60
Patuakhali	2.72	7.13	4.42	1.80
Noakhali	1.09	2.96	1.62	1.17
Tangail	1.48	0.57	0.19	0.49
Chittagong	0.75	2.68	0.84	0.81
Comilla	0.51	0.19	0.25	0.27
Dhaka	2.41	0.56	0.64	1.06
1981/82				
Faridpur	7.13	1.12	0.52	1.94
Sylhet	2.39	1.15	0.64	1.80
Patuakhali	3.83	3.90	2.07	1.66
Noakhali	1.00	0.81	0.77	2.22
Tangail	1.73	0.32	0.42	1.49
Chittagong	0.79	0.69	0.34	2.27
Comilla	0.40	0.16	0.25	0.80
Dhaka	1.11	0.37	0.32	0.99
1982/83				
Faridpur	11.54	2.19	2.11	1.59
Sylhet	3.65	1.78	0.99	1.39
Patuakhali	2.83	5.32	1.41	0.77
Noakhali	1.32	2.71	1.23	1.36
Tangail	2.00	0.54	0.44	0.94
Chittagong	0.67	0.61	0.54	0.92
Comilla	0.99	0.27	0.47	0.59
Dhaka	2.20	0.48	0.59	1.24
1983/84				
Faridpur	7.12	1.78	1.18	0.56
Sylhet	3.91	1.01	0.72	1.07
Patuakhali	1.46	3.41	3.10	1.26
Noakhali	1.31	1.85	0.88	1.06
Tangail	1.21	0.54	0.39	0.17
Chittagong	0.38	1.52	0.62	0.80
Comilla	0.89	0.37	0.26	0.40
Dhaka	1.61	0.37	0.36	0.68

Source: Calculated from Bangladesh Agricultural Development Corporation data on fertilizer sales, opening stocks, and stock replenishment.

Note: The first quarter is July to September, the second quarter is October to December, the third quarter is January to March, and the quarter is April to June.

Table 11--Stocks and sales of fertilizers in the three peak months of each year, 1980/81 to 1983/84

District	1980/81 Stock as Percent of Sales			1981/82 Stock as Percent of Sales			1982/83 Stock as Percent of Sales			1983/84 Stock as Percent of Sales		
Patuakhali	607 (March)	427 (April)	577 (May)	296 (March)	230 (April)	338 (May)	285 (March)	210 (April)	160 (May)	283 (March)	250 (April)	244 (May)
Khulna	357 (Jan.)	253 (Feb.)	221 (March)	118 (Jan.)	137 (Feb.)	114 (March)	254 (Jan.)	243 (Feb.)	228 (March)	409 (Jan.)	277 (Feb.)	240 (March)
Noakhali	343 (Sept.)	392 (Feb.)	292 (June)	167 (Sept.)	206 (Feb.)	347 (June)	234 (Sept.)	340 (Feb.)	259 (June)	191 (Sept.)	297 (Feb.)	162 (June)
Faridpur	506 (Nov.)	476 (Dec.)	350 (May)	186 (Nov.)	200 (Dec.)	416 (May)	485 (Nov.)	492 (Dec.)	420 (May)	633 (Nov.)	535 (Dec.)	120 (May)
Barisal	447 (Sept.)	315 (March)	381 (April)	359 (Sept.)	296 (March)	377 (April)	371 (Sept.)	306 (March)	298 (April)	219 (Sept.)	299 (March)	314 (April)
Dhaka	189 (Oct.)	112 (Nov.)	115 (Dec.)	134 (Oct.)	26 (Nov.)	23 (Dec.)	179 (Oct.)	80 (Nov.)	104 (Dec.)	158 (Oct.)	69 (Nov.)	81 (Dec.)
Kishoreganj	312 (Jan.)	162 (Feb.)	116 (March)	94 (Jan.)	80 (Feb.)	72 (March)	284 (Jan.)	184 (Feb.)	220 (March)	180 (Jan.)	122 (Feb.)	134 (March)
Bogra	189 (Dec.)	107 (Jan.)	115 (March)	48 (Dec.)	103 (Jan.)	88 (March)	347 (Dec.)	201 (Jan.)	135 (March)	258 (Dec.)	211 (Jan.)	133 (March)
Comilla	68 (Nov.)	46 (Dec.)	97 (Jan.)	53 (Nov.)	26 (Dec.)	96 (Jan.)	118 (Nov.)	79 (Dec.)	163 (Jan.)	105 (Nov.)	58 (Dec.)	125 (Jan.)

Source: Calculated from Bangladesh Agricultural Development Corporation data on monthly sales and opening stocks.

Table 12--Fertilizer storage capacity as a percentage of peak monthly sales by district, 1980/81 and 1983/84

District	1980/81	1983/84
Patuakhali	398	645
Khulna	422	326
Faridpur	689	271
Barisal	422	430
Sylhet	255	188
Chittagong Hill Tracts	1,158	185
Noakhali	200	317
Jessore	292	273
Rangpur	544	282
Rajshahi	344	234
Mymensingh	356	236
Dinajpur	428	408
Pabna	196	289
Tangail	108	121
Kushtia	157	322
Dhaka	180	69
Kishoreganj	422	197
Comilla	45	75
Chittagong	225	123
Bogra	150	406

Source: Calculated from Bangladesh Agricultural Development Corporation data on fertilizer sales and storage capacities.

sales and less pressure for rapid replenishment perhaps allowed BADC time for timely transport of fertilizers. As for the high-consuming districts, however, warehousing facilities did not improve despite increases in their sales volumes. Some recent improvement may be noticed in the district of Bogra, which will perhaps be a central fertilizer depot for the whole of Rajshahi Division.

Private Traders and Their Participation

The NMS allows free private trading below PDPs. Traders can get fertilizers from any PDP at which they are registered. The simple registration procedure is a deliberate attempt under the NMS to encourage greater trader participation in the fertilizer business. The only restriction is a minimum (three tons) lift requirement. This is intended to discourage petty dealers at the PDPs and, in turn, encourage wholesaling. One of the principal objectives of the new system is the development of entrepreneurship in the input business.

The initial response to market liberalization was positive, and many dealers registered with the PDPs as both wholesalers and retailers.[8] Later, however, half of the dealers abandoned trading, according to a survey undertaken by the Bangladesh Institute of Development Studies (BIDS) in eight upazillas (Table 13). The original tempo of participation, therefore, did not last long, and the number of traders lifting fertilizers from PDPs gradually declined because of an inability to compete with the larger traders, who became even more dominant in later years when a high rate of commission (Tk 310 per ton) was paid to wholesalers (Table 14). Very recently, the rate of commission has been made uniform at Tk 275 per ton.

It has also been observed that with the introduction of the NMS, the number of traders, inclusive of seasonal operators, increased by about 50 percent over those under the OMS. This increase is significant in the peak period of demand (January-February) when HYV Boro is transplanted. The number of regular traders differs little from what it would have been under OMS, since BADC was in the habit of raising the number of appointed dealers at regular intervals. Immediately before the NMS, this number had been raised to 16 per union. Seasonal traders are generally petty traders who shift from one commodity to another, depending on the employment opportunities and the relative rates of profit.

It is difficult to comment on the services provided by dealers in low-consuming districts, inasmuch as the BIDS dealer survey was limited to high-consuming districts, although the findings related to

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[8]"Wholesalers" are those who pick up 15 tons of fertilizers or more at one time; "retailers" deal in lots of less than 15 tons.

Table 13--Decline in fertilizer wholesaler and retailer participation in eight upazillas, from 1979/80 to 1982/83

Accessibility	Registered in 1979/80		Percent Remaining Active in 1982/83	
	Wholesalers	Retailers	Wholesalers	Retailers
	(number of traders)		(percent)	
Accessible	86	773	60	60
Less accessible	45	555	36	46
Total	131	1,328	52	54

Source: Bangladesh Institute of Development Studies surveys in four accessible and four less accessible upazillas.

Note: "Accessible" indicates that the upazilla (an administrative area smaller than a district) is connected by paved road to a primary distribution point. "Less accessible" indicates that the upazilla is connected by neither road nor rail.

Table 14--Number of dealers in operation and average quantity lifted, 1979/80 to 1982/83

Year	Number of Dealers per Primary Distribution Point	Average Quantity per Lift
		(tons)
1979/80	171	1.48
1980/81	162	4.51
1981/82	118	4.05
1982/83	45	16.00

Source: Bangladesh Institute of Development Studies survey of four primary distribution points.

the less accessible upazillas in those districts may be particularly relevant. The survey findings indicated fewer numbers of registered traders with the PDPs and a lower proportion of active dealers in less accessible localities (Table 13). It would seem to follow that the low-consuming areas, being generally less accessible as well, are even more disadvantaged. BADC, however, is aware of this and maintains its own distribution system along with private trading in remote areas. The main factors affecting participation by traders in the low-consuming districts are the low turnover of fertilizers and, consequently, lower profits available to dealers; poorer orientation to sophisticated trading; and less accessibility to financial institutions and other relevant organizations. The people inhabiting less accessible areas are generally more dependent on land for their livelihood.

The lower turnover of fertilizer per dealer is evident from data showing much smaller quantities of fertilizer traded annually in the low-consuming districts. With the exception of Sylhet, the volume of fertilizer handled in 1983/84 per dealer was only about 30 maunds (approximately one ton).[9]

The survey findings also indicate that dealers in both accessible and less accessible areas hold extremely low stocks. Fifteen percent of the surveyed dealers were holding no stocks at all at the time of the interview. Among those holding stocks, quantities averaged only about two tons (Table 15). There was little difference in this respect between accessible and less accessible areas. Although the information relates to the period of slack demand (May-June), such low local availability could cause problems. In any event, this exercise provides some indication that supply may be inadequate during the off-peak seasons. Fertilizer trading businesses may be closed during the off-seasons and working capital may be diverted to some other business inasmuch as many of the private dealers are involved in other commodity trades (Table 16).

Factors Affecting the Demand for Fertilizers

The study did not find any clear indication that differences in the intensity of use among Bangladesh districts can be attributed to supply constraints at the PDPs. The differences between districts, therefore, must be explained primarily by differences in factors related to demand, including cropping patterns (dependent on irrigation and topography of land), farmers' awareness, land tenancy, and institutional supports, and by differences in factors related to supply and demand. Of these, only the technical factors are reviewed here. For details, see Chapter 4 by Mahabub Hossain.

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[9]It would be helpful if the statistics related to the numbers of dealers collected by BADC were recorded more carefully and reviewed regularly to capture seasonal variation.

Table 15--Stocks of fertilizer with dealers during May and June 1983

Accessibility of Area	Proportion of Dealers Who Held No Stock of				Average Stock per Dealer Holding Stock at the Time of Interview			
	Fertilizer	Urea	TSP	MP	Urea	TSP	MP	Total
	(percent)				(maunds)			
Accessible	15.3	18.6	49.2	57.6	31.7	11.8	8.3	51.7
Less accessible	14.7	22.1	58.8	63.2	29.5	11.0	7.7	48.3
All areas	15.0	14.5	54.3	60.7	30.4	11.4	8.0	50.0

Source: Bangladesh Institute of Development Studies survey, published in Md. Abul Quasem, Abul Barkat, and S. A. Khan, Impact of the New System of Distribution of Fertilizer and Irrigation Machines in Bangladesh (Dhaka: BIDS, 1984).

Table 16--Principal occupations and business involvements of fertilizer traders, May and June 1983

Trader	Principal Occupation		Those Trading in Four Commodities	Those Exclusively Involved in Fertilizer Trade	Those Concentrating in Fertilizer Trade[a]
	Farming	Non-Farming			
	(percent)				
Wholesaler	22	78	48	22	43
Retailer	40	60	32	25	43

Source: Bangladesh Institute of Development Studies survey, published in Md. Abul Quasem, Abul Barkat, and S. A. Khan, Impact of the New System of Distribution of Fertilizer and Irrigation Machines in Bangladesh (Dhaka: BIDS, 1984).

[a]This category includes traders exclusively dealing in fertilizers plus those earning at least 50 percent of their business income from fertilizer trading.

HYVs and Fertilizer Use

Crops do not require the same amounts of fertilizer. The crops that require larger amounts include HYVs of paddy and wheat as well as potatoes, sugarcane, and tobacco. The recommended doses for irrigated HYV paddy and wheat are about 40 percent higher than those for local paddy varieties, which can be (and usually are) grown without fertilizer.[10] The recommended doses for potatoes and sugarcane grown without irrigation are 35 percent higher even than those for HYV cereals. This indicates that areas with more acreage under HYVs, potatoes, and sugarcane are expected to have higher application of fertilizers.

Since HYVs are highly dependent on irrigation, districts with more extensive irrigation coverage are apt to have more HYV acreage and, in consequence, to apply fertilizers more intensively. Conversely, broadcast Aman (B. Aman) is rarely fertilized because it is usually grown in lowlands where floodwaters come earlier and recede later than elsewhere. The duration of these floods is three to four months. Flood protection embankments in those areas can facilitate substitution of HYV-Boro cultivation. Otherwise, HYVs grown in these low-lying belts are vulnerable to seasonal flooding and other flash floods caused by heavy showers. Thus, districts with higher concentrations of B. Aman acreage are apt to use smaller amounts of fertilizer. Furthermore, locations subject to regular tidal washing, such as the coastal belt, are not suitable for fertilization except for higher-lying areas.

Irrigation and Fertilizer Use

Districts that use little fertilizer per acre have less than 10 percent of their cultivated land under modern irrigation (irrigated by tubewells, low-lift pumps, and canals), whereas the high-consuming districts have more than 20 percent of their cultivated land irrigated by these means (Table 17). Similarly, if the HYV acreage is compared, the districts with low fertilizer consumption have less than 20 percent of their total rice and wheat acreage irrigated, while in higher-consuming areas, the figure is more than 30 percent (Table 18).

Some exceptions are Noakhali (41 percent) in Group C, Chittagong Hill Tracts (62 percent) in Group B, and Chittagong (73 percent) in Group A. These three districts would be expected to exhibit greater intensity of fertilizer use. In these districts, large areas are sown with HYV-Aus and HYV-Aman, including pajam rice, grown under rainfed conditions. They require only a little more than half of the

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[10]Bangladesh Agricultural Research Council, Fertilizer Guide for Major Crops of Bangladesh, Soils and Irrigation Publication No. 4 (Dhaka: BARC, 1979).

Table 17--Area irrigated by modern methods by district, 1978/79 to 1982/83

Group/ District	1978/79	1979/80	1980/81	1981/82	1982/83
	(percent of cultivated land)				
Group A					
Tangail	14.20	11.16	15.97	21.72	34.35
Kushtia	32.01	38.03	31.42	31.09	34.93
Dhaka	15.94	15.93	15.97	16.12	19.21
Comilla	15.59	15.72	18.70	20.17	21.03
Chittagong	15.55	17.30	34.05	32.44	36.83
Bogra	13.34	16.67	17.61	23.38	23.38
Group B					
Chittagong Hill Tracts	10.59	18.70	11.30	11.30	11.48
Jessore	9.41	8.57	9.38	10.15	11.10
Rangpur	4.26	7.95	9.29	11.24	11.71
Rajshahi	6.06	6.15	7.97	8.05	7.62
Mymensingh	7.87	8.49	8.73	10.52	15.35
Kishoreganj	24.63	25.98	30.43	31.03	34.16
Dinajpur	5.79	6.90	6.83	7.24	7.49
Pabna	4.77	5.15	6.30	9.76	14.18
Group C					
Patuakhali	7.78	7.39	2.99	3.27	4.54
Khulna	3.86	5.56	5.17	7.02	7.20
Faridpur	4.41	4.64	4.77	5.01	4.66
Barisal	7.70	8.55	9.08	8.67	8.83
Sylhet	10.03	9.70	9.72	12.24	10.69
Noakhali	5.34	7.15	10.45	8.03	8.90
Bangladesh	9.98	10.94	12.12	13.27	15.32

Source: Calculated from data appearing in Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983).

Table 18--HYV area as a proportion of total grain acreage, rice and wheat, 1978/79 to 1982/83

District	1978/79	1979/80	1980/81	1981/82	1982/83
			(percent)		
Patuakhali	8.70	8.46	6.14	5.51	6.97
Khulna	10.83	13.11	13.36	14.44	12.05
Faridpur	6.82	8.20	6.96	13.97	16.15
Barisal	14.33	14.06	15.99	15.70	16.07
Sylhet	15.73	14.26	14.59	14.04	16.30
Chittagong Hill Tracts	42.37	51.19	64.15	59.76	60.38
Noakhali	34.64	37.10	44.74	41.95	41.64
Jessore	10.92	16.62	11.73	20.67	22.05
Rangpur	10.76	21.45	13.94	21.64	23.35
Rajshahi	9.98	12.09	7.91	14.33	19.96
Mymensingh	32.08	36.99	36.88	38.25	38.69
Dinajpur	10.30	14.20	8.87	21.61	20.35
Pabna	10.07	12.78	5.91	17.45	20.07
Tangail	21.30	23.48	16.58	26.44	26.40
Kushtia	25.24	32.80	16.40	33.64	36.26
Dhaka	25.22	27.39	27.59	31.54	35.38
Comilla	36.45	37.76	36.02	44.04	42.60
Chittagong	52.76	59.75	69.91	69.49	73.19
Bogra	23.06	26.17	25.40	32.34	35.08
Kishoreganj	32.42	31.91	37.49	38.89	38.18
Bangladesh	19.71	22.95	21.44	26.01	27.56

Source: Calculated from data appearing in Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983).

amount of fertilizer required by HYVs elsewhere. In Mymensingh, there is also higher coverage by HYV-Aman, specifically pajam.

Furthermore, crop statistics of B. Aman as a percentage of total grain acreage show that the low-consuming districts have greater shares of land under B. Aman--Faridpur has 45 percent, Sylhet has 19 percent, and Jessore has 24 percent. The high-consuming districts also have large coverage of B. Aman (Dhaka has 29 percent, Comilla has 29 percent, and Tangail has 19 percent), but its effect on fertilizer use has been more than counterbalanced by demand for fertilizers associated with their irrigated HYV-Boro and HYV-Aus acreage.

Decline in Fertilizer Use

Fertilizer use in the districts of Patuakhali, Barisal, and Khulna appears to be low mainly because of tidal waters that regularly wash cropland. There has also been a reduction in irrigation in Patuakhali since 1979/80 (Table 17). Nor has HYV acreage increased in those districts, indicating perhaps that little further expansion may occur without construction and repair of coastal embankments. It should also be remembered that tidal lands in this coastal belt are not suitable for the usual HYV dwarf varieties, owing to flood depths.

Aside from generally low fertilizer consumption in several districts, a matter of serious concern is the recent decline in fertilizer use in Patuakhali and Noakhali and stagnation in use in high-consuming Comilla and Chittagong. Stagnation in the latter two districts appears to be caused by the lack of expansion of irrigation and HYV acreage since 1980/81. But fertilizer use in these high-consuming districts did not even increase in 1980/81, despite an increase in irrigation coverage. This may have been due to problems associated with the introduction of the NMS in that division in 1979/80.[11]

The continued decline in Patuakhali and Noakhali in recent years can be partly explained by the reduction in acreage irrigated by low-lift pumps (LLPs) in Patuakhali and by tubewells and pumps in Noakhali. This decline may be related to a rapid rise in rental charges. Furthermore, increasing numbers of engines seem to be diverted to use on boats. There are also reports that in many older areas of Patuakhali inadequate paddy drainage has become a serious problem, reducing the usefulness of applying fertilizers. In Noakhali, many deep tubewells are reportedly no longer in use because

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[11]Md. Abul Quasem et al., Impact of the New System of Distribution of Fertilizer and Irrigation Machines in Bangladesh (Dhaka: Bangladesh Institute of Development Studies, September 1984).

of the high salinity of irrigation water. These problems require immediate study.

PRICES OF FERTILIZERS

Farmgate prices of fertilizers have usually been state controlled, and dealers have been paid a fixed commission. Since April 1983, prices have been decontrolled all over Bangladesh. Traders are now allowed to sell at any price the market can absorb, although ex-PDP prices are still, in a sense, implicit official prices, since commissions are still paid to dealers. Prices were decontrolled to encourage traders, especially those functioning in remote areas. This principle of decontrol was first introduced in the Chittagong Division in April 1982. Before decontrol, farm-gate prices were expected to be at or around the official price. During the 1970s there was no broad-based survey on the basis of which definitive statements about farm-gate price movements could be made, but a case study conducted in two villages of Dhaka District in 1977 did not uncover much difference between official prices and farmgate prices.[12]

Press reports collected from the Daily Ittefaque between 1975/76 and 1983/84 indicate that there were few reports on shortages and price escalation from 1976/77 to 1979/80. In 1981 there were complaints about scarcity and high prices (Table 19). Complaints were concentrated in high-consuming districts. The IFDC price data for recent years can, however, provide more insights into price behavior.

IFDC Price Data and Changes over Time

Price data collected by the International Fertilizer Development Center (IFDC) have been divided into three broad phases (Table 20): Phase I refers to the period before price decontrol (September 1981 to March 1982); Phase II is the period when prices in Chittagong Division were decontrolled (April 1982 to March 1983). Phase III is the period (April 1983 to June 1984) after prices were decontrolled in the remainder of the country as well.

Average farm-gate prices during Phase I were found to be higher than official prices for both urea and TSP. The difference was by Tk 12 per maund for the former and Tk 13 per maund for the latter: that is, an increase of 10 and 13 percent over the official price. An acute shortage of fertilizer occurred during this period, so the results may be somewhat atypical. Table 20 also shows that prices

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[12]Md. Abul Quasem and Mahabub Hossain, "Fertiliser Use in Two Selected Areas of Bangladesh," Bangladesh Development Studies 7 (No. 4, 1979): 69-86.

Table 19--Fertilizer shortages reported by the Ittefaque Press, 1975/76 to 1983/84

District	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
					(reports/year)				
Patuakhali	1	...	...	...	...	...	...	...	
Khulna	1	...	...	...	...	...	...	...	...
Faridpur	...	...	...	1	...	1	1	...	...
Farisal	...	...	...	...	...	...	1	...	...
Sylhet	...	No	...	...	...	...	...	No	...
Noakhali	...	report	...	...	...		...	report	No
		on						on	report
Chittagong Hill Tracts	...	Shortage	...	...	...	...	...	Shortage	on Shortage
Jessore	...	...	...	...	1	...	...	...	...
Rangpur	...	...	1	...	1	3	2	...	...
Rajshahi	...	...	...	1	...	1	2	...	...
Mymensingh (excluding Jamalpur)	1	...	...	...	1	1	2	...	...
Kishoreganj	...	...	...	...	...	...	...	...	...
Dinajpur	1	...	...	1	1	1	1	...	...
Pabna	...	...	1	1	...	...	3	...	...
Tangail	...	...	...	...	...	...	...	...	...
Kushtia	...	...	...	...	...	...	1	...	...
Dhaka	2	...	1	...	...	2	1	...	...
Comilla	1	...	1	2	1	...	2	...	...
Chittagong	2	...	...	...	...	2	2	...	...
Bogra	2	...	1	...	...	2	1	...	...
Bangladesh	11	0	5	6	5	13	19	0	0

Source: Daily Ittefaque, various articles.

Table 20--Prices of fertilizers by district, under price control and decontrol

Stage	Chittagong Division			Other Divisions		
	Average Price	High-Consuming District	Low-Consuming District	Average Price	High-Consuming District	Low-Consuming District
Urea						
Phase I	139.82	138.82	140.81	135.40	132.84	137.96
Phase II	146.97	144.68	149.26	143.11	141.92	144.30
Phase III	150.84	148.89	152.78	149.45	148.47	150.43
Total	145.88	144.13	147.62	142.65	141.08	144.23
TSP (granular)						
Phase I	123.68	120.95	126.40	112.78	114.01	111.50
Phase II	133.58	134.80	132.35	132.12	130.48	133.76
Phase III	141.94	140.65	143.23	140.71	140.95	141.47
Total	136.07	132.13	133.99	128.54	128.48	128.91
MP						
Phase I	83.88	83.37	84.39	86.82	85.70	87.94
Phase II	102.60	91.91	113.29	105.67	105.93	105.40
Phase III	115.99	114.57	117.41	106.67	100.48	112.86
Total	100.82	96.62	105.03	99.72	97.37	102.07

Source: Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter (Dhaka, various issues).

Notes: In the Chittagong Division there are high-consuming districts (Chittagong and Comilla) and low-consuming districts (Noakhali and Sylhet). In other divisions, high-consuming districts include Dhaka, Bogra, Tangail, and Kushtia, and low-consuming districts include Pabna and Rajshahi.

Phase I is September 1981 to March 1982, Phase II is April 1982 to March 1983, and Phase III is April 1983 to June 1984.

were consistently higher in Chittagong Division for all types of fertilizers. The maximum difference in average prices among the divisions was Tk 3 for urea and Tk 7 for TSP. This might be due to the early introduction of NMS in December 1978, which allowed free trading in Chittagong. Traders could charge higher prices for profits comparable to those earned from other commodity trade. Chittagong is also an area where growth in demand for fertilizer was higher during the 1970s (as indicated by higher application growth rates). This regional price difference was more prominent in Phase I and later declined, owing primarily to faster subsequent price escalation in the remaining divisions following nationwide decontrol of prices in Phase III. During Phase II, traders in the controlled or regulated zones might have been influenced to raise prices by the example of traders in the decontrolled state of Chittagong Division. BADC was also in a weaker position to exercise its control, as free trading was allowed under the NMS.[13]

Average price spreads between farm-gate and official (ex-PDP) prices widened considerably during the 1981 scarcity period (October to December 1981) and again during the second half of 1984. The remaining 20 months of this entire period showed little variation between ex-PDP and farmgate prices, even after price decontrol (Figures 7-12). This suggests that when BADC was able to maintain adequate national supplies, there was little scope for further price increases and supernormal profits for traders. Regression estimates suggest that price spreads can be reduced only marginally with larger PDP stocks of fertilizer in both high- and low-consuming districts, especially for TSP and MP (Table 21). For urea, the relationship between opening PDP stocks and the price spread was somewhat stronger. All in all, it appears that deregulation enabled traders to raise prices, but they remained close to official prices except at times of national scarcity.

Transmission of Prices to Farm Gate

To what extent will ex-PDP price increases be transmitted to the farm gate? It is theoretically possible that part of the increase in price may be absorbed by traders who are earning supernormal profits, facilitated by restricted state supplies, particularly since there are now no restrictions on farm-gate fertilizer prices. But in the situation shown in Figures 7-12, price spreads between ex-PDP and

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[13]A study by Mohinder S. Mudahar (Fertilizer Price Deregulation and Public Policy: The Case of Bangladesh [Muscle Shoals, Ala.: International Fertilizer Development Center, 1984]) indicates a narrowing of the farm-gate price differences between these two zones after complete price deregulation and concludes that deregulation had a positive impact. But the present analysis reaches different conclusions, emphasizing that price deregulation resulted in increased prices in previously regulated zones.

Figure 7--Monthly ratios of farm-gate to ex-PDP urea prices in Bangladesh and Dhaka District, 1981-84

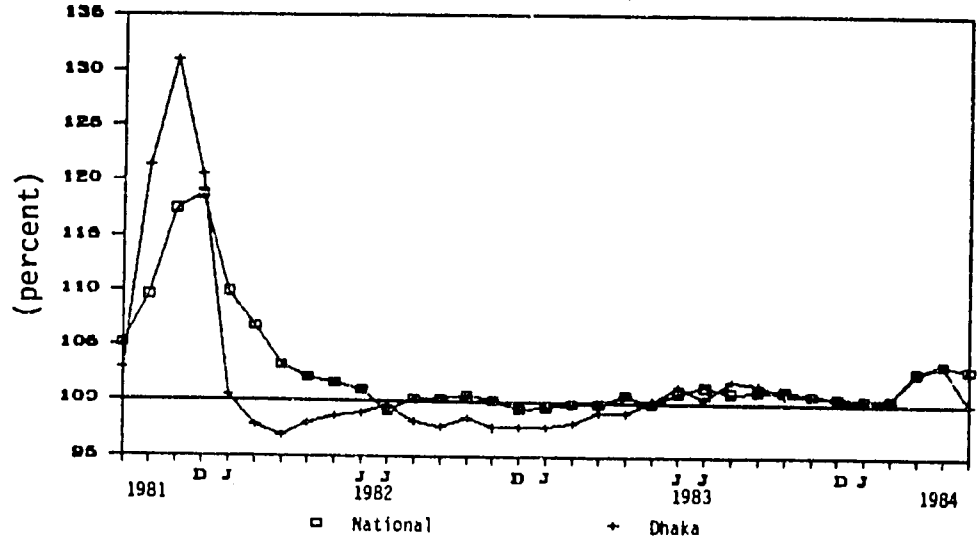

Figure 8--Monthly ratios of farm-gate to ex-PDP urea prices in Bangladesh and Noakhali District, 1981-84

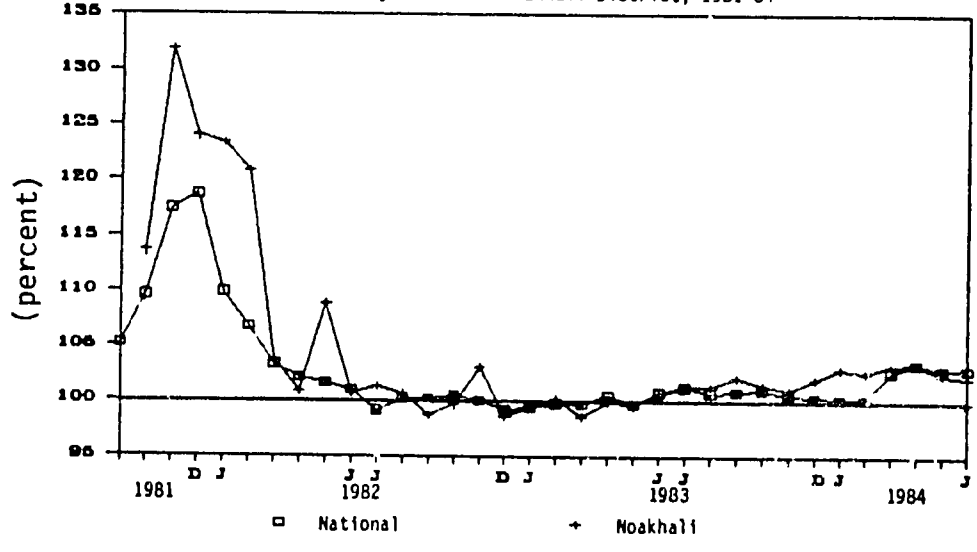

Figure 9--Monthly ratios of farm-gate to ex-PDP urea prices in Bangladesh and Rajshahi District, 1981-84

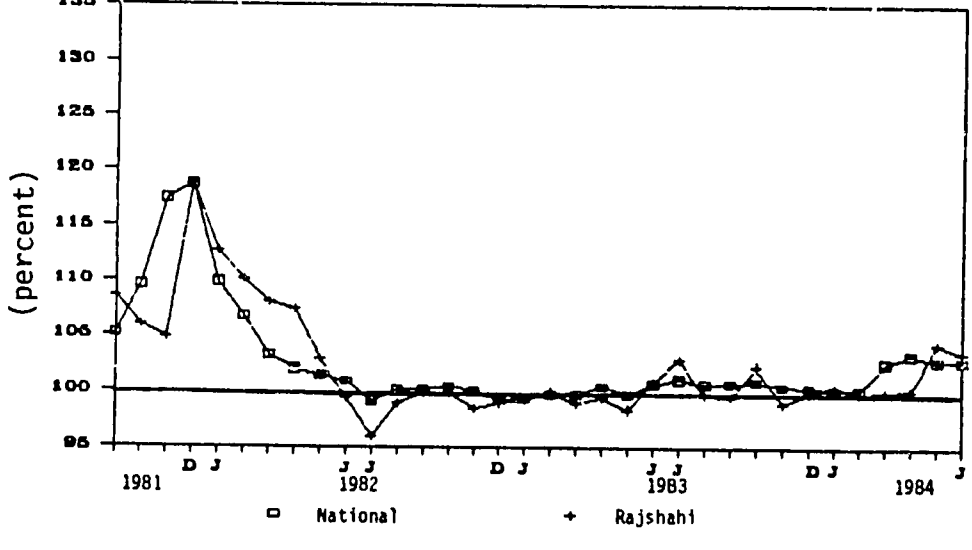

Figure 10--Monthly ratios of farm-gate to ex-PDP TSP prices in Bangladesh and Dhaka District, 1981-84

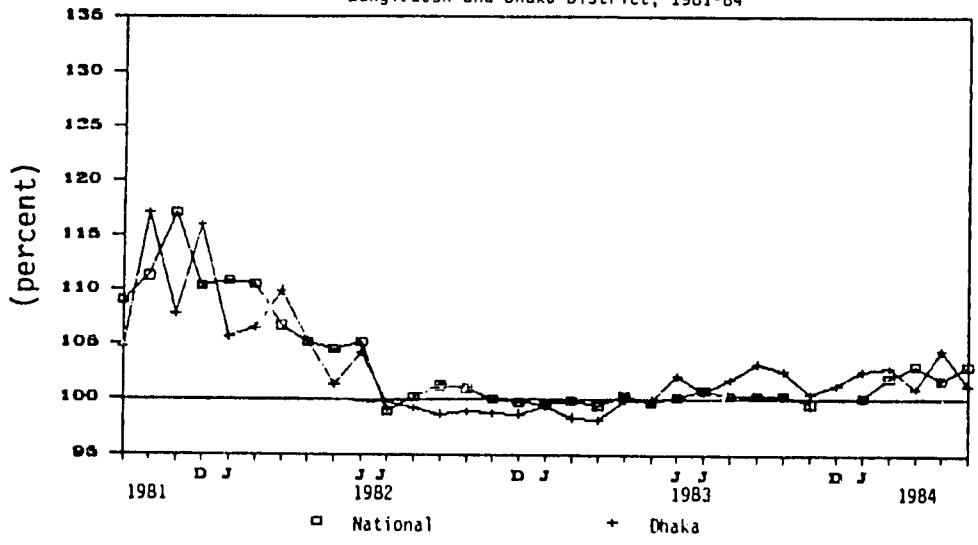

Figure 11--Monthly ratios of farm-gate to ex-PDP TSP prices in Bangladesh and Noakhali District, 1981-84

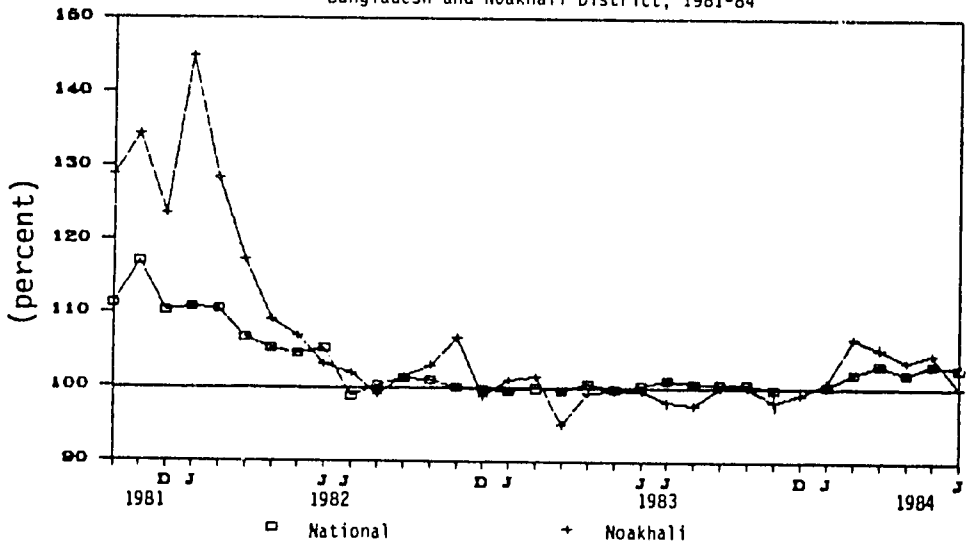

Figure 12--Monthly ratios of farm-gate to ex-PDP TSP prices in Bangladesh and Rajshahi District, 1981-84

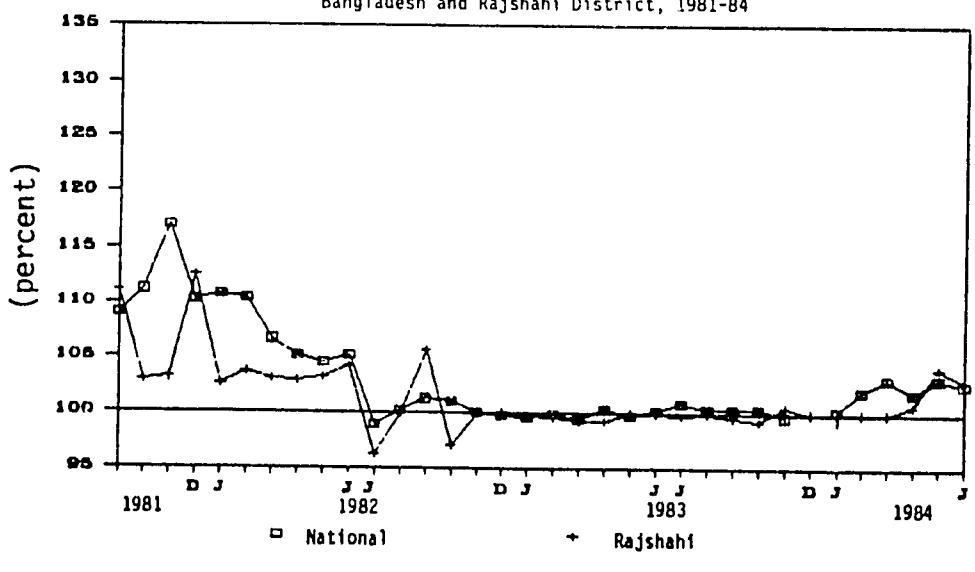

Table 21--Effect of opening stocks on the spread between farm-gate and ex-PDP prices--regression estimates

Type of Fertilizer	Constant Term	Regression Coefficient: Opening Stock	Target Sales	Actual Sales	$\bar{R}^2$
Urea					
High-consuming districts	104	-0.00081 (5.79)	0.00148 (0.44)	-0.00103 (3.12)	0.28
Low-consuming districts	109	-0.00081 (4.26)	0.00090 (1.29)	-0.00056 (0.74)	0.19
TSP					
High-consuming districts	104	-0.00052 (2.48)	-0.00067 (0.17)	0.00072 (1.85)	0.05
Low-consuming districts	111	-0.00106 (2.72)	-0.00256 (1.80)	-0.00394 (1.86)	0.13
MP					
High-consuming districts	103	-0.00033 (0.67)	-0.0022 (1.23)	-0.00275 (1.61)	0.02
Low-consuming districts	107	-0.00167 (1.69)	-0.00378 (0.74)	0.00349 (0.83)	0.05

Sources: Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, various issues); and BADC data on monthly sales, target sales, and opening stocks of fertilizer collected from official records.

Notes: The dependent variable is monthly farm-gate prices as a percent of ex-PDP prices. Figures in parentheses are estimated t-values.

farm-gate prices were minimal, except for several months of short supply in 1981/82 and again in the autumn months of 1984. This indicates that the supply at PDPs maintained by BADC was usually adequate and that prevailing market prices were fairly normal most of the time. Therefore, unless PDP supplies are low, any increase in the ex-PDP price of fertilizer is apt to be fully transferred to the farmers.

The increase in official prices in July 1982 resulted in almost the same increase at the farm gate in both urea and MP, but not in TSP(G), where the farm-gate price increment remained lower by 4 percent (Table 22). This lower increment was basically due to higher farm-gate TSP prices prevailing before the ex-PDP price increase. But the stock available with the BADC at that time was adequate. The depletion of stock during December-February had resulted in an

Table 22--Farm-gate price changes in fertilizer due to increases in official (ex-PDP) prices in July 1982

Fertilizer	Price Before Increase[a]	Price After Increase[b]	Change in Market Price	Change in Official Price
	(taka per maund)		(percent)	
Urea	132.26 (132.0)	149.45 (148.0)	13.0	12.12
TSP(G)	120.35 (115.0)	141.12 (140.0)	17.35	21.74
MP	94.54 (90.0)	115.49 (110.0)	22.16	22.22

Source: Bangladesh Agricultural Development Corporation, Monthly Fertilizer Newsletter, various issues.

Notes: Figures in parentheses are official (ex-PDP) prices per maund.

[a]This is the average price for April-June 1982 for the districts of Dhaka, Tangail, Chittagong, Comilla, Noakhali, Sylhet, and Pabna.

[b]This is the average price in August, September, and October 1982 for the above-mentioned districts.

abnormal rise in TSP farm-gate prices. Even though supply had improved and prices were gradually declining, the TSP farm-gate price had not yet stabilized at the time of the ex-PDP price increase.

Conversely, the change in TSP farm-gate prices following the December 1981 ex-PDP price increase exceeded the official rate by 8 percent. The farm-gate price increases were lower than the official ones for urea and MP. This was due to the abnormal scarcity at this time. While the short-supply situation was already easing for MP and urea, it was still severe for TSP and its stock recovery was slower. The rate of commission for dealers was also raised by 22 percent (from Tk 226 to Tk 275 per ton). The circumstances surrounding the December 1981 ex-PDP price increase therefore cannot be considered normal.

Prices in High- and Low-Consuming Districts

Higher prices generally prevailed in low-consuming districts than in high-consuming districts for each type of fertilizer (Table 20). The price differential was similar whether prices had largely been decontrolled in the division or not. Prices in low-consuming districts are assumed to have been higher because turnover of fertilizers was lower and the risk relative to expected profit in these districts was higher. Since the availability of fertilizers at the low-consuming district PDPs was more plentiful than at PDPs in high-consuming districts, supply constraint is not likely to have been the cause unless it occurred below the PDP level. Part of the increment in prices might have been caused by higher costs of transportation, which, unfortunately, could not be investigated due to a lack of relevant data. BADC-approved tender rates for fertilizer movements could not be properly examined owing to a lack of adequate records about movement distances, modes of transportation, and volumes of fertilizer transported by each route.

Prices in Remote and Accessible Areas

Below PDPs, prices are expected to vary depending on the distance and volume of fertilizers transported and the mode of transport used, at least during the period since decontrol. Previously, BADC dealers received commission on the basis of distance. Price data relating to all these variables are not available. In this section, the examination is limited to the extent of price differences between these two types of areas. This exercise is also based on IFDC data, which have been divided into four phases for the convenience of analysis of price movements. Phases I and II precede decontrol, while Phases III and IV follow decontrol.

The analysis shows that less accessible areas faced higher prices for all types of fertilizers throughout the survey period and the highest prices prevailed in TSC-operated areas (Table 23).

Table 23--Fertilizer prices in accessible and less accessible areas of Bangladesh, 1982-84

Phase	Accessible Areas	Less Accessible Areas	Areas Served by TSCs
		(taka/maund)	
Price of urea			
Phase I	134.58	139.25	n.a.
Phase II	143.34	146.06	150.50
Phase III	146.72	148.79	149.50
Phase IV	148.40[a]	152.13[a]	n.a.
Price of granular TSP			
Phase I	122.50	127.50	n.a.
Phase II	138.21	140.52	144.00
Phase III	139.12	140.71	140.67
Phase IV	140.27[a]	145.13[a]	n.a.
Price of MP			
Phase I	91.08	92.13	n.a.
Phase II	107.51	109.51	113.50
Phase III	110.64	112.06	110.25
Phase IV	115.40[a]	120.07[a]	n.a.

Source: Bangladesh Agricultural Development Corporation/International Fertilizer Development Center price data.

Notes: "Accessible" is within 5 miles of PDPs in remote areas and within 20 miles of PDPs where road and/or rail connections are available. "Less accessible" is more than 5 miles from PDPs in remote areas and more than 20 miles from PDPs where road and/or rail connections are not available. "n.a." indicates data are not available.

Phase I is January - April 1982, Phase II is May 1982-April 1983, Phase III is May - December 1983; and Phase IV is February - June 1984.

[a]Areas within 15 miles of PDPs or BADC sales centers are "accessible" areas; areas beyond 15 miles are "less accessible."

Prices in less accessible areas were higher principally because transportation systems were poorer and other related risks were greater. The price difference between accessible and less accessible areas fell during Phases II and III. This was not because of relative improvement in normal supply nor in economies of scale in fertilizer movement. Rather, it was because the acute shortage of supply throughout Bangladesh occurring around December 1981 made prices during Phase I particularly high in the less accessible areas. The effects of this crisis continued longer in the less accessible locations, with prices rising more rapidly and remaining high longer than in more accessible areas. The degree of such increases was also dependent on demand.

From Table 23 it is clear that in early 1984, the price differences increased again. The exact reasons for this are not known, but it may be due partly to changes in the definition of "accessible" and "less accessible" areas. Cut-off distances were increased during Phase IV, limiting "less accessible" areas to a smaller group of more remote locations. This definitional shift may have increased the average transport costs more among the remote group than among the more accessible group. The findings of a study conducted by the Centre for Development Science are quite relevant.[14] This study found the price difference between accessible (close to PDPs) and less accessible areas to be Tk 8 per maund for urea and Tk 11 per maund for TSP. These differences are due not only to lower transport costs in accessible areas but also to greater competition among suppliers, since wholesalers operating around PDPs often pass on part of their commission to retailers and other intermediaries.

Impact of Price Increases on Farms of Different Sizes

Fertilizer price increases can affect sales in different localities in different ways, depending on the local output response to fertilizers and to agroecological conditions. The effect may also differ by farm size. Small farms are expected to be particularly affected because of their poor purchasing capacity. In general, any reduction in use is likely to be directed toward less fertilizer-responsive crops, which in Bangladesh are primarily local rainfed paddy and other minor crops. In the case of serious resource constraints, acreage under highly fertilizer-responsive crops may be reallocated to other crops. Data relating to several relevant variables are not available. The short survey conducted in six areas for this research project in November 1984 specifically refers to prices within a period of supply crisis. The survey villages were

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[14]Centre for Development Science, Bangladesh Unnayan Parishad, "Fertilizer Price Decontrol Study," Dhaka, May 1984.

selected with care and all farm households there were interviewed. Villages in both high- and low-consuming districts specializing in specified crops were included. For example, Munshiganj is a potato-growing area while Meherpur is an important wheat-growing area.

The comparative price figures presented earlier in Table 5 show that during late 1984 TSP prices increased more than 50 percent due to an acute supply crisis. The increase was as high as 84 percent in Kushtia. The rate of increase was lower for urea (5 to 25 percent). Farmers' opinions further suggest that there was also as much as a 20 percent increase in the price of TSP last year. In one of the study areas, however, there was no increase at all. This tends to suggest that the rate of increase varies depending on the area and season as determined by supply and demand.

There was minimal variation in prices paid by different sizes of farms in the case of urea, except in two villages where small farms paid higher prices (by about Tk 25 per maund at Chandra and Tk 7 at Banguri). For TSP, however, small farms paid higher prices in all the surveyed villages except Munshiganj (Table 24). The price increments compared with those paid by large farms were between Tk 6 and Tk 16 per maund. This shows that small farms are in a particularly disadvantageous position during a supply crisis. The differences between prices paid by large and small farms cannot alone reflect the full extent of discrimination, since the quantities purchased at these prices have not been examined. If small farmers have to accept larger reductions in their desired quantities when supplies are short, that may be even more damaging than facing higher prices. It is also sometimes observed that the large farms often get discounts from dealers for bulk purchases. They are also found to purchase ahead of the season when prices are more apt to be low. These aspects require more detailed study.

Explanation of Abnormal Fertilizer Prices in 1984/85

In 1984 there were fertilizer shortages and a rmal fertilizer price increases (Table 24). According to BADC, the reported shortages were mainly due to the NMS because the BADC claims to maintain an adequate supply of fertilizer at PDPs throughout the country and any scarcity then arises ostensibly from the hoarding of traders. Under the NMS, there are no restrictions on hoarding. The proponents of NMS, on the other hand, argue that because prices have increased BADC does not hold adequate stocks. An attempt has been made to investigate the controversy.

The price data collected by BIDS from six areas indicate large increases in 1984/85, particularly for TSP (Table 24). The data exhibit wide variations, however. In Faridpur, the per maund price increases were Tk 130 for TSP and Tk 16 for urea.

Table 24--Fertilizer prices paid by operators of farms of different sizes in selected locations during a period of supply scarcity, November 1984

Location	Urea			TSP		
	Small Farms	Medium Farms	Large Farms	Small Farms	Medium Farms	Large Farms
	(taka/maund)					
Munshiganj, Dhaka (N = 148)	200	201	200	210	210	210
Gangi, Meherpur (N = 148)	170	170	169	240	238	234
Patuakhali (N = 152)	175	174	177	...	...	...
Khankhanapur, Faridpur (N = 76)	179	170	182	285	279	279
Chandra, Dhaka (N = 172)	212	188	184	240	224	224
Banguri, Dhaka (N = 154)	197	189	191	222	218	214

Source: Field survey.

Notes: The ex-PDP price of urea was Tk 162 per maund, and of TSP, Tk 154 per maund. "Small farms" are 2.5 acres or less; "medium farms" are 2.51-5.0 acres; "large farms" are more than 5.0 acres. N represents the number of farms surveyed.

BADC actually started the 1984-85 fiscal year with an opening stock of fertilizers that was lower than any of the past five years. Such depletion of stocks was most severe for TSP, for which opening stocks in 1984/85 totaled only 48 percent of the 1983/84 opening stock. The position was better for urea, for which 1984/85 opening stocks were 30 percent greater than in 1983/84. This higher opening stock position for urea suggests that there might not have been farm-gate price increases for the product had there been efficient distribution. Shortages in the opening stocks of MP were less severe than for TSP (10 percent lower than those of 1983/84), and prices did not rise appreciably.

Fertilizer sales in recent years have grown continuously since 1981/82: sales increased 13 percent in 1982/83 and another 18 percent in 1983/84. Similar sales growth (for example, 15 percent) would imply 1984/85 sales of 1,278 thousand tons. The target fixed for 1984/85, however, was only 1,220 thousand tons, which may have been influenced by reduced sales in earlier years. Conversely, the sales target for 1981/82 was once fixed at 1.2 million tons, although sales in the previous year had been only 874,000. This implies that the criteria BADC uses to set targets may require more careful examination.

Further, if monthly sales from July to November for the previous few years are carefully examined, it appears that consumption in 1984/85 was not unusual (Table 25). There were, of course, fluctuations from year to year, even for the same month during the 1980-84 period. The changes in monthly demand from one year to the next may be partly caused by the timing of rainfall, floods, and so forth, aside from changes in the cropping pattern and growth in use. The weather-related influences, of course, are difficult to predict.

During 1984, large areas under B. Aman, T. Aman, and jute were damaged by flood. Part of this damaged land has now been recultivated with Rabi crops, including mustard, potatoes, and wheat, which are also heavy consumers of fertilizers, in addition to normal

Table 25--Monthly sales of fertilizer, 1980/81 to 1984/85

Month	1980/81	1981/82	1982/83	1983/84	1984/85
	(tons of fertilizer materials)				
July	44,602	41,895	31,988	28,702	49,750
August	57,103	53,079	43,359	59,058	69,936
September	92,788	91,226	88,562	104,629	112,000
October	65,893	103,686	77,704	70,370	128,546
November	86,451	88,973	98,265	131,383	163,665

Source: Bangladesh Agricultural Development Corporation.

Notes: Sales data beginning in 1983/84 are in metric tons; data before that year are in long tons. A long ton is approximately 101.6 percent of a metric ton.

acreage under these crops. Furthermore, upland acreage under T. Aman increased in 1984/85 because of the regularity of rainfall throughout the season. Some areas under T. Aman were transplanted twice and fertilizer was applied twice. All these factors generate additional demand for fertilizers. In addition, distribution of 15,000 tons of fertilizers free of charge via the government's flood rehabilitation program for T. Aman, mustard, and wheat also encouraged sales of fertilizers. When fertilizer plans for 1984/85 were being formulated, some of these factors could not be foreseen. It was, consequently, difficult to forecast such demand well ahead of time, particularly for imported TSP, the scarcity of which has been most acute. Flood damage to Aus, Boro, and B. Aman, at least in the low-basin areas of the country, may have reduced the purchasing power of many farmers in 1984/85, affecting fertilizer sales. But this appears to have been offset by liberal distribution of institutional credit and higher jute prices.

The impact of the 1984/85 fertilizer crisis may have been distributed throughout the country by the behavior of traders under NMS. Because of a shortage in any one area, for example Munshiganj, the traders from those localities may have immediately rushed to nearby PDPs, say Narayanganj, Joydebpur, or Barisal, where the peak period of demand is somewhat later. With the sudden withdrawal of fertilizer by traders from Munshiganj, shortages may have appeared in those localities because of late replenishment by BADC through rescheduling of movement plans. Traders from these newly created deficit localities, in turn, may have had to move to some other neighboring PDPs to meet their local demand. Thus, a shortage in one area could have been distributed quickly among other areas of the country. Market speculators may have hoarded fertilizers temporarily. Several traders are reportedly involved in such practices.[15] It will be possible to get a better quantitative sense of this phenomenon now that PDP sales records for the later part of the year are available.

FERTILIZER SALES AND INSTITUTIONAL SUPPORTS

Fertilizer use may be encouraged by undertaking intensive crop production projects, including financial support through institutional credit mechanisms or flood protection, drainage, and irrigation projects.

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[15]During periods of supply shortage traders may be expected to make more frequent trips to PDPs as replenishments arrive, carrying smaller-than-normal volumes per lift. Speculators, however, may be expected to purchase larger volumes of fertilizer per lift. Field investigations at one PDP (Joydebpur) revealed fewer rather than greater numbers of lifts of large volume relative to previous years.

Crop Production Projects

Every year the Department of Agriculture undertakes different projects for specific crops: for example, the Intensive Transplant Aman Production Program and the Rabi Production Program (which includes mustard, wheat, and pulses). To implement these intensive projects, it plans for distribution of seeds, fertilizers, and institutional credit. High-fertilizer-consuming districts have recently received larger fertilizer allocations because of the greater acreage under such programs in those districts, as their topography and soil may have been more suitable for intensive cropping. In addition, expansion of irrigation has also facilitated such intensive cropping.

In each of the crop production projects, a certain portion of the total loan is earmarked for fertilizers. Its share varies from crop to crop. Irrigated Boro crops receive more than 30 percent of all crop loans for HYV-Boro, and irrigated wheat receives 48 percent. This suggests that areas having larger acreage under irrigation may receive a larger amount of institutional credit. The distribution of credit in the districts in 1982/83 shows that the high-fertilizer-consuming districts received a larger amount per acre (Table 26). This is undoubtedly because of more extensive irrigation there. The low- and medium-consuming districts received lesser amounts. Execution of development projects such as flood protection and irrigation can aid the adoption of HYVs. Such projects, which facilitate HYV adoption, and other crop production projects can increase fertilizer demand in these districts.

Agriculture Extension Services

The success of intensive crop production projects depends on services provided by agriculture extension personnel. Their services are most important while introducing new crops and inputs in a locality. In the case of the Department's regularly executed projects for promoting intensive production of paddy and other cash crops, such as potatoes, wheat, and mustard, their services are more useful in encouraging application of recommended doses of fertilizer and timely use of pesticides. The success of intensive crop production projects in a district and, in consequence, increased use of fertilizer, may therefore be a function of the numbers of extension personnel employed by the Department of Agriculture. An exercise has been undertaken to understand the relationship between the numbers of extension personnel employed in a district and fertilizer use.

The disposition of extension personnel among districts could be collected only for 1983/84. Information for other years was not available. It may be that the 1983/84 positions form a pattern similar to those of other years because the government appoints extension workers on the basis of long-term administrative allocations. The only difference that may arise is from vacancies created

Table 26--District-wide distribution of institutional credit, extension personnel, and fertilizer traders, 1983/84

District	Loans Disbursed per Cropped Acre[a]	Proportion of Wholesalers Receiving Bank Guarantees	Number of Dealers per 100,000 Acres of Cropped Land	Average Quantity of Fertilizer Traded per Dealer	Average Cropped Area Supervised by an Extension Worker
	(taka)	(percent)		(tons)	(1,000 tons)
Tangail	125	17	8	52	3.24
Kushtia	134	9	11	52	3.13
Dhaka	436	18	11	55	1.54
Comilla	140	2	4	140	2.83
Chittagong	334	27	26	25	3.00
Bogra	102	7	12	60	3.24
Chittagong Hill Tracts	18	n.a.	n.a.	...	1.71
Jessore	112	16	1	222	3.26
Rangpur	69	2	8	35	4.03
Rajshahi	131	4	8	55	3.41
Mymensingh (excluding Jamalpur)	61	n.a.	5	118	3.26
Kishoreganj	n.a.	4	3		
Dinajpur	79	8	3	120	4.10
Pabna	105	n.a.	5	77	3.39
Patuakhali	61	4	4	14	4.98
Khulna	94	5	5	28	3.00
Faridpur	60	3	4	32	3.08
Barisal	263	3	8	17	3.07
Sylhet	50	2	2	90	5.88
Noakhali	69	13	22	9	3.75
Bangladesh	125	14	7	51	3.19

Note: n.a. means not available.

[a]These data are for 1982/83 and exclude credit distributed by the Rupali, Pubali, and Uttara Banks.

by transfers or resignations. The intensity of extension service is similar throughout the country, irrespective of whether the consumption in any particular district was high or low, and thus appears to have little direct relation to differences in the intensity of fertilizer use among districts. The more favorable situation in Dhaka district is due to inclusion of the headquarters staff.

Bank Guarantees to Wholesalers

To facilitate smooth distribution of fertilizers below PDPs, wholesalers are allowed to procure fertilizers from PDPs against bank guarantees valuing up to Tk 100,000 per trip. Repayment should be made within 60 days of the receipt of fertilizers. This type of bank support has been found to be concentrated in high-fertilizer-consuming districts. This is not surprising in view of the wider scope for fertilizer trading in those districts. The small size of the fertilizer market in low-consuming districts limits such operations. However, Comilla and Noakhali are, to some extent, exceptions.[16]

This type of financial support may enable wholesalers to sell on credit to retailers. A 1984 survey by BIDS indicated that about 80 percent of the retailers questioned bought around 50 percent of their fertilizer on credit from wholesalers.[17]

It may be of interest to note that traders are greater in number where the fertilizer market is wider, and the average volume traded per dealer in those districts is also larger (Table 26). The number of traders per acre of cropped land dealing in low-consuming districts is around half the number operating in the high-consuming districts. New traders may not be attracted because the average transaction size is smaller and the profits lower compared with other commodity trades.

SUMMARY AND CONCLUSIONS

Farmers in Bangladesh use mostly urea, TSP, and MP. In recent years, DAP, zinc sulfate, and NPK have also been used. The share of imports among total fertilizers procured in 1983/84 was 32 percent.

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[16]The recorded numbers of dealers in these two districts may not be dependable. The total number of traders in operation in Noakhali was given to be 2,785, whereas in Comilla it was only 425. In contrast, fertilizer distributed in Comilla was four times greater than that of Noakhali. The data relating to traders require continuous monitoring because of seasonality of demand.

[17]Quasem et al., Impact of the New System of Distribution of Fertilizer.

During the 1972/73-1981/82 period, 47 percent of imported fertilizers were purchased with grants, 46 percent with credit, and 7 percent with cash. The leading donor countries supplying fertilizer under grant are Canada, Norway, and Saudi Arabia and the principal supplier under credit is the United States.

BADC is the sole importer and distributing agency for fertilizers to PDPs located in 95 important market centers. In remote areas, BADC distributes through TSCs. Private traders operate below PDPs and TSCs. They lift fertilizers from PDPs at which they are registered. They get a fixed commission of Tk 275 per ton and have typically sold at or near state-controlled prices. In April 1983, the government decontrolled farm-gate prices throughout the country, allowing traders to sell at whatever prices the market can absorb.

In 1983/84, 115 pounds of product were applied per acre of cultivated land. There are, however, wide variations among districts, ranging from 16 pounds to 277 pounds per acre. Among the low-consuming districts, Noakhali and Patuakhali experienced a declining trend during the 1979/80-1983/84 period, and Barisal experienced stagnation. The intensity of use in recent years has remained almost unchanged in the high-consuming districts of Comilla and Chittagong. Variations in fertilizer use are due mainly to differences in area under irrigation and high-yielding varieties (inclusive of pajam and wheat).

Availability of fertilizers at PDPs was not found to be a constraint in the low-consuming districts. High-consuming districts were sometimes more constrained. Replenishment of fertilizers at PDPs was, however, more frequent there. Availability of greater storage capacities (relative to sales) appears to have facilitated the better stock position of the low-consuming districts.

Price spreads between farm-gate prices and official (ex-PDP) prices were minimal except during the periods of supply crisis in the fall of 1981 and of 1984. For the most part, therefore, the supply maintained by BADC was adequate and the market prices prevailing during most of the period appear to have been normal. Most of the increase in official (ex-PDP) prices in July 1982 was transmitted to the farms.

Prices of fertilizers have been higher in the decontrolled districts (Chittagong Division), perhaps because of larger demand and earlier introduction of NMS there. The difference in price between controlled and decontrolled areas declined following decontrol of prices all over the country. This narrowing of price differences was due to sharper rises of prices in the regulated zones after decontrol.

Prices in low-consuming districts have consistently been higher than those in high-consuming districts, particularly for urea and

TSP(G). This appears to be due to lower turnover of fertilizers as well as higher transport costs to traders there.

Prices in remote areas are higher than those in accessible areas. Areas close to PDPs tend to have lower prices due to lower transportation costs and a greater number of competing wholesalers.

Fertilizer sales appear to have been facilitated by institutional supports to a greater extent in the high-consuming districts. These supports relate to intensive crop production projects, provision of institutional credit to growers, and bank guarantees to wholesalers.

8. THREE NOTES ON FERTILIZER SUBSIDY REMOVAL IN BANGLADESH

Abu Abdullah

NOTE 1: THE POLITICAL ECONOMY OF FERTILIZER PRICING POLICY

Introduction

Consumption of chemical fertilizer has increased rapidly in Bangladesh over the last 20 years. Average application rates remain low, but coverage is quite extensive. Most cereal crops, as well as some noncereal food and nonfood crops, receive at least small quantities of fertilizer. Usage is not restricted to large farmers, but is common to farms of various sizes.

One of the policy instruments used for encouraging fertilizer consumption has been price subsidy. There are no consistent time series data showing the extent of the subsidy, but there is little doubt that the rate of subsidy was initially quite high and has declined, especially during the last few years, as a result of a deliberate government policy choice. According to estimates by Atiqur Rahman, the rate of fertilizer subsidy was 28.8 percent in 1973/74. It increased to 58.8 percent in 1975/76 and fell back to 40.8 percent in 1977/78.[1] Although the method used by Rahman differs from either of those employed by Raisuddin Ahmed in Chapter 3, use of either the economic subsidy or budgetary subsidy methodology adopted by Ahmed would show a similar increase, then decline, in the rate of subsidy. The decline continued after 1977/78, reaching 25.3 percent (budgetary subsidy) or 23.1 percent (economic subsidy) by 1983/84, then falling sharply again during the succeeding year.[2]

From discussions with concerned officials, it is clear that this reduction in the rate of subsidy was not an independent decision but was adopted only under strong pressure from the donors: notably the World Bank and the U.S. Agency for International Development. This pressure escalated during 1984-85, with the World Bank insisting that the fertilizer subsidy be completely eliminated by June 1985.

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[1]Atiqur Rahman, "Public Expenditure on Agriculture: Bangladesh, 1973/74 - 1977/78," Bangladesh Institute of Development Studies, Dhaka, June 1980 (mimeographed), p. 63.

[2]See Chapter 3, by Raisuddin Ahmed, especially Tables 5 and 8.

The government of Bangladesh therefore decided to sponsor a study on fertilizer price policy. The central focus of the study, according to the Terms of Reference, is to determine "...desirable fertilizer pricing adjustment while ensuring continued farm incentives to achieve progress in foodgrain production." The present paper aims to elaborate the appropriate framework for such an analysis.

The Basic Issues

Fertilizer is an agricultural input, used fairly extensively and likely to be used even more in future, partly produced domestically and partly procured from abroad, in whose procurement and distribution the government retains a major role. If the government decides to relinquish that role, the question of a price policy disappears. But if it does not, then the government must decide on the price at which it will sell this input, the mechanism through which fertilizer will be sold, and the people or organizations (wholesalers, retailers, individual consumers, cooperatives) to whom it will sell. (It is assumed here that the price at which the government buys fertilizer is either not a policy instrument or, at any rate, not one that is relevant for the purposes of this analysis.) This note concentrates primarily on the question of the selling price, assuming that the current distribution system (sales to wholesalers through primary distribution centers) is given.

The considerations that should guide government decisionmaking in this matter can be divided into four areas: budgetary implications, fertilizer price, effects on agricultural production, and effects on distribution of income.

First, selling fertilizer at prices below costs implies a deficit that will have to be financed. Prices above costs would yield revenue. The government needs to raise revenues only because some of its activities must, or should, run deficits. The point is to decide which activities should generate revenues and which should receive subsidies.

Note that reference to selling price, instead of subsidy, restores a degree of generality to the topic. There is nothing special about the zero subsidy price. If it is desirable to eliminate subsidies, chances are good that it is also desirable to impose a tax. The reason that the zero subsidy price appears special is that it is supposedly the price that would prevail if market forces were allowed to operate unhampered. This, however, is not true for a number of reasons that require no elaboration.

In actual cash terms, fertilizer sales have not imposed a burden on the exchequer. This is because significant amounts of fertilizer

are received as aid.[3] As in the case of food aid, selling this part of the supply at partially subsidized prices (in economic terms) still generates enough revenue to more than pay for the subsidy on the remainder of fertilizers sold.

Second, price influences consumption, and hence, in the case of fertilizer, agricultural output. Of course fertilizer price is not the only determinant of fertilizer use, and fertilizer use is not the only determinant of production. Nevertheless, other things being equal, a rise in price will discourage use, and a drop in use will, unless compensated by the substitution of some other input, cause a relative fall in output. If output growth were the only objective, and there were no resource constraint, fertilizer would be given away. Of course, there is a resource constraint. It is therefore necessary to ask whether the costs of the subsidy in opportunities foregone (that is, in other feasible areas of productive expenditure) are counterbalanced by the benefits in increased output.

Third, whatever else fertilizer price may be, it is also always a mechanism of income redistribution. Changes in fertilizer price will affect the distribution of income in two ways. First, a rise in price will unambiguously mean a loss to farmers, at least those farmers who use fertilizer. This will be so irrespective of the price elasticity of demand for fertilizer. The decision to raise fertilizer prices is therefore, other things remaining constant, a decision to inflict an income loss on farmers. Of course this in itself need not mean that such a step is undesirable. If it is decided that agriculture must be taxed or must at least receive less subsidization, then raising input prices is one obvious way of doing so.

Second, an increase in fertilizer prices may affect different classes of farmers differently. It will not directly affect nonusing farmers or landless laborers, though it might affect them indirectly insofar as higher input prices are passed on to them as high output prices. It will have greater effect on the people who spend proportionately more of their incomes on fertilizer.

If it is decided that agriculture should be taxed more (or subsidized less), the desirability of using fertilizer price as a device for accomplishing this end will depend partly on this second distributional aspect: on whether this instrument is likely to have a progressive or regressive impact.

The optimum price for fertilizer, or any other input, has to be determined in the light of the above considerations. However, some broader issues should be made explicit.

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[3]Ibid.

First, fertilizer price is one policy instrument out of many that can and is being used to pursue goals that are not always very clearly articulated. Its efficacy and its likely effects have to be judged in the context of the whole policy package. Raising the price of fertilizer would mean one thing if it were accompanied by a vigorous and sustained move to encourage the healthy development of cooperatives linking middle-size farms.[4] Raising it in the overall context of privatization would mean something quite different.

Currently the government is pursuing a policy of privatization of irrigation equipment, which will no longer be rented out to users but must be bought outright by cooperatives, informal groups, or individuals. Credit availability has been increased to help prospective buyers. At the same time, private trade in fertilizer is being encouraged by closing down the thana sales centers and relaxing the conditions for lifting fertilizer from the primary distribution points.[5]

Taken by itself, raising fertilizer prices will harm all categories of farmers that use fertilizers. The question whether rich farmers will sustain greater direct losses as a proportion of income than smaller ones will be addressed in the next note. But in an indirect sense, with rented irrigation equipment no longer available, poorer farmers will by and large have to buy water from larger ones, who will be able to pass on some of the loss to poorer farmers via higher prices for both irrigation equipment and fertilizer. Generous credit access and lax repayment enforcement are already compensating rich farmers. Fertilizer trade will provide another avenue for compensation favoring wealthier farmers. As part of this policy environment, therefore, raising fertilizer prices would be one more nail in the coffin of small and medium farmers.

On the other hand, in the overall context of an agricultural strategy based on cooperatives of small and middle-size farmers (preferably after land reform has eliminated rich farmers, so that the situation approaches that in Japan or Taiwan) raising the price of one input could be accompanied by policies--credit, irrigation, extension, and so forth--that would more than compensate <u>all</u> the losers and represent a more cost-effective rural development strategy.

Second, in evaluating one particular policy or a whole policy package, the overriding objectives of the policy must be constantly kept in mind. In the context of Bangladesh the broad objective must be growth with equity. For agriculture, this will translate into policy packages that, first, do not hasten the ongoing process of

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[4]See Chapter 4, by Mahabub Hossain, Tables 34 and 41.

[5]See Chapter 7, by Md. Abul Quasem.

differentiation and pauperization and, second, do not raise the price of foodgrains over and above "normal," inevitable, inflationary rates.[6]

The Opportunity Cost of the Subsidy

Not even the staunchest proponents of subsidy elimination would argue that this would have no adverse effect on fertilizer use and output growth. They would argue that the resources saved by eliminating the subsidy could be used in more productive ways within agriculture itself. The following areas of investment are usually suggested as being superior: irrigation and flood control, provision of credit, research and extension, and rural roads.

It is also suggested that if some of these investments bypass the issue of equity, this could be handled by some other policy instrument, for example, a more precisely targeted food subsidy scheme.

Given that investments have been identified that are more productive than the subsidy at the margin, it still remains to be established that the most appropriate way of raising funds for these investments is to raise the price of fertilizer and that funds generated by raising fertilizer prices are in fact likely to be used in these productive ways.

To establish that price increase is most appropriate, all other possible sources of revenue must be scrutinized, including diversion from other less productive uses, new taxes, and deficit financing. There is no way of establishing that the funds raised will be used productively, however. All that can be done is to try to be politically realistic in making recommendations.

The alternative of deficit financing for keeping fertilizer prices low also merits discussion. Deficit financing is normally not encouraged as a device for promoting development. But some government activities are bound to require deficit financing; among them, a fertilizer subsidy would not necessarily be a poor choice for inclusion. This is because the main cost of deficit financing is generalized inflation, and a fertilizer subsidy has built-in anti-inflationary effects. To the extent that cereal output goes up and prices fall, this will have a generally depressing effect on prices and money wages. Thus, fertilizer subsidy would involve a transfer from future to present income.

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[6]"The dilemma is how to increase production...without increasing domestic prices and leaving more malnourished as a result of poverty?" (J. R. Tarrant, "Food Policy Conflicts in Bangladesh," World Development 10 [No. 2, 1982]: 105).

Lastly, when funding alternative investments with the savings effected through subsidy elimination, the activities that can be so funded must be carefully specified. To the extent that the subsidy on provision of irrigation equipment is going to be withdrawn, the total cost of an irrigation program need not be funded from revenue transfers. Only annual net increments will require funding, and if irrigation equipment were to be supplied at a cost-plus price, perhaps not even that. It would make more sense to have a tax on irrigation equipment, because this is more likely to be bought by wealthier farmers. In this case, expansion of irrigation would make no demands on budgetary resources. Similarly, a credit program that charged interest rates above costs would in principle need no budgetary support, unless the aim was to expand the program faster than levels which self-financing would feasibly allow.

Thus, if more resources are to be generated from agriculture, there are at least three prices that may be considered as instruments: those of fertilizer, irrigation equipment, and credit. To decide which is best, it is necessary to compare the productivity and equity effects of raising a certain amount of resources through these three alternatives. There can be little doubt that raising the price of irrigation equipment or institutional credit would be distributionally superior to raising fertilizer prices.

Conclusions

The above discussion leads to these conclusions: First, in judging the desirability of a fertilizer price regime, it is preferable to avoid being obsessed by the idea of zero subsidy as a given goal. Depending on circumstances, the optimal price for an input may involve negative, zero, or positive subsidy. Second, fertilizer price policy cannot be judged in isolation but only in the context of the overall policy package in which it is embedded.

Third, the appropriate price of fertilizer, or any other input, depends on development objectives. Prime objectives for food policy in Bangladesh include providing incentives to growers without raising foodgrain prices unduly and arresting or at least not hastening the process of disintegration of small farms. Raising the price of fertilizer is likely to run counter to both these objectives.

Fourth, in the existing context of unequal landholdings, a consequently enfeebled cooperative system, and privatization of fertilizer trade and sale of irrigation equipment, raising fertilizer prices could have adverse distributional consequences as well as some adverse effects on output.

Finally, the adverse effects on output could be compensated for by investments in irrigation, credit, and so forth. But it is by no means clear that such funds need to be raised by increasing fertilizer prices. There may be less costly sources, including taxing

these investments themselves, cuts in expenditures outside agriculture, and deficit financing.

NOTE 2: DISTRIBUTIONAL ASPECTS OF FERTILIZER PRICING POLICY

With an average holding size of roughly 1.5 acres per household (nearer to 2 if the landless are excluded from the denominator), the average Bangladesh peasant is poor. This average, however, conceals a significant degree of inequality among farm households. The poorest of the poor are the landless and the near-landless (those owning 0.5 acres or less) who constituted 48.7 percent of rural households in 1979.

Abstracting from regional variations, those owning more than five acres of land may be considered above the danger line. They grow more than enough rice to feed themselves, and they sell some surplus rice as well as other crops for their cash requirements. This category constituted 7.7 percent of all rural households in 1979.

Between these extremes lies a group that may be called the small and middle farmers. Those near the lower end of this group are in chronic financial deficit, and even those near the top are under perpetual threat of irreversible downward movement initiated by any shock (natural, market, or personal) to their delicately balanced household economies. The ranks of the landless are constantly replenished by those within this stratum who succumb to such shocks. Table 1 presents available evidence on the distribution of landownership in 1979.

Over time, as the population has grown and the nonagricultural production sector has failed to generate any sustained dynamism, the situation on the land has worsened. Landlessness is increasing rapidly and farms are getting smaller. The spread of HYVs and the proliferation of rural off-farm activities, which may not be even as remunerative as wage labor, have enabled the rural economy to at least continue to provide for the increasing population. But available evidence suggests that poverty, however measured, has been growing, and, in particular, the proportion of undernourished people has been rising.

Detailed information on changes in land ownership is not available. But the distribution of area operated would probably show a broadly similar movement, though somewhat dampened by operation of the tenancy market. When agricultural census data for 1960 and 1982 are compared, it is clear that the proportion of small farms, those operating less than 2.5 acres, has risen significantly (from 31.6 percent to 67.5 percent), while the proportion of larger farms (more than 2.5 acres) has fallen from 48.4 percent to 32.5 percent (Table 2).

Table 1--Pattern of distribution of landownership, 1979

Size of Farm	Share of Households	Share of Land Owned
(acres)	(percent)	
Less than 0.5	48.7	3.5
0.5 to 1.0	11.8	5.3
1.0 to 2.5	20.7	20.9
2.5 to 5.0	11.2	24.5
5.0 to 10.0	5.5	23.2
More than 10.0	2.2	16.5

Source: Bangladesh Bureau of Statistics, "1979 Land Occupancy Survey," Statistical Pocket Book of Bangladesh, 1983 (Dhaka: BBS, 1984), p. 208.

Table 2--Changes in distribution of landholdings, 1960-82

Size of Farm	Distribution of Farms		Total Share of Land Operated		Change in Land Operated
	1960	1982	1960	1982	
(acres)			(percent)		
Less than 1.0	24.3	34.0	3.2	7.1	122
1.0 to 2.5	27.3	33.5	12.9	22.3	73
2.5 to 7.5	37.7	27.6	45.7	47.0	3
More than 7.5	10.7	4.9	38.1	23.6	-38

Source: Bangladesh Bureau of Statistics, "1979 Land Occupancy Survey," Statistical Pocket Book of Bangladesh, 1983 (Dhaka: BBS, 1984), p. 208.

The literature is replete with expressions of concern for the landless. The record is less encouraging regarding concrete attempts to improve their lot. The Rural Works Program was launched in the early 1960s to provide some supplementary employment while contributing to rural development through the creation of infrastructure. This program, and the larger Food-for-Work Program, continue to be the main elements of the poverty alleviation strategy. More recently, the Grameen Bank has, with considerable success, used credit as a catalyst for the generation of nonfarm self-employment. But its area of operation still encompasses less than 3 percent of the villages in the country.[7] Real wages for agricultural laborers appear to be recovering some lost ground, but unemployment and underemployment remain serious problems.

The Comilla model put the middle-size farmer at center stage. The basic vision of the model was that if the middle-size farmers could unite and act together in pooling their financial resources, in obtaining credit, in adopting new cultivation practices (particularly those based on irrigation), and in produce and input marketing, they could protect themselves against exploitation by landlords, traders, and moneylenders, and also make a successful transition to a more dynamic agriculture.

The program was fairly successful in the beginning, and some of its basic elements were replicated nationwide under the Integrated Rural Development Program (IRDP). But it seems to be running out of steam, to a large extent because of competition from programs for which the interest and repayment requirements are easier. In recent years, in pace with this development, the government's rural development strategy has displayed an increasing tendency to "bank on the rich peasant."

Those who are poor in land are in general also poor in other assets. Their access to other resources is likely to be limited, partly because those resources are available only to landowners and partly because the landless have neither purchasing power nor political power. Table 3, based on the IFDC/BARC surveys, provides some information relevant to this issue. The table indicates, for example, that farmers cultivating up to one acre comprised 31.5 percent of all households, but operated only 12.6 percent of the land. They used 15.6 percent of all fertilizer, received 3.2 percent of all institutional credit, and operated 16.7 percent of all irrigated area.

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[7]See, for example, Mahabub Hossain, "Credit for the Rural Poor: The Grameen Bank in Bangladesh," Research Monograph 4, Bangladesh Institute of Development Studies, Dhaka, 1984; and Mahabub Hossain, "Credit Alleviation for Rural Poverty: The Experience of Grameen Bank in Bangladesh," Washington, D.C., September 1986.

Table 3--Shares of land operated, and consumption of modern inputs by farm size groups, 1981/82

Size of Farm	Distribution of Farms	Quantity of Land Operated	Fertilizer Use	Credit	Irrigated Land[a]
(acres)		(percent)			
Less than 1.0	31.5	12.6	15.6	3.2	16.7 (20.5)
1.0 to 2.5	32.8	22.0	23.2	21.9	25.1 (17.8)
2.5 to 5.0	21.9	27.5	28.8	35.7	27.9 (15.7)
More than 5.0	13.8	37.9	32.4	39.2	30.2 (12.4)

Sources: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1980-82 (Muscle Shoals, Ala.: IFDC, 1984).

Irrigation data are based on landholding data from the same survey and on data on proportions of irrigated land from a study of deep tubewells conducted by the Bangladesh Institute of Development Studies. See also Md. Abul Quasem, Abul Barkat, and S. A. Khan, Impact of the New System of Distribution of Fertilizer and Irrigation Machines in Bangladesh (Dhaka: Bangladesh Institute of Development Studies, 1984).

[a]Figures for irrigation are estimated by applying the proportion of irrigated land by farm size group (figures within parentheses) to landholding data from the IFDC/BARC survey.

An interesting observation that can be made from this table is that, although the poorer farmers have a reasonable degree of access to both fertilizer and irrigation, they do a bit better with irrigation than with fertilizer. The superior access to irrigation is mainly a result of the fragmentation of holdings. This fragmentation led the state to promote formation of farmers' groups to facilitate irrigation development (because individual farmers would not have enough land in one contiguous plot to make mechanized irrigation worthwhile). This same fragmentation now makes it imperative for the larger farmer to sell water to his poorer neighbors, if irrigation is going to be profitable for him.

It should be noted, though, that although poor farmers, given their landholdings, have reasonable access to irrigation, they do not generally own irrigation machinery. A BIDS study found that 62 percent of the owners of equipment owned outright by individuals or groups also owned more than five acres of land.[8]

Ownership matters at least in one important way: the owners may be able to extract a monopoly price for water from users whose plots lie within the command area of an irrigation machine. The same study found that while the Bangladesh Agricultural Development Corporation charged 960 taka per acre to deep tubewell users, individuals or groups who owned machines charged an average service fee of 1,891 taka.[9]

Irrigation, especially privatized irrigation, has its drawbacks from the point of view of equity because it may be a built-in device that enables rich farmers to extract a good part of the incremental output from poorer ones. From this viewpoint, a fertilizer subsidy is preferable to subsidizing irrigation equipment sales.

A rise in the price of fertilizers, which is an input quite widely used by peasants, would mean an immediate income loss to all farmers who use fertilizer. Table 4 gives two estimates of the income loss to different groups of farmers. Both are based on the assumption of a 20 percent rise in fertilizer prices. One incorporates the assumption that levels of use are unchanged; the second, that levels of use are adjusted, reflecting the operation of estimated demand elasticities (assumed constant in the relevant range).

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[8]Md. Abul Quasem, Abul Barkat, and S. A. Khan, Impact of the New System of Distribution of Fertilizer and Irrigation Machines in Bangladesh (Dhaka: BIDS, 1984), Table 3.45, p. 136.

[9]Ibid., Table 3.22, p. 107.

Table 4--Income effect of a 20 percent rise in fertilizer prices

Size of Holding	Proportion of Households	Average Fertilizer Use Per Household	Additional Expenditure on Fertilizer 1	Additional Expenditure on Fertilizer 2
(acres)	(percent)	(pounds of nutrients)	(taka)	
Less than 1.0	31.5	113	38	33
1.0 to 2.5	32.8	233	79	69
2.5 to 5.0	21.9	433	147	128
More than 5.0	13.8	773	249	229
All farms	100.0	329	112	97

Sources: The data on distribution of households and use of fertilizer are from Bangladesh Agricultural Research Council and International Fertilizer Development Corporation, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1980-82 (Muscle Shoals, Ala.: IFDC, 1984).

Additional expenditures on fertilizer were calculated according to assumptions discussed in the text, using data on fertilizer prices and demand elasticities from the chapter by Mahabub Hossain.

The amounts involved are not large. At current levels of application and world and domestic prices, therefore, eliminating the subsidy on fertilizer would not impose a heavy burden on any group of farmers. Table 5, which presents some rough calculations of the tax burden in proportion to total income and additional income from fertilizer use, reinforces this impression.

The implied price rise from fertilizer subsidy removal approximates a flat rate income tax of 0.8 - 1.0 percent of household income and captures 7.3 - 7.7 percent of the income generated from fertilizer use. Ideally a more progressive tax might be preferable: one that would exempt at least the two bottom groups and tax the top group at a higher rate. However, it may be difficult to devise an administratively feasible tax that would have all the desirable properties.

Still, it is not possible to conclude that the burden of a price rise falls lightly on everyone. The two bottom groups, with an annual household income of less than Tk 11,000, are primarily households that are perpetually in deficit. They are apt to be indebted, they have reduced consumption levels as far as possible and sometimes farther, and they are certainly not voluntarily unemployed for a day. For such people, even raising Tk 30 may not be easy.

Second, if application rates rise, if world prices go up significantly, as they are likely to, and if the currency continues to depreciate, as it is almost bound to, the cost of maintaining a subsidy, as well as its distributional impact, could increase considerably. Although the government may be justified in eliminating the subsidy at this point in time, this must on no account be interpreted as an unconditional acceptance of the general principle of zero subsidy.

Table 5--Proportionate burden of subsidy elimination

Size of Holding	Average Household Income	Additional[a] Income from Fertilizer	Additional Expenses[b] as Share of Household Income	Additional Expenses[b] as Share of Income from Fertilizer
(acres)	(taka)		(percent)	
Less than 1.0	8,134	498	0.8	7.6
1.0 to 2.5	10,672	1,028	1.0	7.7
2.5 to 5.0	20,352	1,910	0.9	7.7
More than 5.0	43,330	3,410	0.9	7.3
All farms	16,300	1,450	1.0	7.7

Notes and sources: Household incomes are from a Bangladesh Institute of Development Studies study on the Chandpur Irrigation Project. The estimated income may be somewhat higher than the national average.

[a]Calculation of additional income from fertilizer is based on the assumption of an output response of 2.2 pounds of paddy per pound of fertilizer materials and an output price of Tk 165 per maund of paddy.

[b]This is based on the higher estimate from Table 4 (assuming no change in fertilizer use).

NOTE 3: AGRICULTURAL CREDIT AND FERTILIZER USE

The volume of institutional credit to agriculture has gone up dramatically in recent years--about eightfold between 1976-77 and 1982-83 (Table 6). According to Mahabub Hossain, the amount of institutional credit in 1982-83 amounted to about 12 percent of total cost of cereals production and about 40 percent of the cost of material inputs.[10] Available evidence indicates, however, that only a small proportion of cultivators receive such loans. According to figures provided by the IFDC/BARC surveys,[11] the percentage of farmers receiving credit in any one season did not exceed 5.9 in 1980-81, nor 4.6 in 1981-82, so that, even if it is assumed that no farmer received credit in more than one season, only 14 percent of surveyed farmers had access to institutional credit in 1980-81 and 11 percent in 1981-82. It is also evident that the better farmers had superior access.[12]

It is interesting to note in this connection that in the operations of the Bangladesh Krishi Bank, the share of total loans going to those holding less than 2.5 acres of land declined from 54.7 percent in 1976-77 to 32.1 percent in 1980-81, while the share of those holding more than 7.5 acres went up from 17.7 percent to 36.6 percent (Table 7). The performance of the Bangladesh Shamabaya Bank Ltd. (BSBL) and of some of the nationalized commercial banks appears to be better in this respect, however. As much as 67.7 percent of BSBL loans, for example, went to borrowers holding no more than 2.5 acres, whereas only 3.8 percent went to those holding more than 7.5 acres (Table 8).

This indicates that those who do receive institutional credit are borrowing amounts that, on the average, more than cover their cash costs of production. This may imply some diversion of credit to nonproductive uses, and suggests that a redirection of credit toward smaller farmers would increase efficiency of credit utilization.

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[10]Mahabub Hossain, "Increasing Food Availability in Bangladesh: Constraints and Possibilities," a report prepared for the Ministry of Agriculture and Forests, Dhaka, April 1984, p. 34.

[11]Bangladesh Agricultural Research Council and the International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis of Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Alabama: IFDC, 1982 and 1984).

[12]See Chapter 4, by Mahabub Hossain, Tables 14 and 15.

Table 6--Fertilizer use and agricultural credit, 1976/77 - 1983/84

Year	Agricultural Credit	Expenditure on Fertilizer: Total	Expenditure on Fertilizer: As Share of National Agricultural Credit	Sums of District Data: Agricultural Credit	Sums of District Data: Expenditure on Fertilizer
	(Tk millions)		(percent)	(Tk millions)	
1976/77	864	773.223	89	1,072.9	773.299
1977/78	1,569	1,085.444	69	1,230.7	1,094.766
1978/79	1,632	1,291.174	79	1,292.4	1,233.115
1979/80	2,821	1,891.399	67	2,640.7	1,901.233
1980/81	3,734	2,435.275	65	3,429.2	2,436.998
1981/82	4,238	2,798.989	66	3,867.2	2,792.507
1982/83	6,788	3,803.647	56	4,102.6	3,353.079
1983/84	10,087	4,850.874	48	...	...

Sources: The first column on agricultural credit is from Mahabub Hossain, "Institutional Credit for Rural Development: An Overview of the Bangladesh Case," Bangladesh Journal of Agricultural Economics, Vol. VIII, No. 1 (June 1985), pp. 1-16. The agricultural credit data calculated as sums of district data are from Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983). The total expenditures on fertilizer are calculated from ex-PDP fertilizer price data and sales data elsewhere in this collection (see Mahabub Hossain, Chapter 4, Tables 1 and 18). The column on district fertilizer expenditures is calculated from the same price information, and sales data, disaggregated by district found in BBS, 1982 Statistical Yearbook of Bangladesh. This procedure somewhat underestimates farmers' expenditures on fertilizers but provides reasonably accurate information about trends.

Table 7--Bangladesh Krishi Bank loan distribution by size of holdings and size of loans, 1976/77 - 1980/81

Size of Holdings/Loans	1976/77		1977/78		1978/79		1979/80		1980/81	
	Borrowers	Loan	Borrowers	Loan	Borrowers	Loan	Borrowers	Loan	Borrowers	Loan
					(percent)					
Size of holdings										
Less than 2.5 acres	60.4	54.7	54.4	39.1	52.2	42.7	52.2	35.7	56.0	32.1
2.5 - 7.5 acres	29.9	27.6	35.3	34.2	36.8	30.3	36.8	26.1	33.7	31.3
7.5 - 12.5 acres	8.0	13.1	8.1	15.4	9.3	13.8	9.3	25.3	8.8	16.5
More than 12.5 acres	1.7	4.6	2.2	11.3	1.7	13.2	1.7	12.9	1.5	20.1
Size of loans										
Less than 1,000 Tk	78.6	53.8	66.7	32.8	73.1	34.7	73.2	24.7	32.6	8.2
1,000 - 3,000 Tk	20.5	34.2	25.2	26.5	20.3	26.2	18.2	18.4	42.0	27.7
3,000 - 10,000 Tk	0.5	4.1	5.4	24.4	5.1	20.7	4.1	14.5	16.8	18.9
10,000 - 20,000 Tk	0.4	5.4	2.6	9.3	1.2	11.0	3.0	22.1	2.7	8.7
20,000 - 50,000 Tk	...	0.2	0.1	2.8	0.2	4.8	1.5	16.4	1.5	13.7
More than 50,000 Tk	...	2.3	...	4.2	0.1	2.6	...	3.9	0.4	22.8

Source: Government of Bangladesh and International Development Agency, Bangladesh Agricultural Credit Review, Vol. III (Dhaka: Government of Bangladesh, 1983), Table 6.

Table 8--Loan distribution by size of holdings and size of loans, various credit institutions

	Size of Holding					Size of Loan					
	Less than 2.5 acres	2.5-7.5 acres	7.5-12.5 acres	12.5-33 acres	More than 33 acres	Less than Tk 1,000	Tk 1,000-3,000	Tk 3,000-10,000	Tk 10,000-20,000	Tk 20,000-50,000	More than Tk 50,000
	(percent)										
Short-term loans											
Sonali											
Borrowers	49.6	46.0	4.4	...	...	72.0	21.1	6.2	0.7	...	...
Loan	45.1	42.6	12.3	...	...	36.8	28.1	27.8	7.3	...	...
Janata											
Borrowers	70.6	29.1	0.3	...	...	71.0	27.4	1.6	...	...	...
Loan	66.6	32.7	0.7	...	...	48.5	45.3	6.2	...	...	...
Agrani											
Borrowers	89.1	10.8	0.1	...	...	84.5	15.0	0.5	...	...	...
Loan	53.7	32.9	13.1	0.3	...	43.4	40.2	3.1	0.1	13.1	...
Bangladesh Shamabaya											
Borrowers	71.7	25.6	2.7	...	...	77.3	21.3	1.4	...	...	...
Loan	67.7	28.5	3.8	...	...	50.8	40.6	8.6	...	...	...
Long-term loans											
Sonali											
Borrowers	...	88.0	12.0	...	...	...	...	5.3	94.7	...	...
Loan	...	86.7	13.3	...	...	...	...	3.6	96.4	...	...
Janata											
Borrowers	25.5	35.2	24.8	13.8	0.7	...	0.7	35.2	64.1	...	...
Loan	15.9	29.8	28.2	25.0	1.1	...	0.1	18.0	81.9	...	...
Agrani											
Borrowers	54.9	45.1	...	...	...	2.7	14.5	33.3	49.5	...	...
Loan	52.3	47.7	...	...	...	0.2	0.3	31.3	65.5	...	...
Bangladesh Shamabaya											
Borrowers	58.4	34.4	6.3	0.9	...	27.5	50.7	21.8	...	...	...
Loan	54.4	35.3	8.9	1.4	...	14.3	46.3	39.4	...	...	...

Source: Government of Bangladesh and International Development Agency, Bangladesh Agricultural Credit Review, Vol. III (Dhaka: Government of Bangladesh, 1983), Table 6.

Given that credit coverage is so narrow, it follows that relatively small proportions of fertilizer purchases are financed by this means. Even if it were accepted that 14 percent of all farmers receive loans and assumed that they, being drawn disproportionately from among the relatively wealthy farmers, use twice as much fertilizer as the average, total fertilizer sales financed by institutional credit would not exceed 30 percent. One study conducted in two villages indicates that 24 percent of fertilizer purchases in 1977/78 were financed by institutional credit, and 15-16 percent in 1983/84.[13]

From the scattered evidence cited above, not much can be firmly deduced about the possible effects on fertilizer use of expanding institutional credit availability. If propensities to spend credit on different items are relatively stable, and if marginal propensities do not exceed average ones, then providing additional credit of Tk 100 could increase expenditure on fertilizer by about Tk 16.

It was shown earlier that if fertilizer prices were raised by 20 percent, each farmer using fertilizer would have to spend on average an extra Tk 112 to maintain the level of use. However, after adjusting their use levels to the new price, farmers would in any event be spending Tk 97 more than before (Note 2, Table 4). A new credit program aimed at restoring application levels to those with the subsidy would therefore have to finance only the difference--Tk 15. This would mean roughly Tk 100 to be advanced to each using household. According to the IFDC/BARC survey, 67 percent of surveyed farmers used fertilizer in the 1981/82 Boro season, 62 percent in the 1982 Aus season, and 67 percent in the 1981 Aman season (Tables 9, 10, and 11). If complete overlap is assumed, then 67 percent of all farms used fertilizer in 1981/82. In a micro study covering two villages, a much higher adoption rate was found: 98 - 100 percent for 1983/84.[14] Because the IFDC figures are based on a larger sample, the lower estimate for households using fertilizer is adopted but increased marginally to 70 percent to allow for some diffusion since 1981/82. Bangladesh farm households total approximately 12 million, suggesting a figure of about 8.4 million fertilizer-using households, and a required credit program increment of about Tk 840 million.

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[13]Ibid., Table 16.

[14]Ibid., Table 35.

Table 9--Use of fertilizer by farm size, Boro season

Farm Size	Farmers Using Fertilizer			Average Use		
	1979/80	1980/81	1981/82	1979/80	1980/81	1981/82
(acres)	(percent)			(maunds per acre)		
Less than 1.0	68	66	71	1.42	1.54	2.22
1.0-2.5	66	64	64	1.21	1.16	1.61
2.51-5.0	67	60	66	0.95	1.02	1.58
More than 5.0	78	74	72	1.11	1.14	1.24
All farms	68	67	67	1.20	1.21	1.54

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis from Farm Survey Data, 1979-80 and 1980-82 (Muscle Shoals, Ala.: IFDC, 1982 and 1984).

Table 10--Use of fertilizer by farm size, Aus season

Farm Size	Farmers Using Fertilizer			Average Use		
	1979/80	1980/81	1981/82	1979/80	1980/81	1982/83
(acres)	(percent)			(maunds per acre)		
Less than 1.0	60	59	59	0.85	0.84	0.90
1.0-2.5	60	54	58	0.73	0.79	0.70
2.51-5.0	63	69	64	0.68	1.00	0.81
More than 5.0	67	71	70	0.82	0.84	0.73
All farms	62	62	62	0.70	0.88	0.76

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis from Farm Survey Data, 1980-82 (Muscle Shoals, Ala.: IFDC, 1984).

Table 11--Use of fertilizer by farm size, Aman season

Farm Size	Farmers Using Fertilizer 1980	Farmers Using Fertilizer 1981	Average Use 1980	Average Use 1981
	(percent)		(maunds/acre)	
Less than 1.0	54	65	0.83	0.91
1.01-2.5	57	66	0.76	0.97
2.51-5.0	67	72	0.84	1.05
More than 5.0	72	71	0.79	0.94
All farms	61	67	0.80	0.97

Source: Bangladesh Agricultural Research Council and International Fertilizer Development Center, Agricultural Production, Fertilizer Use and Equity Considerations, Results and Analysis from Farm Survey Data, 1980-82 (Muscle Shoals, Ala.: IFDC, 1984).

Given the already disturbingly low agricultural loan repayment ratio (Table 12), it is not at all clear that another large expansion of agricultural credit is the most advisable course. It is possible that to continue to induce larger and larger volumes of borrowing, interest rates would have to be reduced below costs of funds. It would certainly be imprudent to assume that such a program expansion would be self-financing. On the contrary, substantial budgetary allocations, even after the initial year, might be required.

An alternative would be to offer new loans equal to the value of the cost difference resulting from higher fertilizer prices at the current level of fertilizer use and to tie these loans to the purchase of fertilizer. This would involve a more modest expansion of the credit program, by Tk 126 million.

The basic question, however, is whether credit availability is actually an important constraint. If it is not, then providing more credit need not encourage fertilizer consumption appreciably. If farmers, on the whole, can be assumed to equate the marginal productivity of fertilizer to price (at least roughly), then provision of more credit need not have any great effect on use (Table 13). Although it would seem intuitively obvious that a cash constraint must be operative, at least for the smaller farmers, hardly any direct evidence is available. The indirect evidence is ambiguous.

Table 12--Disbursement and recovery of agricultural credit by different financial institutions, 1976/77 - 1982/83

Year/Credit Transaction	BKB	BRDB[a]	NCBs[a]	BSBL	Cooperative Loans
		(taka in crore)			
1976/77					
Disbursement	39.04	7.50	45.28	...	38.84
Recovery	29.74	5.30	39.78	...	
1977/78					
Disbursement	54.80	13.59	40.79	...	55.30
Recovery	38.18	9.14	32.43	68.40	
1978/79					
Disbursement	74.66	11.79	68.40	20.11	74.66
Recovery	52.17	9.42	47.89	11.89	
1979/80					
Disbursement	141.49	25.29	113.55	27.04	14.15
Recovery	74.73	13.46	53.[illegible]0	16.94	
1980/81					
Disbursement	209.20	24.25	136.04	27.64	28.97
Recovery	131.08	19.36	74.14	16.13	
1981/82					
Disbursement	271.04	30.79	134.22	16.69	27.18
Recovery	194.03	23.01	99.29	19.33	
1982/83					
Disbursement	400.81	48.94	236.80	23.75	...
Recovery	201.83	26.51	99.79	20.96	
Total					
Disbursement	1,191.04	162.16	771.08	115.23	239.10
Recovery	721.76	106.20	446.62	85.25	

Source: Bangladesh Bureau of Statistics, 1982 Statistical Yearbook of Bangladesh (Dhaka: BBS, 1983), p. 282.

Notes: The acronyms refer to Bangladesh Krishi Bank (BKB), Bangladesh Rural Development Board (BRDB), National Commercial Banks (NCBs), and Bangladesh Shambaya Bank Ltd. (BSBL). 1 crore = 10 million.

[a]These data are not mutually exclusive because BRDB is disbursed by one of the NCBs and it is normally included in NCB figures. The totals for BKB, BSBL, and NCBs are identical to the national totals in Table 1 for 1978/79 and 1979/80 and fall short by about Tk 20 million or less for most other years. For 1977/78 and 1982/83, the discrepancies are much larger.

Table 13--Output response by crop to fertilizer nutrient application, based on farm survey data, 1979-81

Response	Aus	Aman	Boro	Wheat
Local varieties				
Average	5.5	3.6	8.1	
Minimum	1.3(1981/82)	2.0(1979/80)[a]	3.4(1980/81)	...
High-yielding varieties				
Average	5.6	4.1	4.1	2.4
Minimum	4.5(1980/81)	2.5(1979/80)[a]	2.6(1979/80)	1.9(1980/81)

Source: Technical paper in this volume by Mahabub Hossain, Tables 18 and 31.

Notes: The mean ratios of fertilizer nutrient prices (weighted by sales shares of different types of fertilizer in total national sales) to average prices of paddy (all types) were for 1978/79, 1.47; for 1979/80, 1.46; for 1980/81, 2.06; and for 1981/82, 1.93.

The average figures denote average output response of the indicated crops to unit fertilizer nutrient application in paddy weight, covering all three years of the IFDC/BARC survey.

The minimum figures denote the lowest of the three average survey responses, calculated from the three different survey years.

[a]Data for the 1979/80 Aman season have been criticized as unreliable owing to quality control problems during the season when the survey was initiated.

Table 6 and the Appendix Tables 14-18 present data on total value of fertilizer sales and total volume of institutional credit to agriculture for the country as a whole and by districts. A glance at these tables and their graphical presentations in Figure 1 and Figures 2-6 in the appendix reveals that the two magnitudes roughly tend to move together, both over time and across districts. However, one cannot deduce from this that an expansion of credit would increase fertilizer use. In all probability, any historical causality may run the other way lending institutions will probably expand their activities in areas where the demand for credit has increased or is expected to increase as a result of HYV diffusion.

A comparison of fertilizer response ratios with fertilizer-to-paddy price ratios appears in Table 13. Without knowing much more about farmers' processes of forming expectations about prices, it is not possible to say much on the basis of such a comparison. That price ratios deviated from actual marginal productivities does not necessarily mean that farmers are constrained to use fertilizer at a point below their demand curve. But for what it is worth, there is a presumption that farmers are using less than optimal doses of fertilizer on all crops, except perhaps local Aus and Aman; and even on these crops the doses might only be considered to be near optimal, if the minimum observed response ratio is regarded as the relevant one. If farmers are indeed using less fertilizer than the profit-maximizing amounts, one potential reason is shortage of cash.

But this implies an inconsistency. The Boro season still dominates fertilizer consumption. In 1983/84, for example, 55.7 percent of yearly fertilizer sales were during the Boro season, while Aman and Aus contributed roughly comparable shares (23.6 and 20.6 percent, respectively).[15] Except for the Aman season, there is a clear tendency for application rates to decline with farm size, and this tendency is particularly marked in the Boro season (Tables 9, 10, and 11). This means that smaller farmers are much more likely to be using fertilizer at optimum levels. It is difficult to believe that cash would be a constraint for the richer farmers but would not be for the poorer ones. Indeed it is difficult to believe that any constraint, whether it be supplies, knowledge, or cash, would favor the poor. A more plausible explanation is that rich farmers have alternative uses for their funds, which at the margin yield more than fertilizer use.

On balance, then, institutional credit is probably not an important barrier to increased fertilizer use, and therefore credit may not be an appropriate instrument for sustaining fertilizer application under current circumstances, in the face of a moderate price increase.

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[15]Ibid., Table 2.

APPENDIX

Table 14--Fertilizer use and agricultural credit by district in Dhaka Division, 1976/77 to 1982/83

Year	Dhaka		Faridpur		Jamalpur		Mymensingh		Tangail	
	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer
	(taka in crore)									
1976/77	16.57	8.1540	5.08	1.3426	0.77	a	10.68	9.4489	2.39	2.4228
1977/78	11.04	9.9800	6.00	2.8181	1.50	a	14.39	14.3126	2.35	3.3803
1978/79	13.36	3.9286	5.67	2.5550	1.72	a	5.23	16.4072	2.28	4.8638
1979/80	40.18	16.0030	9.68	4.0189	5.70	5.4199	17.90	17.1403	5.28	6.5916
1980/81	61.11	22.5468	10.72	4.0616	5.85	7.5465	22.79	23.3641	10.34	9.6862
1981/82	98.49	27.2945	10.22	5.1731	8.78	8.5623	24.20	24.7557	11.59	12.7495
1982/83[b]	79.18	14.0392	12.03	22.2069	9.26	11.8921	18.75	34.8617	14.46	18.1810

Sources: The data on agricultural credit are derived from Mahabub Hossain, "Institutional Credit for Rural Development: An Overview of the Bangladesh Case," Bangladesh Journal of Agricultural Economics, Vol. VIII, No. 1 (June 1985), pp. 1-16. The expenditures on fertilizer are calculated from ex-PDP fertilizer price data and sales data elsewhere in this collection (see Mahabub Hossain, Chapter 4, Tables 1 and 18).

Note: 1 crore = 10 million.

[a]Jamalpur District was under Mymensingh until 1979.

[b]Agricultural credit data for 1982/83 from three national commercial banks (Rupali, Pubali, Uttara) are not available.

Table 15--Fertilizer use and agricultural credit by district in Chittagong Division, 1976/77 to 1982/83

Year	Chittagong		Chittagong Hill Tracts		Comilla		Noakhali		Sylhet	
	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer
	(taka in crore)									
1976/77	7.33	9.0391	.70	.3925	6.00	10.2666	3.68	4.1428	9.01	2.5804
1977/78	16.40	10.6804	.57	.3963	8.13	14.9519	5.74	5.0968	10.67	3.5965
1978/79	19.65	11.7075	.80	3.4341	10.24	19.7342	5.12	5.4660	10.88	3.6483
1979/80	33.00	14.6979	.61	.7910	18.75	27.6152	11.84	8.4364	16.76	6.2379
1980/81	53.38	17.3287	.83	1.2247	26.34	31.1656	11.97	9.6099	16.88	7.4625
1981/82	46.41	18.5832	.73	1.7069	28.54	35.7368	12.01	10.1549	15.31	8.8234
1982/83[a]	37.83	29.9347	.42	1.4908	30.87	21.4793	9.27	11.0103	12.69	11.7813

Sources: The data on agricultural credit are derived from Mahabub Hossain, "Institutional Credit for Rural Development: An Overview of the Bangladesh Case," Bangladesh Journal of Agricultural Economics, Vol. VIII, No. 1 (June 1985), pp. 1-16. The expenditures on fertilizer are calculated from ex-PDP fertilizer price data and sales data elsewhere in this collection (see Mahabub Hossain, Chapter 4, Tables 1 and 18).

Note: 1 crore = 10 million.

[a]Agricultural credit data for 1982/83 from three national commercial banks (Rupali, Pubali, Uttara) are not available.

Table 16--Fertilizer use and agricultural credit by district in Khulna Division, 1976/77 to 1982/83

Year	Barisal		Jessore		Khulna		Kushtia		Patuakhali	
	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer
	(taka in crore)									
1976/77	6.11	2.0582	4.73	3.1370	3.40	1.2829	3.31	3.1307	2.26	.5404
1977/78	5.93	3.8754	5.49	4.6279	4.26	1.8305	2.62	4.5215	2.65	1.2232
1978/79	6.72	4.0909	7.05	5.4117	7.19	1.7530	5.23	4.9366	3.48	1.4243
1979/80	11.08	6.0195	13.21	8.9708	13.37	3.3340	9.35	9.3052	9.07	2.1467
1980/81	13.07	6.9585	18.04	11.4617	15.23	4.8365	11.88	11.5267	6.37	1.8141
1981/82	14.66	7.0089	16.11	13.2901	13.96	5.2156	12.64	12.2897	6.63	.6570
1982/83[a]	43.74	10.0997	19.40	6.2045	12.73	6.7049	11.96	13.6704	5.71	2.8201

Sources: The data on agricultural credit are derived from Mahabub Hossain, "Institutional Credit for Rural Development: An Overview of the Bangladesh Case," Bangladesh Journal of Agricultural Economics, Vol. VIII, No. 1 (June 1985), pp. 1-16. The expenditures on fertilizer are calculated from ex-PDP fertilizer price data and sales data elsewhere in this collection (see Mahabub Hossain, Chapter 4, Tables 1 and 18).

Note: 1 crore = 10 million.

[a]Agricultural credit data for 1982/83 from three national commercial banks (Rupali, Pubali, Uttara) are not available.

Table 17--Fertilizer use and agricultural credit by district in Rajshahi Division, 1976/77 to 1982/83

Year	Bogra		Dinajpur		Pabna		Rangpur		Ranjpur	
	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer	Agricultural Credit	Expenditure on Fertilizer
	(taka in crore)									
1976/77	3.27	5.0948	5.81	3.2559	2.42	2.7816	6.05	4.1613	7.12	4.0974
1977/78	5.26	6.4676	5.77	5.0054	2.80	4.8254	6.69	6.2573	4.81	5.6295
1978/79	3.33	8.4795	4.73	5.6172	2.99	5.1649	6.66	7.4406	6.91	7.2531
1979/80	7.40	13.5739	9.52	8.9062	5.42	7.8744	12.01	13.0251	13.94	10.0154
1980/81	8.71	19.3660	12.32	11.8720	7.57	9.7359	13.90	16.3895	15.62	15.7423
1981/82	10.65	25.2392	9.72	13.0040	9.54	11.6759	16.00	19.7252	20.53	17.6148
1982/83[a]	12.52	29.5605	13.26	20.4542	15.80	19.3783	27.28	24.4109	22.14	25.1271

Sources: The data on agricultural credit are derived from Mahabub Hossain, "Institutional Credit for Rural Development: An Overview of the Bangladesh Case," Bangladesh Journal of Agricultural Economics, Vol. VIII, No. 1 (June 1985), pp. 1-16. The expenditures on fertilizer are calculated from ex-PDP fertilizer price data and sales data elsewhere in this collection (see Mahabub Hossain, Chapter 4, Tables 1 and 18).

Note: 1 crore = 10 million.

[a]Agricultural credit data for 1982/83 from three national commercial banks (Rupali, Pubali, Uttara) are not available.

Table 18--Total distribution and value of fertilizer

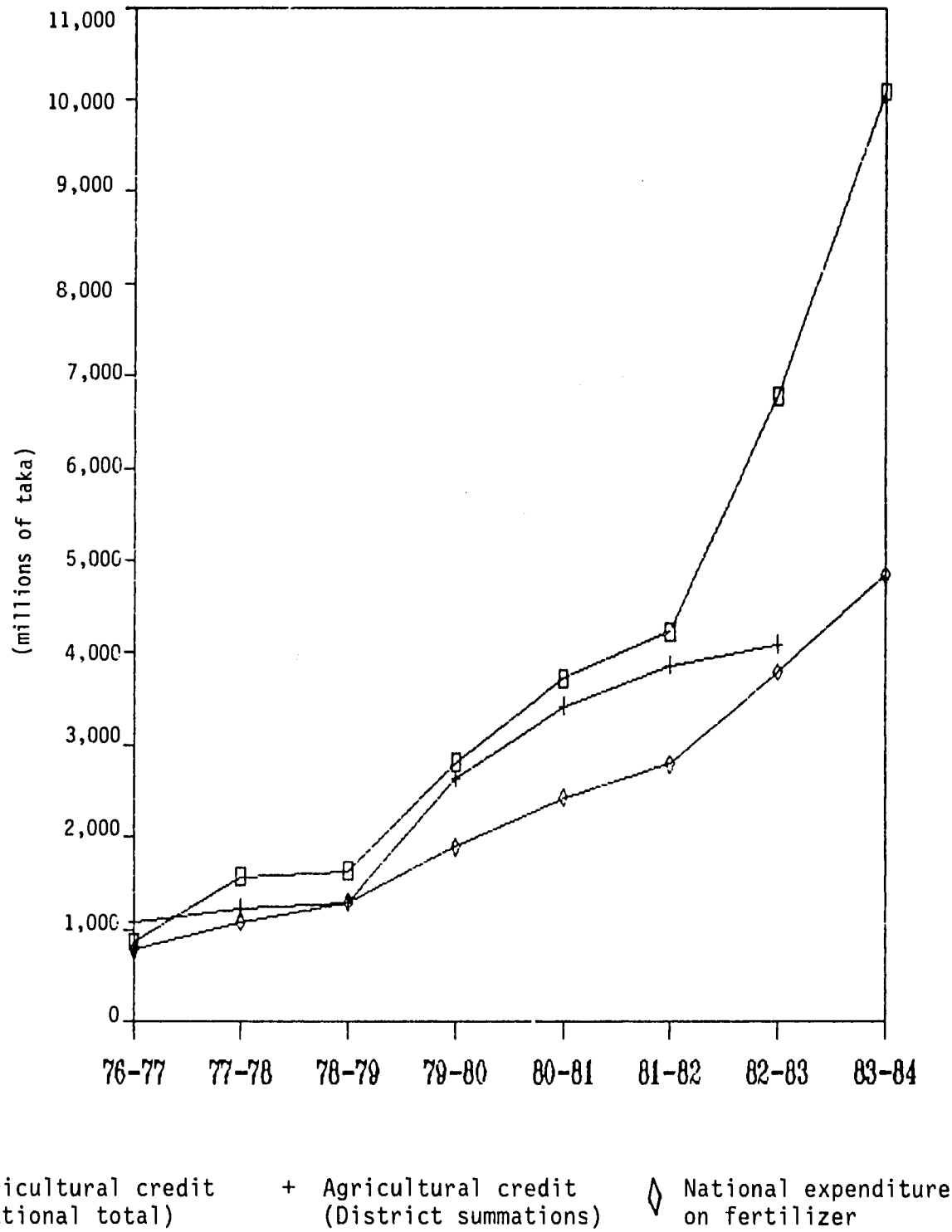
Year	Urea (tons)	Price Per Ton (taka)	Value (1,000 Tk)	TSP (tons)	Price Per Ton (taka)	Value (1,000 Tk)
1974/75	174,195	1,375	239,518	75,175	1,100	82,692
1975/76	311,959	1,650	514,732	110,055	1,320	145,273
1976/77	353,229	1,650	582,828	125,585	1,320	165,772
1977/78	477,447	1,650	787,788	191,332	1,320	252,558
1978/79	467,321	1,925	899,593	175,173	1,512	264,862
1979/80	533,273	2,475	1,319,850	205,422	1,925	395,437
1980/81	559,579	3,025	1,692,726	215,104	2,475	532,382
1981/82	513,152	3,630	1,862,741	205,850	3,168	652,133
1982/83	629,058	4,070	2,560,266	205,999	3,850	793,096
1983/84	708,070	4,455	3,154,451	200,730	4,235	1,104,191

Year	MP (tons)	Price Per Ton (taka)	Value (1,000 Tk)	DAP (tons)	Price Per Ton (taka)	Value (1,000 Tk)	Total Fertilizer (tons)	Total Value (1,000 Tk)
1974/75	17,509	825	14,445	...	...	...	266,879	336,655
1975/76	21,737	1,100	23,911	...	...	...	443,751	683,916
1976/77	22,385	1,100	24,623	...	...	...	501,199	773,223
1977/78	40,998	1,100	45,098	...	...	...	709,777	1,085,444
1978/79	43,117	1,237	53,336	38,121	1,925	73,383	723,732	1,291,174
1979/80	46,204	1,512	69,860	42,930	2,475	106,252	827,829	1,891,399
1980/81	45,643	1,925	87,863	40,431	3,025	122,304	860,757	2,435.275
1981/82	50,287	2,475	124,460	43,982	3,630	159,655	813,271	2,798,989
1982/83	50,420	3,025	152,520	73,161	4,070	297,765	958,638	3,803,647
1983/84	63,222	3,327	210,340	93,831	4,070	381,892	1,065,853	4,850,874

Source: Bangladesh Agricultural Development Corporation data appearing in Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various issues.

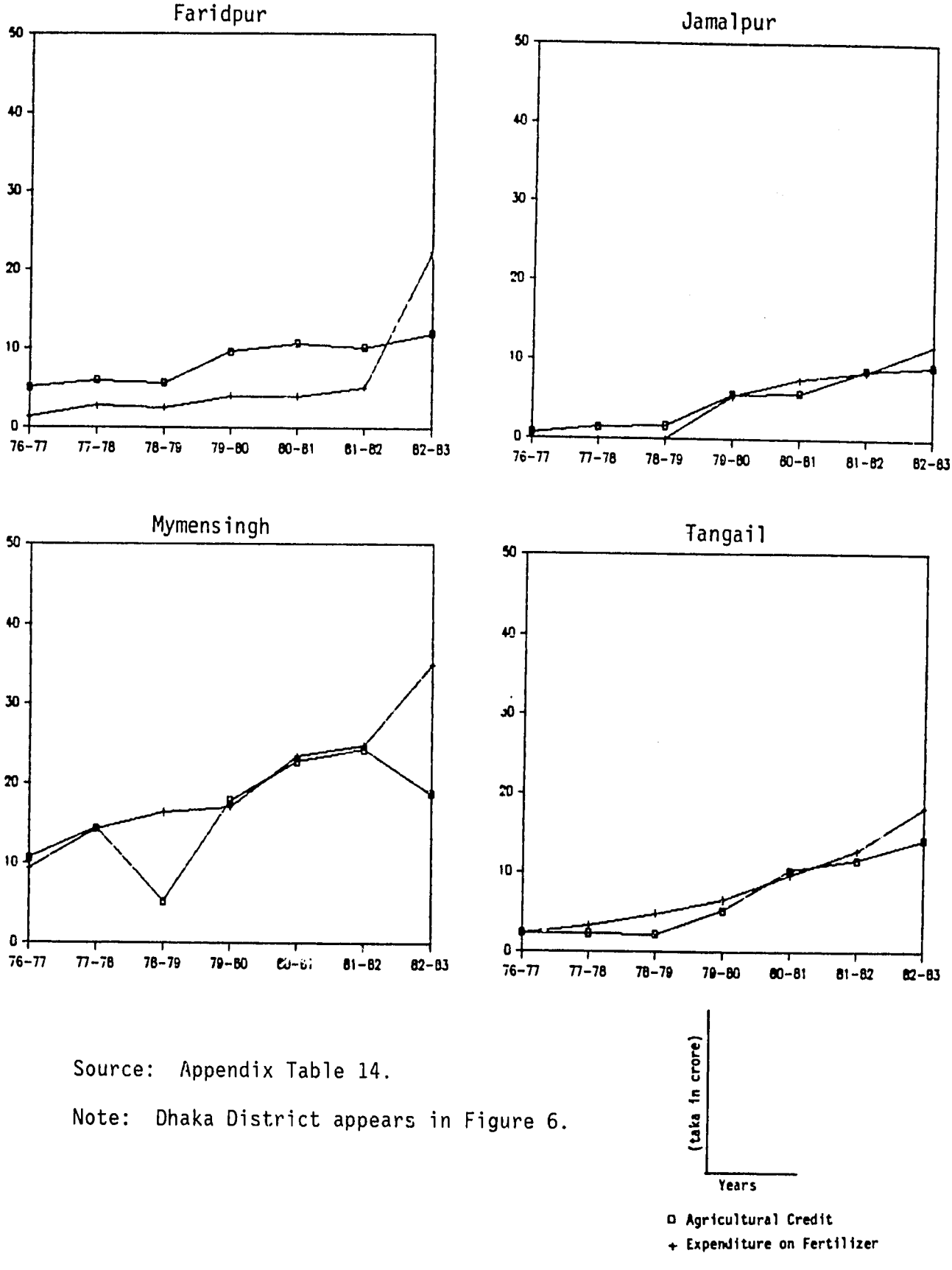
Note: These data do not include small amounts of minor fertilizers.

Figure 1--Fertilizer use and agricultural credit, 1976/77 to 1983/84



Source: Table 1, district-wide summations.

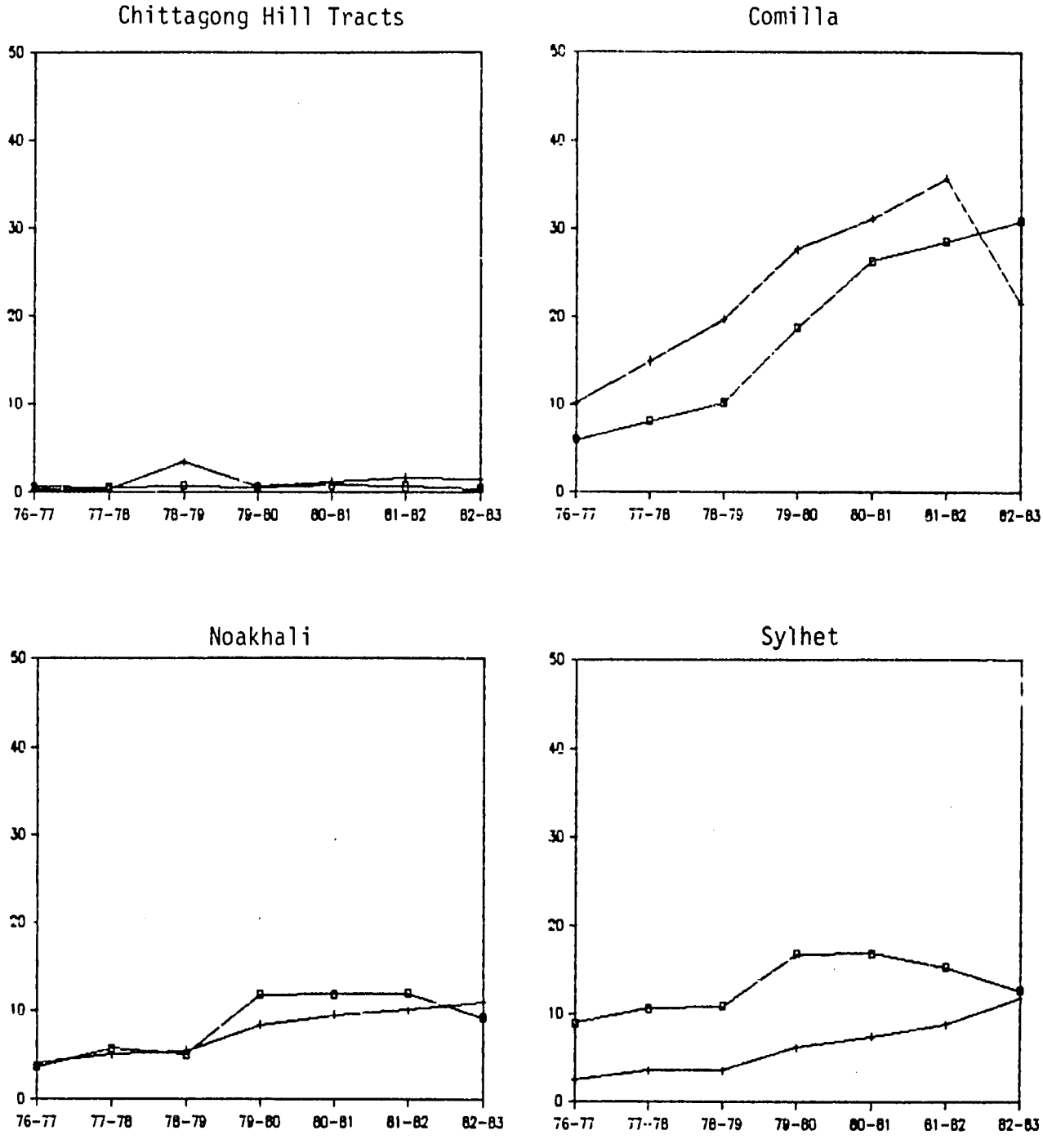
Figure 2--Fertilizer use and agricultural credit by district in Dhaka Division, 1976/77 - 1982/83



Source: Appendix Table 14.

Note: Dhaka District appears in Figure 6.

Figure 3--Fertilizer use and agricultural credit by district in Chittagong Division, 1976/77 - 1982/83



Source: Appendix Table 15.

Note: Chittagong District appears in Figure 6.

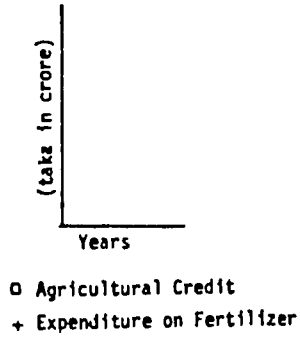
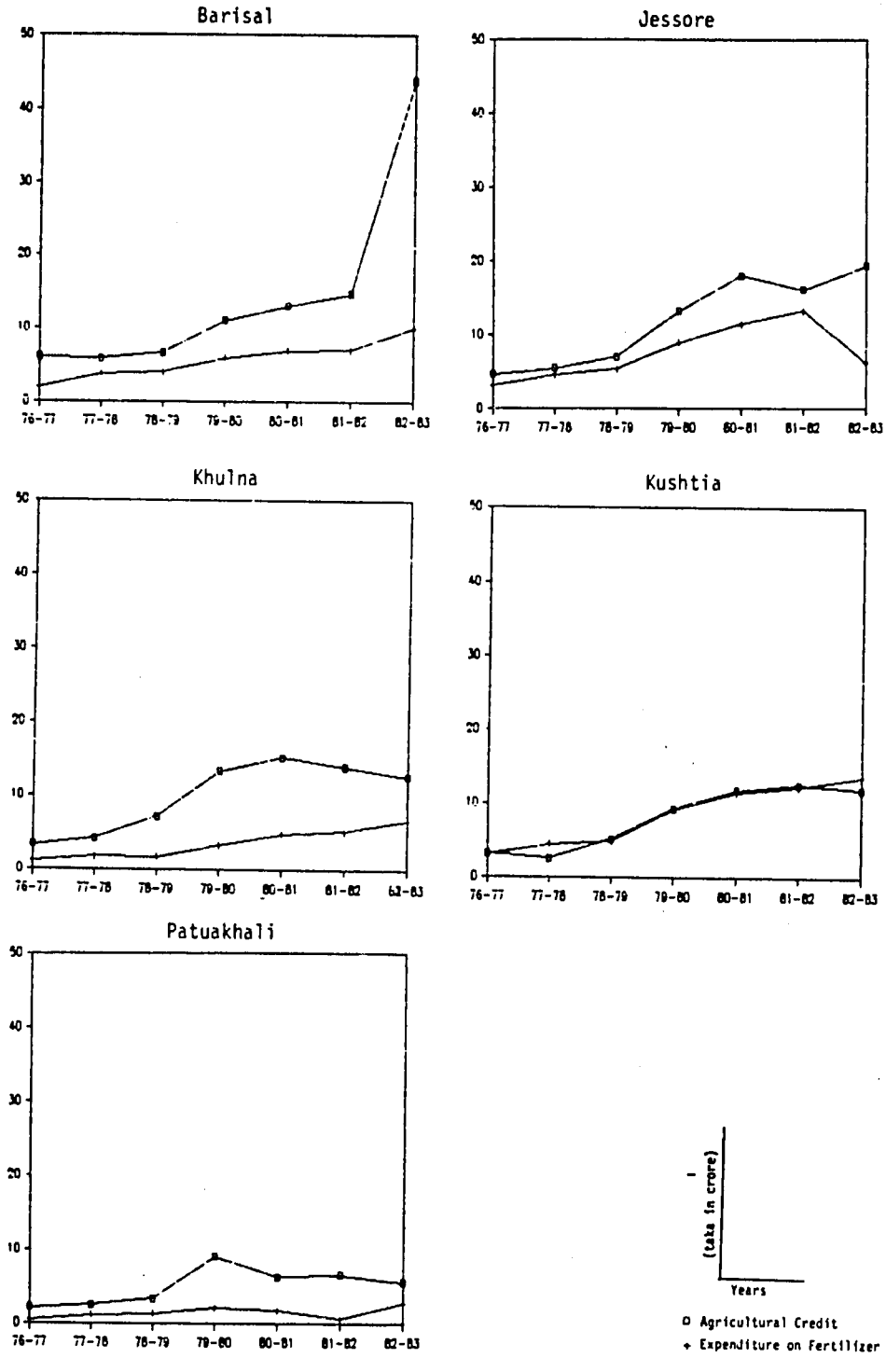
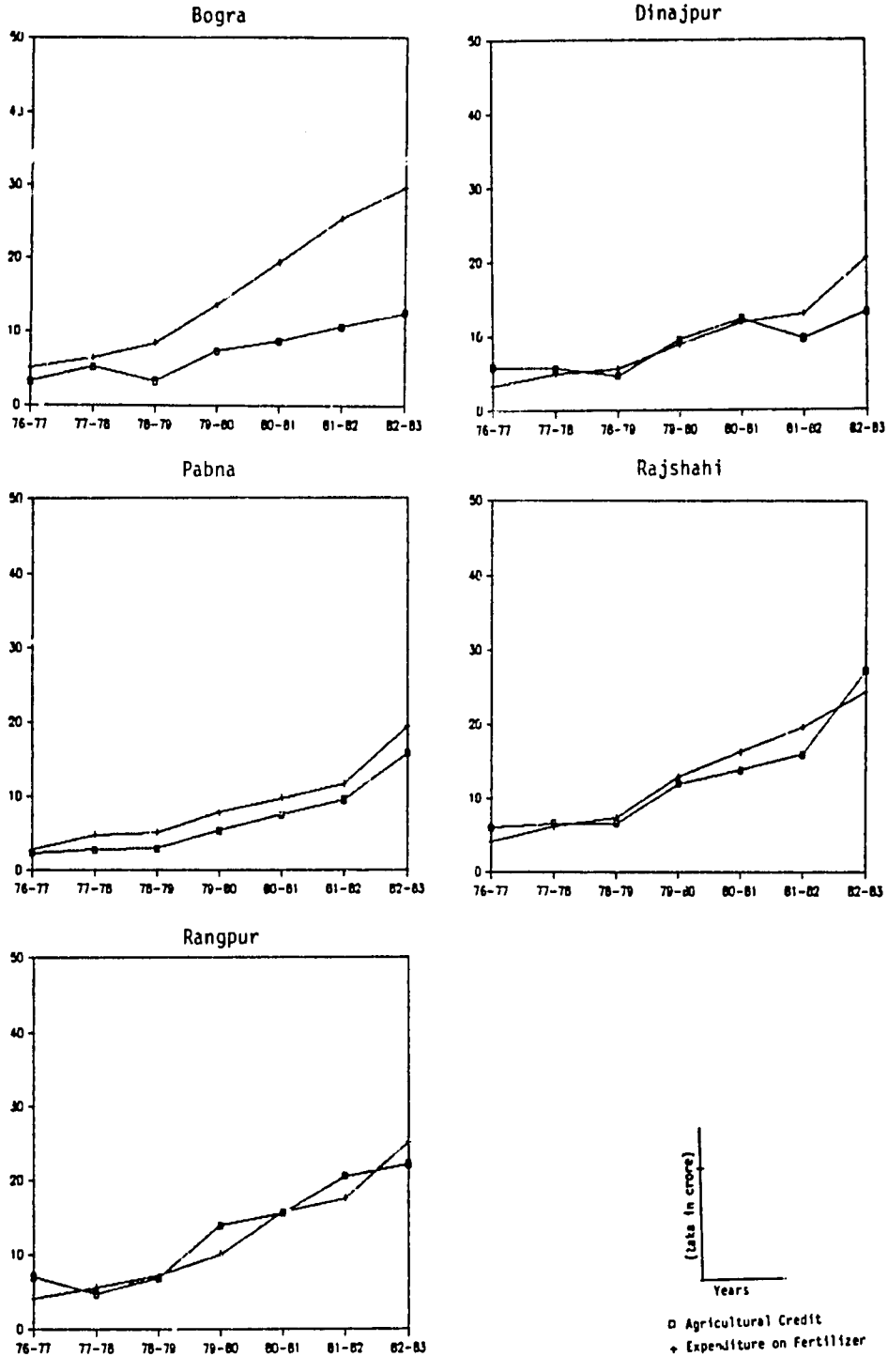


Figure 4--Fertilizer use and agricultural credit in Khulna Division, 1976/77 - 1982/83



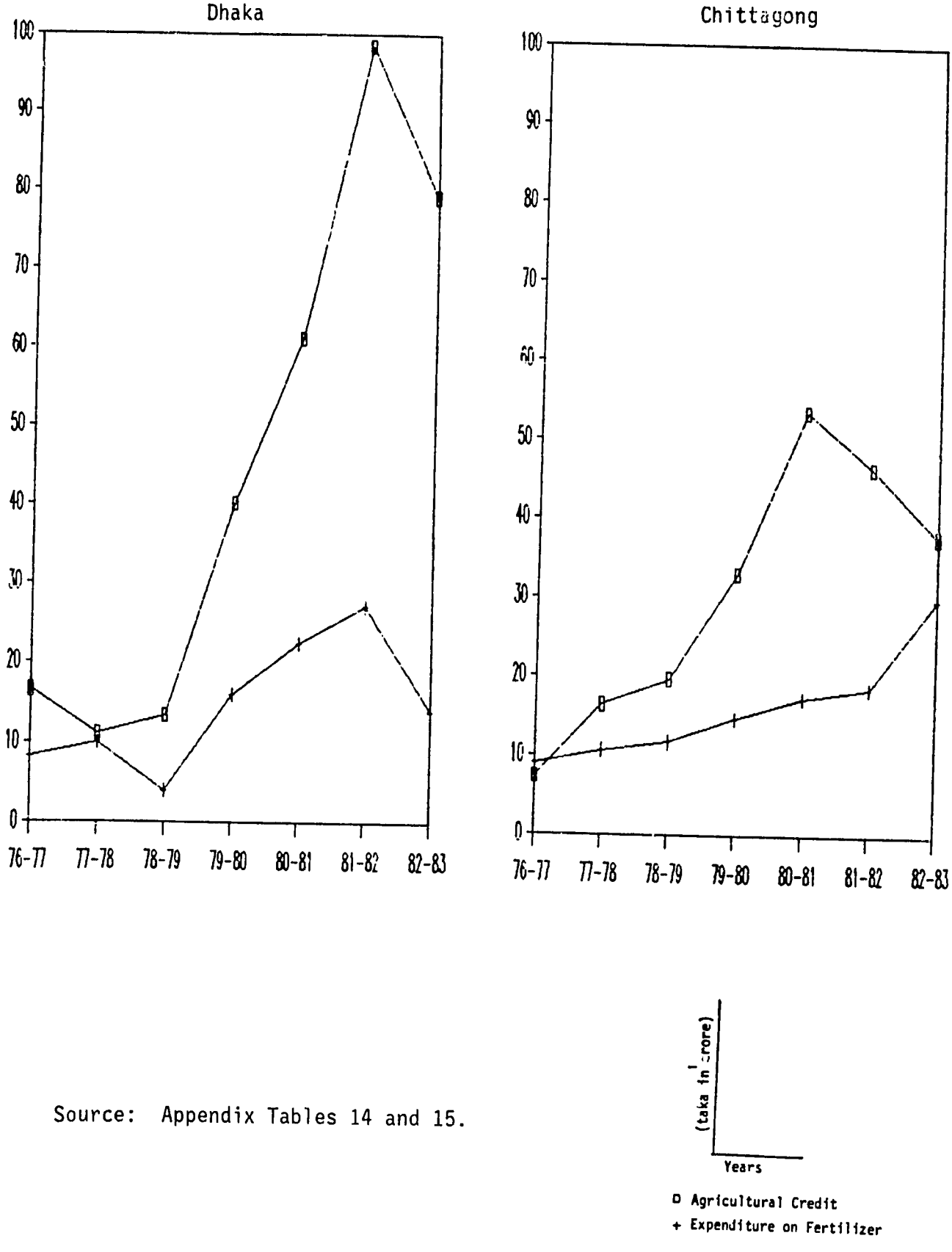
Source: Appendix Table 16.

Figure 5--Fertilizer use and agricultural credit by district in Rajshahi Division, 1976/77 - 1982/83



Source: Appendix Table 17.

Figure 6--Fertilizer use and agricultural credit by district in Dhaka and Chittagong Districts, 1976/77 - 1982/83



Source: Appendix Tables 14 and 15.

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