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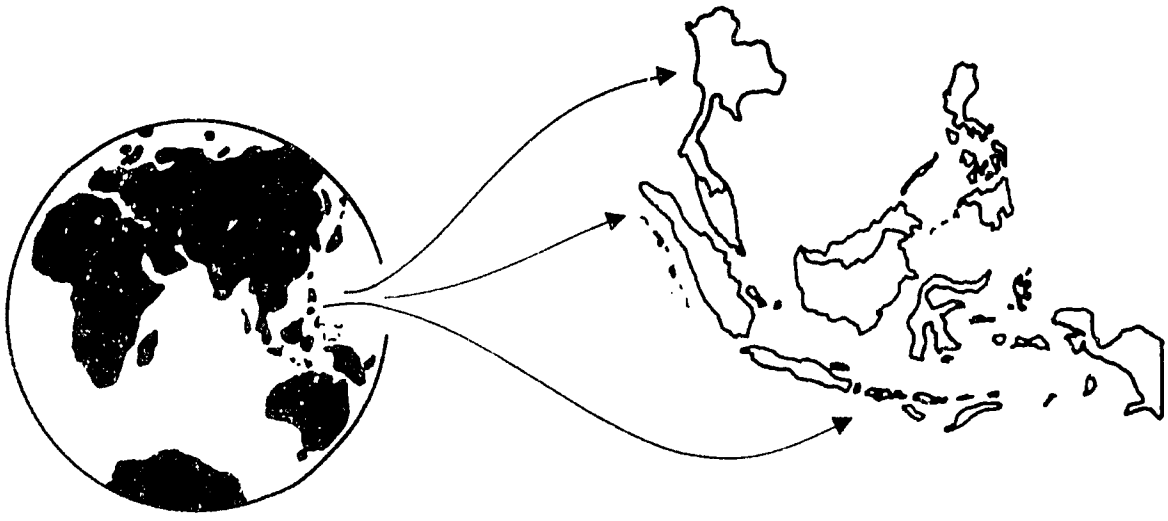
ECONOMIC EVALUATION OF FERTILIZER SUPPLY STRATEGIES FOR THE ASEAN REGION: LINEAR PROGRAMMING APPROACH



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ABSTRACT

This study was undertaken to illustrate the use of a dynamic linear programming model for planning the development of a fertilizer industry. The model was applied to the countries of the ASEAN region.

As formulated, the model permits evaluation of different supply strategies, specifically in reference to least cost supply patterns, optimum production levels, cost penalties when deviation from optimum occur, and estimates of variable and total costs and of capital investments.

To evaluate the impact of different fertilizer supply strategies in the region, four scenarios were created. They are: (1) each country in the region can secure its fertilizer needs from least cost sources, (2) a 100% regional self-sufficiency in nitrogen (N) production is required, (3) a 100% regional self-sufficiency in nitrogen production and 50% self-sufficiency in phosphate (P_2O_5) production are required, and (4) each country acts independently of each other and uses its own facilities, as far as possible, to meet its needs.

Results of the study show the effect of different supply strategies on fertilizer cost. It measures savings that could be realized through cooperative agreements. It also shows the added costs that the region will have to pay to achieve different degrees of self-sufficiency.

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ECONOMIC EVALUATION OF FERTILIZER SUPPLY STRATEGIES FOR THE ASEAN REGION: LINEAR PROGRAMMING APPROACH

A Joint Publication of
International Fertilizer Development Center (IFDC)
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PREFACE

One of the first IFDC publications (IFDC T-2, 1976) was a methodology study examining the potential for regional cooperation in fertilizer production between the member countries of the Association of Southeast Asia Nations (ASEAN). The essential elements of this publication, which was financed by The World Bank, were drawn from a working document drafted by The World Bank in collaboration with IFDC.

With some of the highest population growth rates in the world and with economies based primarily on agriculture, the ASEAN nations have developed and continue to develop fertilizer production capabilities aimed primarily at supporting the planned growth of the agricultural sector. Fertilizer is increasingly becoming a strategic material; hence, national control of at least a part of the fertilizer supply is considered desirable. Any move away from the free market system carries with it costs which can be evaluated. In view of the very rapid economic development of the ASEAN nations, it was felt that an improvement in the methodology used earlier and its application to evaluate possible alternative fertilizer supply strategies would give a valuable insight with respect to their relative economic advantages to the ASEAN countries.

Consequently, in late 1977 IFDC invited staff of the various agencies involved in the fertilizer sector of the ASEAN countries to prepare an information base in order to evaluate various supply strategies by using the new fertilizer sector planning model.

Unavoidable delays occurred in preparing the final report of the study. The results reported in this study are, however, based on an update of the information to reflect the fertilizer supply situation during 1979.

IFDC wishes to acknowledge the support and enthusiasm of the following who assisted in developing the information base and its update: Mr. Miguel Zosa, Ms. Bernadette Comotan-Abad, Mr. Filemon Cabungcal, and Mr. Jesus Gallegos, Fertilizer and Pesticide Authority, Manila, Philippines; Mr. Kusmono, Ministry of Industry, Jakarta, Indonesia; Dr. A. Wahab and Mr. Soedharyono Mustafa, P.T. Pupuk Sriwidjaja, Jakarta, Indonesia; Mr. Daniel Selvaretnam, Singapore Economic Development Board; Mr. Gumthorn Utrawuthipong, Thai Central Chemical Co., Ltd.; and Mr. Phachuap Phawandon and Mr. Trakarn Chairat, Ministry of Industry, Bangkok, Thailand.

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IFDC is also indebted to der Forschungsanstalt fur Landwirtschaft (FAL), at Braunschweig-Volkenröde, West Germany, for their having seconded Dr. Lueder von Bremen to IFDC to formulate the mathematical programming model used in the study and for the use of their computer facilities at latter stages of the analyses.

Donald R. McClure

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Summary and Conclusions

A dynamic linear programming model was developed and used to determine least cost fertilizer supply strategies for the Association of Southeast Asian Nations (ASEAN). The overall objective of this study was to illustrate the use of the model as a planning tool for the fertilizer industry. The study provides an example of its applications in planning investment programs and establishing guidelines for international cooperation agreements in the fertilizer sector. The model results for alternative fertilizer supply strategies appear extremely useful to provide guidelines for national planners to ensure adequate amounts of fertilizer in consuming regions at the lowest possible cost.

The dynamic nature of the model permits solutions which are relevant to changing fertilizer technology, fertilizer demand, production capacities, and price relationships. The time period covered by the model is 1981-92, using 1978-80 as the base period. All calculations are for midyears of four 3-year subperiods.

The study considered the economic implications of alternative supply strategies for the ASEAN region and for individual ASEAN countries. Four different scenarios were simulated to measure the impact of alternate supply strategies for meeting projected fertilizer demand on individual countries and the region as a whole. These four scenarios can be described briefly as follows:

Scenario I--It is an unrestrictive scenario which permits each country to secure its fertilizer needs from least cost sources. Essentially this means that countries can produce it domestically or purchase it from other ASEAN countries or from the world market.

Scenario II--It requires a 100% regional self-sufficiency in nitrogen fertilizers, except for subperiod 1, when only 95% self-sufficiency is possible with the existing facilities. No imports of nitrogen fertilizers from outside the ASEAN region are permitted. Phosphate fertilizers can be obtained from any least cost sources.

Scenario III--It is similar to scenario II with respect to regional self-sufficiency for nitrogen. A restriction is added, however, that limits imports of phosphate (P_2O_5) fertilizers to 50% of total regional needs.

Scenario IV--In this scenario each country uses its own facilities as far as possible to meet its needs. Imports are allowed if a country's capacities are not sufficient to meet the demand.

When policies dictate a deviation from optimum allocation of resources, direct comparisons of total costs to supply fertilizer needs under different strategies permit determination of added cost.

Results presented in this report show that a supply strategy based on findings of scenario I is the most profitable for the ASEAN region and for each of its countries. The total amount of fertilizers needed can be supplied at an avoidable cost[1] of US $5,809 million (1979). This amount includes the cost of imports and of domestic production. The total fertilizer supplied to the region would have a market value of US $11,378 million. Approximately 85%-90% of total nitrogen fertilizer will be produced in the region; the remainder will be imported from world markets. For phosphate fertilizers, 53%-71% of the P_2O_5 will be imported, and the rest will be produced in the region.

Furthermore, the results indicate that all existing urea plants should operate at 98%-100% capacity and that expansion urea plants at Aceh and Bontang in Indonesia, Bintulu in Malaysia, and Sattahip in Thailand be completed during 1983-85. The expansion plant at Limay in the Philippines should not be given further consideration.

With respect to ammonium sulfate (AS), it should not be produced in the region. To supply nitrogen (N) in the form of urea is a lower cost alternative. Diammonium phosphate (DAP) should be produced at Gresik in Indonesia and at Leyte in the Philippines. The production of NPK[2] (15-15-15) fertilizer should take place only at Petaling Jaya in Malaysia.

Approximately 30% of the nitrogen and 5% of the phosphate (P_2O_5) fertilizer require transportation from one ASEAN country to another. Cooperative agreements based on production guidelines provided by this scenario would guarantee an adequate supply of fertilizer for all consuming areas of the region at the least possible cost.

Comparisons of scenario I with scenarios II and III show that the predetermined regional levels of self-sufficiency for nitrogen and phosphate will be achieved at an additional cost. For scenario II, it is estimated that a total of US $6,019 million is needed to meet demand requirements. This represents an added cost of US $210 million to meet the regional self-sufficiency requirement of 100% for nitrogen production.

For scenario III, it is estimated that a total of US $6,164 million is needed to meet demand requirements. This represents an added cost of US $355 million, over and above that for scenario I, to meet regional self-sufficiency requirements of 100% in nitrogen and 50% in phosphate (P_2O_5) fertilizer production. It is estimated that to achieve the 50% self-sufficiency in phosphate fertilizer production requires an extra US $145 million.

Scenario IV, which represents the most probable path that ASEAN countries will follow, provides total fertilizer needs at a cost of US $7,328 million or US $1,519 million more than the least cost supply alternative of scenario I. The main reason for this high cost is that existing inefficient plants, with relatively high production costs, will be operated.

This study clearly demonstrates the potential effect of different supply strategies on fertilizer costs. In general, the lowest fertilizer prices are for scenario I and the highest for scenario IV. This provides an indication of the possible consequences of alternative supply strategies on fertilizer prices, fertilizer use and, therefore, on agricultural production.

It is not claimed that results presented in this report comprise an exhaustive study of the subject. This is a preliminary investigation designed to provide guidelines to policymakers involved in fertilizer

1. "Avoidable costs" are defined as the minimum net total costs of production, imports, exports, transportation, and plant construction.

2. NPK fertilizers are nitrogen-phosphate-potash fertilizers expressed as a ratio of the N-P_2O_5-K_2O.

sector planning. It shows potential benefits that could be obtained from economic cooperation in developing regional fertilizer industry. Results and conclusions are tentative and subject to change with further refinements in model and input data.

Introduction

Rapidly escalating energy prices have threatened traditional fertilizer sources, especially of nitrogen, throughout the world. Furthermore, the cost of manufacturing fertilizers has been rising and will probably continue to do so in the future. Government planners and decisionmakers in developing countries are fully cognizant of the adverse effects on fertilizer use and food production of the fertilizer shortages and increased prices which occurred during the 1973-75 fertilizer crisis. Reoccurring of such events and the lack of fertilizer supply at the farm level are causing many governments to create or expand domestic fertilizer production as an integral part of their national fertilizer supply strategy.

Government officials may not be fully aware that development of domestic fertilizer production facilities does not always represent an optimum allocation of scarce resources. It may be more costly to increase domestic production to meet total supply requirements than to rely fully or partially upon imports. Fertilizer production decisions in one country may affect not only the cost of fertilizers in other importing countries but also the pattern and cost of supply for an entire economic region.

Most fertilizer production feasibility studies deal only with the construction or expansion of single facilities and not with long-term strategies to provide least cost supply of all fertilizer requirements for a region or even a country. However, since capital investments are high and require long-term commitment, it is important to evaluate the economic implications of several supply alternatives before selecting a given project.

Indonesia, the Philippines, Malaysia, and Thailand--the agricultural countries of the ASEAN region--have many of the raw materials and much of the production capacity to meet the growing fertilizer demand of the region.[3] From both a regional and national point of view, there has been a growing interest in the ASEAN region for obtaining a greater degree of self-sufficiency in fertilizer production in order to develop a relatively more stable and secure fertilizer supply strategy.

The national planners from the ASEAN region expressed an interest in determining possible least cost national and regional fertilizer supply alternatives. An initial study was jointly conducted by The World Bank and IFDC. The results are reported by Foster, Livingston, and Stangel (1976). An update of this study was then undertaken by a working group within IFDC. The initial preparations for this study were completed during the second half of 1977. This included conceptualization of the problem, the formulation of a mathematical model, the programming for input generation, and, in collaboration with country representatives, the collection of appropriate data. During mid-1978, a draft report of the preliminary results was discussed with government and industry representatives from the ASEAN countries. Based on these discussions and on the knowledge received during further visits to the region during 1978 and 1979, the ASEAN Fertilizer Sector Planning Model was modified to reflect mid-1979 conditions. The main inputs to and the results obtained from the updated model runs are presented in this report.

The study quantifies a more or less realistic first approximation of the fertilizer situation in the ASEAN region in 1979. The expansion of production facilities contemplated at the time, availability of fertilizer raw materials, and demand projections for 17 consumption regions through 1992 have been incorporated. A dynamic linear programming model was developed to determine the least cost solutions for supplying the estimated fertilizer demand to consuming regions from 1981 to 1992. The results of the analysis give a first approximation of the costs which countries will incur under four different supply strategies. Thus, even though most of the production facilities considered are in operation or being developed, information with respect to technological and economic implications of different strategies which may be useful for the future development of the fertilizer economy in the ASEAN region is generated.

The model used for this study offers a systematic means to handle a large amount of data needed for obtaining optimum solutions for dynamic situations, such as those now occurring in the fertilizer sectors of many developing countries. Such an approach can be meaningfully applied to other regions, individual countries, or marketing regions within a country, in order to determine best fertilizer supply strategies and thus serve as a guide for fertilizer sector planners.

Objectives of the Study

The overall objective of the study is to illustrate the use of a dynamic linear programming model for planning the development of the fertilizer industry. The model has been developed and applied to the ASEAN region. More specifically, the study provides insights with respect to planning investment programs and implications for regional cooperative agreements dealing with fertilizer projects. Furthermore, it permits the economic evaluation of alternative supply strategies to meet projected fertilizer requirements.

The ASEAN region was selected not only to illustrate the usefulness of this approach for planning purposes but also because the region is important and is experiencing rapid developments with respect to fertilizer supply. The planning period considered was 1981 through 1992. The model, as used in this study, permits evaluation of different supply strategies, specifically in reference to:

1. Least cost supply patterns with respect to location, size, and timing of capacity expansion of plants or construction of new plants in the region.

2. Optimum levels of domestic production and imports from different sources by each country in

3. Singapore, the fifth ASEAN member country, is not included in the analysis since it is neither a major fertilizer producer nor a consumer of fertilizer.

order to satisfy projected fertilizer needs for selected time periods.

3. Estimates of cost penalties for the region when member countries deviate from optimum supply alternatives or from cooperative agreements.

4. Variable costs, total supply costs, and capital investments.

Overview of Economic and Agricultural Situation

A brief description of the economic and agricultural situations in the four ASEAN countries is provided below.

Income, Area, and Population

Selected socioeconomic indicators for the ASEAN countries are presented in Table 1. Malaysia has the highest per capita gross national product (GNP) in the region. In relation to other countries it is about double that of the Philippines and Thailand and triple that of Indonesia. The GNP per capita is growing at annual rates ranging from 2.6% in the Philippines to 4.6% in Thailand. Accurate information on income distribution is not generally available. However, according to 1970/71 data from the Philippines and Malaysia, the bottom 20% of the households control less than 4% of the income, and the top 20% control approximately 54%-57%.

Indonesia is the largest of the four countries, with an area of 2,027,000 km², equivalent to approximately six times that of Malaysia, seven times that of the Philippines, and four times that of Thailand. Both Indonesia and the Philippines consist of a large number of islands, creating several administrative and infrastructural problems. At the same time they have a large potential for developing port facilities for water transport.

Indonesia, with 136 million inhabitants in 1978, is one of the most populous countries in the world and the most populous in the ASEAN region. Malaysia, Thailand, and the Philippines have 13.3 million, 44.5 million, and 45.6 million inhabitants, respectively.

Annual population growth rate in Indonesia is the lowest of the region and is equal to 1.8%. Malaysia, the Philippines, and Thailand have the same population growth rate of 2.7%. A large proportion of Indonesia's population lives in Java, and a large proportion of Malaysia's population lives in peninsular Malaysia. In Java, the density of population is very high compared with that of the outer islands. The Indonesian Government is heavily involved in translocating part of the population from Java to the outer islands through transmigration schemes. In each of the ASEAN countries over two-thirds of the population live in rural areas and thus depend on agriculture as the major source of their livelihood.

Projected Food Deficits

The projected food deficits for 1990, as estimated by the International Food Policy Research Institute (IFPRI) (1977), are reported in Table 2. Currently, Indonesia and Malaysia are food-deficit countries, Thailand is considered to have food surplus, and the Philippines is just marginally self-sufficient in food

TABLE 1. SELECTED SOCIOECONOMIC INDICATORS FOR THE ASEAN REGION

Socioeconomic Indicators	Unit of Measurement	Year	Indonesia	Malaysia	Philippines	Thailand
GNP per capita	$ per capita	1978	360	1,090	510	490
Growth in GNP per capita	% per year	1960-78[a]	4.1	3.9	2.6	4.6
Area	thousand km²	-	2,027	330	300	514
Population	million	mid-1978	136.0	13.3	45.6	44.5
Rate of inflation	% per year	1970-78[a]	20.0	7.2	13.4	9.1
Distribution of GDP:						
Agriculture	%	1978	31	25	27	27
Industry	%	1978	33	32	35	27
Manufacturing	%	1978	9	17	25	18
Services	%	1978	36	43	38	46
Exports	million US $	1978	11,643	7,413	3,425	4,085
Imports	million US $	1978	6,690	5,929	5,143	5,256
Population growth	% per year	1970-78[a]	1.8	2.7	2.7	2.7
Labor force in agriculture	% of total	1978	60	50	48	77
Rural population	% of total	1980	80	71	64	86
Daily calorie supply	calories per capita	1977	2,272	2,610	2,189	1,929
Calories as % of requirements		1977	105	117	97	105
Share of household income:						
Lowest 20%		1970/71	N.A.	3.3	3.7	N.A.
Highest 20%		1970/71	N.A.	56.6	53.9	N.A.

a. Average for stated period.

Source: The World Bank. 1980. World Development Report.

TABLE 2. PROJECTED FOOD DEFICITS FOR 1990 IN ASEAN COUNTRIES[a]

Country	Low Income Growth		High Income Growth		At 110% of Food Energy Requirement	
	Deficit, '000 mt	% of Consumption	Deficit, '000 mt	% of Consumption	Deficit, '000 mt	% of Consumption
Indonesia	5,985	14	7,656	17	4,240	10
Malaysia	387	11	454	13	434	13
Philippines	1,443	11	1,738	13	3,632	24
Thailand[b]	(6,972)	(45)	(6,771)	(43)	(7,302)	(48)
Region	843	1	3,077	4	1,004	1

a. Food consists of staples, including cereals, root crops, pulses, and groundnuts.
b. Figures in parentheses imply food surplus.

Source: Calculated from IFPRI (1977).

requirements. It is projected that through 1990 Thailand will remain a food surplus country. Indonesia, Malaysia, and the Philippines are not expected to be able to meet their requirements from domestic production in the future, in spite of attempts by these governments to achieve food self-sufficiency. The food deficit as a proportion of domestic consumption is estimated to be about 10%-17% in Indonesia, 11%-13% in Malaysia, and 11%-24% in the Philippines, depending upon the assumptions with respect to income growth and nutritional standards. Thailand will have a food surplus from 43% to 48% of domestic consumption.

At both low and high income growth, 77%-79% of the region's food deficit will be in Indonesia. However, in order to provide 110% of the food energy requirements, the food deficit in Indonesia and the Philippines becomes about 51% and 44% of the region's deficit, respectively. This is mainly because the existing nutritional standards in the Philippines are estimated to be lower than the minimum requirements. However, for the region as a whole the net food deficit is about 1%-4% of the consumption requirement, implying that food surplus from Thailand is large enough to substantially compensate for food deficits in Indonesia, Malaysia, and the Philippines.

Role of Trade

These countries trade bilaterally, through the ASEAN arrangements, and with other countries in the region and outside. During 1977 Indonesia and Malaysia had positive international trade balances; whereas, the Philippines and Thailand had negative international trade balances. The major export product from Indonesia is oil, followed by rubber and coffee. The major export products from Malaysia are rubber, palm oil, cocoa, and tin. The Philippines exports coconuts, sugar, bananas, and apples while Thailand exports cassava, maize, rice, sugar, and rubber. The agricultural sector plays a major role in the balance of trade of these countries. As a result, growth in domestic production of agricultural commodities can play an important role in influencing foreign exchange situations through expansion in foreign exchange earnings or foreign exchange savings. Fertilizer has a large potential to expand crop yields and, thus, domestic agricultural production.

Role of Agriculture

Agriculture plays an important role in economic growth in each of these countries. With the exception of Indonesia, where oil is a major export item, the agricultural sector is a major source of foreign exchange earnings. Table 1 shows that approximately 30% of the gross domestic product (GDP) comes from the agricultural sector. A large proportion of the total labor force is involved in agriculture-related activities. The labor force in agriculture ranges from 48% in Malaysia to 77% in Thailand. Even though all four countries emphasize diversification of crop production, rice is still the main food crop and the staple food commodity.

Fertilizer Use and Crop Production

Rice is the single major crop in each of these countries, with the exception of Malaysia where rubber and oil palm are the most important ones. These three crops receive most of the fertilizer used in these countries.

In the last decade, the major sources of expansion in rice production were yield increases in Indonesia, Malaysia, and the Philippines and area expansion in Thailand. Table 3 shows the proportion of growth in rice production attributed to fertilizer use. It ranges from 17% in Thailand to 31% in Malaysia. The rice yields and the contribution of fertilizer to rice yield increases are expected to play even greater roles in the future if the large projected food deficits are to be reduced. Table 3 also shows that fertilizer use during 1978/79 varied from 16.5 kg/ha in Thailand to 57.1 kg/ha in Malaysia.

The Governments of Indonesia, Malaysia, and the Philippines are making a concerted effort to improve crop yields by providing modern farm inputs such as water, fertilizer, seed, and insecticides; they are also providing economic incentives through favorable crop and input prices. The Indonesian Government through the "BIMAS" program and the Philippines Government through the "MASAGANA 99" program have been fairly successful in stimulating modernization of the "rice" sector through an increase in the adoption of modern farm technology.

TABLE 3. FERTILIZER AND RICE INDICATORS FOR THE ASEAN REGION

Fertilizer and Rice Indicators	Unit of Measurement	Year	Indonesia	Malaysia	Philippines	Thailand
N consumption	'000 mt	1978/79	524.0	106.9	205.4	153.5
P_2O_5 consumption	'000 mt	1978/79	135.4	90.5	49.8	104.4
K_2O consumption	'000 mt	1978/79	75.4	172.7	56.6	30.0
Fertilizer use/hectare on arable land and permanent crops	kg/ha	1978	44.9	57.1	38.5	16.5
Rice (paddy) production	'000 mt	1979	26,350	2,161	7,000	15,640
Rice (paddy) area harvested	'000 ha	1979	8,850	757	3,500	8,300
Rice (paddy) yield	kg/ha	1979	2,977	2,855	2,000	1,884
Contribution of fertilizer to rice production growth	%	1965-75	24	31	27	17

Source: FAO. 1980. Production Yearbook.
FAO. 1980. Fertilizer Yearbook.
Mudahar. 1979. "Policy Implications of Increased Fertilizer Efficiency for Rice Production in Asia."

Overview of the Fertilizer Sector

Actual and Planned Supply Capacities

The actual installed fertilizer production capacity (1979) and the expansion in capacity currently planned for the ASEAN countries are reported in Table 4. Production capacity for nitrogen, phosphate, and potash (N, P_2O_5, and K_2O) fertilizers amounts to 1.205 million mtpy, 307,000 mtpy, and 28,000 mtpy, respectively.[4] At 1978/79 regional consumption levels, nitrogen (N) production capacity is approximately 22% greater than that of consumption, phosphate (P_2O_5) production capacity is equal to 81% of that of consumption, and potash (K_2O) production capacity is only 8% of that of consumption.

Including the potential expansion of production facilities considered in this study, production capacities could increase to 2,339,000 mtpy of nitrogen and to 600,000 mtpy of P_2O_5 in 1991. These capacities would be equivalent to 236% and 182% of the nitrogen and P_2O_5 consumption in 1979, respectively, and 116% and 71% of the projected nitrogen and P_2O_5 consumption for 1991.

Production Facilities

The production facilities in operation and those planned or being considered in 1979 are described briefly below. The main characteristics of existing and planned facilities are shown in Appendix Table A-1. The approximate location of the facilities is shown in Figure 1.

Indonesia has seven fertilizer complexes in operation. They include four ammonia/urea complexes under PUSRI at Palembang (Sumatra), one ammonia/urea complex under Kujang at Cikampek (Java), one ammonia/sulfuric acid/AS complex, and one TSP/DAP/NPK complex under Petrokimia at Gresik (Java). The PUSRI and Kujang complexes utilize natural gas for ammonia. Petrokimia uses fuel oil for ammonia production and imports sulfur, phosphate rock, and phosphoric acid for other intermediate or finished fertilizer products.

A new ammonia/urea complex for KALTIM near Bontang (Kalimantan) and another near Aceh (Sumatra) are approaching the initiation of construction. Kujang is considering adding another ammonia/urea complex at the existing Cikampek site. Petrokimia's Gresik plant has also been contracted for expansion to produce an additional 500,000 mtpy of TSP using imported rock and phosphoric acid.

In Malaysia ammonia is produced near Port Dickson from refinery gas. That ammonia is utilized in facilities near Petaling Jaya to produce ammonium sulfate and ammonium nitrate. Another plant uses locally produced nitrogen fertilizers and imported phosphate and potash fertilizers to produce granular NPK products. These are plants which simply mix fertilizers. An ammonia/urea complex based upon natural gas is planned for construction near Bintulu (Sarawak), Malaysia.

In the Philippines fertilizer plants are located at Limay and Pasig (around Manila Bay), at Toledo City, and at Iligan City. All plants are more than 15 years old and produce a wide range of products, most of which are low analysis. Actually some of these plants are temporarily shut down for renovation. Present capacity does not meet domestic fertilizer demand. The Philippines, having facilities at Limay and Toledo City, is the only ASEAN country currently producing phosphoric acid.

New production facilities for ammonia/urea may be located near Limay, and a phosphoric acid/DAP/NPK complex is to be located on Leyte. Recent developments indicate that the latter complex, which may also include ammonium sulfate production, would depend upon sulfuric acid from the copper smelting industry.

In Thailand the existing Mae Moh ammonia/urea/AS complex is considered in the study on the basis that it could be renovated. Since the model runs were made, the Thai Government has decided to close

4. Some of the P_2O_5 and all of the K_2O production refer to P and K contained in NPK fertilizers and are based on imported raw materials. Presently, some P_2O_5 is produced in the Philippines, but there is no production of K_2O in the region.

TABLE 4. EXISTING AND POTENTIAL FERTILIZER PRODUCTION CAPACITY IN ASEAN REGION

Country	Location Site	Product	Nutrient, Thousand mtpy N	P_2O_5	K_2O
		Existing Installed (1979)			
Indonesia	Palembang I	Urea	41	0	0
	II	Urea	166	0	0
	III	Urea	245	0	0
	IV	Urea	245	0	0
	Gresik	AS	27	0	0
		DAP	13	33	0
		NPK	7	7	7
		TSP	0	137	0
	Cikampek	Urea	245	0	0
TOTAL			989	177	7
Malaysia	Port Dickson/ Petaling Jaya	AS	11	0	0
		NPK	13	13	13
TOTAL			24	13	13
Philippines	Limay	Urea	26	0	0
		NPK	31	31	0
	Pasig	AS	5	0	0
	Toledo City	AS	15	0	0
		NPK	8	8	8
	Iligan City	AS	9	0	0
TOTAL			94	39	8
Thailand	Mae Moh	Urea	10	0	0
		AS	10	0	0
	Bangkok	NPK	78	78	0
TOTAL			98	78	0
TOTAL OF EXISTING			1,205	307	28
		Potential Expansion			
Indonesia	Aceh	Urea	245	0	0
	Bontang	Urea	245	0	0
TOTAL			490	0	0
Malaysia	Bintulu	Ammonia/urea	245[a]	0	0
TOTAL			245	0	0
Philippines	Limay Bay	Urea	137	0	0
	Leyte	DAP	37	96	0
TOTAL			174	96	0
Thailand	Sattahip	Urea	109	0	0
		NPK	105	141	16
		MAP[b]	11	56	0
TOTAL			225	197	16
TOTAL OF POTENTIAL EXPANSION			1,134	293	16
TOTAL OF EXISTING AND EXPANSION			2,339	600	44

a. Ammonia capacity; urea capacity is equivalent to 216,000 mtpy of N.
b. MAP is an intermediate for NPK production in the Bangkok facility.

the facilities. However, this change does not greatly affect the study results since its production capacity was rather low. Additional capacity in Thailand consists of an NPK mixing and granulation plant which is based upon imported fertilizer materials.

A new fertilizer complex is being considered for Thailand. Plans exist for an ammonia/urea complex and a phosphoric acid/MAP/NPK complex to be located near Sattahip. At the existing Bangkok facility, MAP is considered as an intermediate for NPK production.

Fertilizer Production

Production of nitrogen in the ASEAN region has increased from 131,800 mtpy in 1970 to 822,600 mtpy in 1979 (Appendix Table A-2). This is equivalent to an annual compound growth rate of 22.6%. Indonesia is solely responsible for this dramatic increase. This country, which accounted for approximately 30% of the total regional production during 1970, produced approximately 83% of the total during 1979. Production in other ASEAN countries has remained relatively

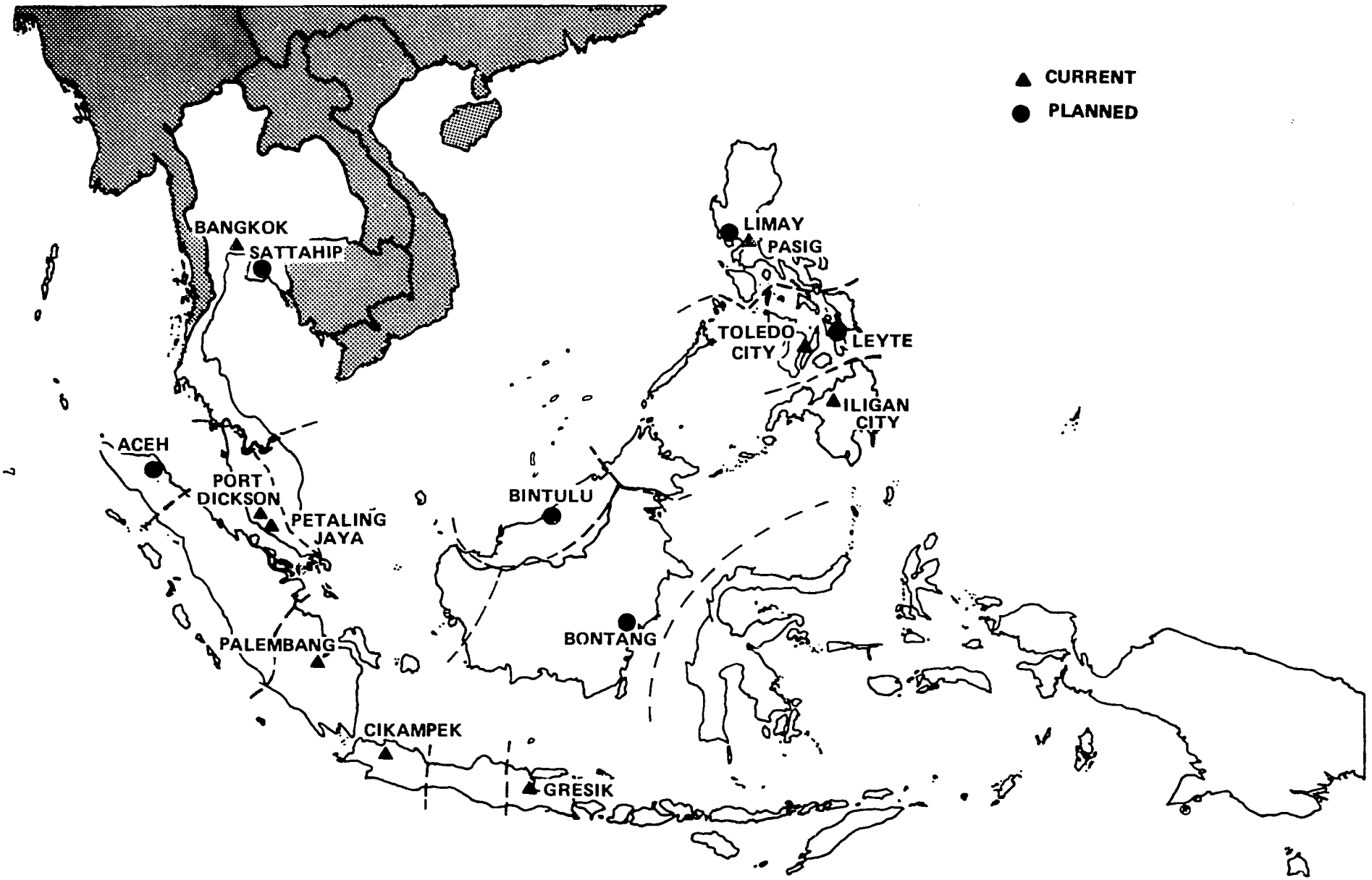

Figure 1. Marketing Regions and Locations of Existing and Planned Production Facilities in ASEAN Countries.

stable and, therefore, does not show any definite patterns of change.

Prior to 1979 small quantities of phosphate fertilizers were produced in the ASEAN region; in 1979 approximately 65,000 mt of P_2O_5 was produced. Only the Philippines produces phosphoric acid. Malaysia converts some phosphate to soluble P_2O_5 during NPK production using sulfuric acid. Thailand mixes diammonium or monoammonium phosphate with other materials and granulates NPK fertilizers. Indonesia's facility at Gresik is based on imported rock and phosphoric acid, and it began producing in late 1979. This facility will substantially increase the region's capacity to produce phosphate fertilizers.

Although there is no production of potash in the ASEAN region, small quantities of imported potash are included in NPK formulations in each of the countries.

Fertilizer Imports

The imports of nitrogen in the ASEAN region increased from 227,000 mt in 1970 to 416,500 mt in 1979 (Appendix Table A-2). Indonesia exported 106,000 mt and imported only 17,100 mt of nitrogen during 1979. On the other hand, the Philippines imported 117,500 mt, Malaysia imported 103,000 mt, and Thailand imported 178,900 mt.

Imports of P_2O_5 by the ASEAN group increased from 149,600 mt in 1970 to 329,700 mt in 1979. Of this amount Indonesia and Thailand imported 121,500 mt and 125,000 mt, respectively, accounting for approximately 75% of the total P_2O_5 imports of the ASEAN countries. During the same year Malaysia and the Philippines imported 75,000 mt and 8,200 mt, respectively.

Imports of K_2O by the ASEAN countries have increased from 122,600 mt in 1970 to 355,100 mt in 1979. During that time Thailand and the Philippines each increased imports only by 15,000 mt, while imports of K_2O into Malaysia increased by 134,000 mt and into Indonesia by 69,000 mt. Of the total ASEAN imports of K_2O in 1979, 190,000 mt or about 54% was made by Malaysia.

Fertilizer Consumption

Annual regional consumption of nutrients for the period 1970-79 is shown in Appendix Table A-3. During this period nitrogen consumption increased from 308,000 to 990,000 mt: P_2O_5 from 189,000 to 330,000 mt; and K_2O from 105,000 to 335,000 mt. From 1970 to 1979 the consumption of nitrogen and K_2O increased by 220% and that of P_2O_5 by 75%.

The greatest increase in consumption of nitrogen and P_2O_5 occurred in Indonesia while the greatest increase in K_2O consumption was in Malaysia. The average annual increases in nitrogen consumption between 1970 and 1979 were 19.5% for Indonesia, 13.5% for Thailand, and 8.2% for Malaysia and the Philippines. The average annual increases in consumption of P_2O_5 and K_2O were also fairly high for all the countries, except for the Philippines. In the Philippines, the P_2O_5 consumption ranged between 40,000 and 50,000 mtpy; whereas, K_2O consumption has been gradually increasing from 30,000 mtpy in 1970 to 56,600 mtpy in 1979.

Fertilizer use in the ASEAN countries on a per hectare basis is still low. It ranged from 16.5 kg/ha in Thailand to 57.1 kg/ha in Malaysia during 1978. However, fertilizer use is expanding rapidly in response to HYV use, irrigation expansion, favorable price policy, and various government programs. Rice is the major crop in the region in terms of fertilizer use. Urea is the major source of nitrogen for the rice crop. P_2O_5, K_2O, and complex fertilizers are used mainly on plantation crops, including rubber, oil palm, and cocoa.

With the exception of Thailand, governments are actively involved in different aspects of fertilizer production and distribution. Fertilizer is distributed at the retail level by public, private, and cooperative agencies, with varying degrees of participation. The use of fertilizer subsidies to stimulate consumption is fairly common as an instrument for the reduction of retail prices, except in Thailand.

Availability of Raw Materials

It is rather difficult to appraise the availability of raw materials that are or that could be available within the ASEAN region for the production of fertilizers. This is partly due to the fact that a demand for such raw materials, with the exception of oil and gas of which the region has large reserves, has not really existed in the past. Appendix Table A-4 contains a summary of the natural resources of the region relevant to the fertilizer industry.

The known oil and gas reserves and their production levels are reported in Table 5. Indonesia is the leading producer of natural gas and oil in the region. Natural gas production in Indonesia increased from 126.0 billion ft^3 in 1973 to 816.3 billion ft^3 in 1979; production is expected to reach 1.6 trillion ft^3 by 1984. Reserves at their present rate of usage are sufficient to last for at least 40 years; however, the real life of the reserves is unknown because gas discoveries are proceeding at a faster rate than their usage.

Malaysia-Brunei is the second largest producer of natural gas in the region. Production has increased from 5.1 billion ft^3 in 1974 to 302.7 billion ft^3 in 1979. At the 1979 usage rate reserves would last at least 82 years. Malaysian gas is also being discovered at a faster rate than it is being used. Other ASEAN countries are not currently producing natural gas, but Thailand and the Philippines are actively exploring for gas and oil. Thailand has discovered significant quantities of gas in the Gulf of Thailand and plans to have on-shore delivery in 1981.

Lignite is used to some extent as feedstock for power plants in Thailand. It was also used as feedstock for fertilizer production until 1978 when the Mae Moh plant was closed. Phosphate rock deposits in Java, Peninsular Malaysia, Thailand, and the Philippines are considered to be too small for economic exploitation and use in the production of phosphate fertilizers. Pyrites are now used in the Philippines for sulfuric acid production (Limay). Copper smelting in the Philippines will yield byproduct sulfuric acid with potential for use in phosphoric acid production.

Potash deposits in northeast Thailand are large, and exploration is being expanded to determine the feasibility for commercial development. However, because of insufficient economic data these potash deposits were not considered in this study.

TABLE 5. KNOWN OIL AND GAS RESERVES AND GAS PRODUCTION IN SOUTHEAST ASIAN COUNTRIES

Country	Oil Reserves Jan. 1, 1980 10^6 bbl	Oil Reserves Jan. 1, 1980 10^6 mt	Gas Reserves Jan. 1, 1980 10^9 m^3	Gas Reserves Jan. 1, 1980 10^9 ft^3	Gas Production 1979 10^9 ft^3
Indonesia	9,600	1,315	686	24,000	816.3
Malaysia	2,800	384	486	17,000	302.7[a]
Brunei	1,800	247	220	7,700	
Thailand	0	0	229	8,000	0
Singapore	0	0	0	0	0
Philippines	25	3	0	0	0
TOTAL	14,225	1,949	1,621	56,700	1,119.0

a. Total for Malaysia and Brunei.

Source: International Petroleum Encyclopedia, 1980.

Methodology for Study

A dynamic linear programming model was used to determine least cost solutions to supply the fertilizer needs of the ASEAN region under different supply strategies. Four supply strategies were considered for illustrative purposes. Data were collected from each ASEAN country to permit a realistic quantitative description of the existing fertilizer production facilities, fertilizer technology, planned or considered expansion, fertilizer consumption, relevant costs, and prices.

The evaluation of supply strategies is based on production capacity, prices, and cost structure of 1979 which is the midpoint of the assumed base period (1978-80). Four projection subperiods of 3 years each are used in the analysis. This gives a planning period of 12 years (1981-92). The projected input figures and the respective resulting figures are representative for the midyear of each subperiod (1982, 1985, 1988, and 1991).

Investment decisions are based on the assumption of a real interest rate of 2% (nominal interest rate: 10%, inflation rate: 8%).

In general, only those facilities in which the production processes are more complex than simple mixing of ingredients were considered as fertilizer production sites. Thus, if granulation accompanied the simple mixing, the facility was included as a production site. Possible expansion sites were considered only when it was known that they were being contemplated by the respective governments.

The breakdown of the ASEAN countries into 17 consuming regions is shown in Figure 1. This regionalization was done on the basis of information provided by country representatives about existing central ports, transportation systems, marketing areas around each central port, and fertilizer consumption patterns.

The Linear Programming Model

The mathematical formulation of the linear programming model used in the study is presented in Appendix C.[5] A schematic representation of the model's major components and data required for its use are presented in Appendix Figure C-1.

5. Similar mathematical models are also discussed in a recently published book by Choksi, Meeraus, and Stoutjesdijk (1980).

The objective function of the model, which is the decision criterion for evaluating supply strategies, is formulated to minimize the total cost for meeting projected nutrient demand for the ASEAN region over the period 1981-92. This function includes all costs and revenues which will occur under different alternatives. The components of costs and revenues are:

1. Costs which include:
   a. Transportation costs
   b. Import costs
   c. Purchase of byproducts
   d. Production costs
   e. Plant construction costs
2. Revenues which include:
   a. Exports of primary products
   b. Sales of coproducts

Some of the general premises underlying the model are briefly summarized below:

1. Production and cost data for 1979 were used in the model. These data included: production capacities by material and region, possible plant expansion, investment cost, raw material cost, import and export prices, and transportation costs and routes.

2. The linear programming simulation uses the period 1978-80 (mid-1979) as a base and simulates conditions for 1981-92 in four subperiods of 3 years each.

3. All costs and prices are calculated for the middle year of each subperiod. All costs and prices are adjusted for inflation and/or converted to 1979 values where necessary.

4. Formulas used to compute discounting factors and capital recovery factors are outlined in Appendix C.

5. The selection of fertilizer products is influenced by the constraints which require a certain level of domestic production. Product selection is allowed among those which can be produced in the region, except for muriate of potash which is imported.

6. No specific constraints were applied to require nutrients to be supplied as specific fertilizer products. In other words, the demand for nutrients may be supplied in the form of single-nutrient, NP, or NPK products or a combination of these materials. However, several products which could be included in any least cost supply alternative were identified.

Model Constraints

The objective function of the linear programming model described above can be minimized subject to 15 constraints described below.

Constraint 1. Nutrient Supply and Demand Balance--Supply of any plant nutrient in a given region has to be equal to or greater than demand. This constraint applies for all nutrients, regions, and time periods. Supply for a particular region is defined as domestic production, plus imports minus exports.

Constraint 2. Nutrient Imports--Nutrient imports to market regions have to be less than or equal to a predetermined share of consumption. This constraint plays a major role in the creation and evaluation of supply strategies.

Constraint 3. Materials--Raw materials needed for the manufacture of specific fertilizers must be available in adequate amounts. In each region and for each time period, a balance between inputs to be used and outputs to be produced under different technologies must exist.

Constraint 4. Production Capacity--During the first time period production of any given material in any region cannot exceed actual installed capacity. For subsequent time periods, production cannot exceed initial plus added capacity. The time lag between initial investment and start of production at a new facility is fixed at 3 years.

Constraint 5. Capital Availability--Capital investments made in any region for plant construction cannot exceed total capital available from internal and external sources.

Constraint 6 Production Capacity Expansion--Raw Materials--The production capacity expansion that may occur in any region during any time period to produce any fertilizer product is restricted by the availability of raw materials from indigenous reserves.

Constraint 7. Production Capacity Expansion Plants--Production capacity expansion cannot exceed a technologically determined maximum size for new plants.

Constraint 8. Plant Construction Activities--No more than one plant may be constructed to produce a given product in any given location. This constraint applies only to the construction of new plants which are not presently considered. It does not restrict construction of planned facilities even though similar facilities may already exist in the region.

Constraint 9. Fertilizer Supply and Demand Balance--This constraint is included to ensure that in any given region and for any time period the supply of any type of fertilizer will be equal to or greater than demand.

Constraint 10. Transportation Capacity--Interregional transportation of materials by different transportation technologies in any time period cannot exceed available transportation capacity.

Constraint 11. Raw Materials, Intermediates, and Fertilizer Imports--This constraint restricts the quantity of raw materials, intermediates, and fertilizers which can be imported from the world market. Since prices may be lower in the world market, some solutions might include unacceptably high levels of imports if not restricted to politically acceptable levels.

Constraint 12. Material Exports--This constraint restricts the quantity of fertilizers or other materials that can be exported to the world market.

Constraint 13. Byproduct Purchases--The total amount of byproduct materials that can be purchased in any region, during a given time period, cannot exceed what is actually available.

Constraint 14. Coproduct Sales--The total amount of coproduct that can be sold in any region, during a given time period, cannot exceed what is actually available.

Constraint 15. Plant Construction--This integer constraint is used to limit model solutions to construct or not to construct new plants.

Of the above 15 constraints, only 9 were used in the empirical estimation of the model used in this study. Constraints 6, 10, 11, 12, 13, and 14 were not incorporated in the model calculations either because of lack of data and/or they were considered irrelevant for the illustration presented in this report.

Fertilizer Prices

As mentioned earlier, the linear programming model is based upon cost minimization under different supply strategies. This means that cost and price assumptions are very important in determining investment, production, and distribution patterns. Resulting fertilizer prices are used as a means of evaluating the effects of various restrictions upon supply strategies.

The fertilizer prices are considered as equilibrium prices, valid under the cost assumptions and under the specific structural model assumptions. The prices are estimated by the dual solution of the linear programming model. Technically, they can also be called incremental costs, selling price, marginal costs, break-even price, or shadow prices. For simplicity, they will be referred to as fertilizer prices in this report. Their economic meaning is illustrated in Figure 2. Production capacities (C_1, C_2, C_3, and C_4) of a region have been drawn on the x-axis, beginning with the facility with the lowest production costs and then other capacities according to their increasing production costs. The y-axis represents production costs and fertilizer prices. The curves with slope downward to the right represent average production costs, which, in this figure, are shown to decrease for each plant as its capacity use increases. Regional fertilizer demand (D) is shown as a vertical line at different levels. The point where the supply and demand curves intersect determines the price level per unit of product. It can be seen that, if quantity Q_1 is needed to satisfy demand for a region with demand equal to D_1, capacities C_1 and C_2 are sufficient to supply the region with fertilizers. The equilibrium price would be P_1. If the demand increases sufficiently, capacity C_3 would be necessary, which has production costs equal to P_2. Then P_2 becomes the equilibrium price in the region. Capacity C_3 would be operating at break-even levels, but capacities C_1 and C_2 would realize profits, which would be equal to the difference between their production costs and the equilibrium price.

To simplify analysis, a vertical demand curve D (drawn with different levels 1, 2, and 3) was assumed. This means that fertilizer demand at a certain point in time was fixed and not price dependent. However, the necessity to bring into production facilities with higher transformation costs to satisfy demand increased the

C_1, C_2, C_3, C_4 Capacities of different production facilities in order of increasing conversion cost

D_1, D_2, D_3 Three different price inelastic demand curves

P_1, P_2, P_3 Fertilizer (equilibrium) prices

Q_1, Q_2, Q_3 Equilibrium quantities

At three supply/demand situations

in case of demand level D_1:

a b c d: conversion cost of facility with capacity 1
d c e f: contribution to profits of facility with capacity 1
b g h e: conversion cost of facility with capacity 2

a f = P_1: = equilibrium price

a g = Q_1: = production quantity

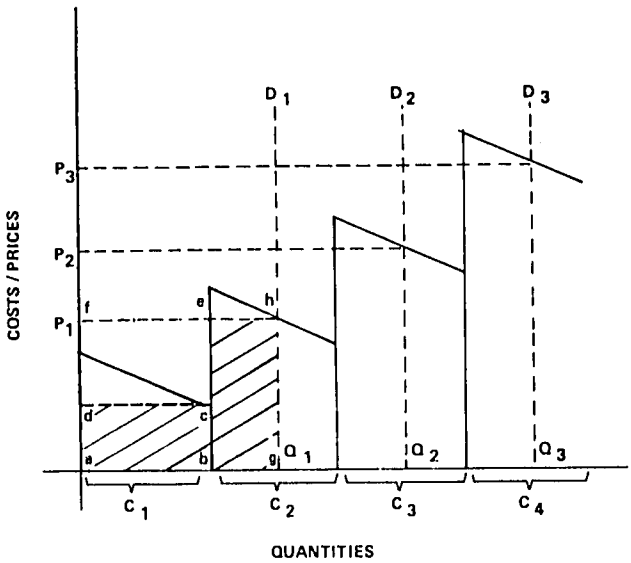

Figure 2. Illustration of Fertilizer Price Determination.

equilibrium prices. The most expensive source of fertilizers a region must use establishes the price level for that region.

To minimize total fertilizer supply costs, the model considers world market supply sources and resorts to imports if the following two conditions are met: (1) world market prices are lower than regional production costs and (2) restrictions imposed in the formulation of the model allow imports to be made. If these two conditions are not met, imports will not occur. Therefore, it is easy to predict that with supply strategies which allow unlimited imports from the world market, regional prices will be lower than or equal to world market prices. Since imports are allowed domestic production may be lower than domestic capacity.

It is unreasonable to expect that all the conditions for perfect competition could be achieved. Furthermore, it may be too optimistic to expect that the prevailing intraregional prices could be represented exactly by the fertilizer prices determined by the model. These prices are an approximation of the actual equilibrium prices which might occur if the assumed conditions prevail. However, these prices do provide information to possibly cooperating countries with respect to the expected long-term price structures and trends.

Fertilizer Supply Strategies

Four strategies, representing different supply situations, were analyzed. These strategies are referred to as scenarios I through IV and can be described as follows:

Scenario I--Each country has the choice of meeting its fertilizer needs from any source. They can produce it locally at their existing facilities, expand those facilities, build planned facilities, or buy fertilizer from other ASEAN countries and world markets. Countries are free to select least cost alternatives.

This scenario will provide a least cost supply alternative for the ASEAN region. It will serve as a basis for possible cooperation agreements among ASEAN countries. Agreements so based will guarantee an adequate supply of fertilizers on a regional basis at the lowest possible cost.

Scenario II--The ASEAN countries, under cooperative agreements, are supposed to produce 100% of their nitrogen needs. This scenario prohibits imports of nitrogen fertilizers from outside the ASEAN region during the planning period, except for subperiod 1 where only 95% self-sufficiency is possible with existing facilities. However, countries can secure their phosphate and potash fertilizer needs from any least cost sources.

Comparison of results for this scenario with those for scenario I will permit estimation of cost due to cooperation to attain 100% self-sufficiency in supply of nitrogen fertilizers.

Scenario III-This scenario is the same as scenario II with respect to nitrogen fertilizers. An additional restriction, which specifies that ASEAN countries will cooperate to attain a 50% regional self-sufficiency for production of phosphate fertilizers, is added. As in scenarios I and II, each country can secure its potash needs from any least cost sources.

Comparison of results for this scenario with results for scenarios I and II will permit estimation of cost due to cooperation to attain 100% regional self-sufficiency in production of nitrogen fertilizers and 50% regional self-sufficiency in phosphate fertilizers.

Scenario IV--It can be defined as the most probable production path for the ASEAN countries. For this scenario, each country produces what it can of N and P with existing and firmly planned facilities and secures the rest from least cost sources. These least cost sources can be other ASEAN countries or the world market.

For this scenario, each country's needs are covered, as far as possible, by domestic sources. If needed for in-country use, domestic production may not be lower than 95% of its capacity and, if production capacity allows, not lower than 95% of the fertilizer needs, provided that the production and handling system of raw materials and intermediate products are adequate.

This scenario will permit evaluation of a situation where no cooperation among ASEAN countries exists. Instead each one of them tries to satisfy its needs with its own production capacity and imports the rest from least cost sources. Each country will use its plants to its own advantage and secure some degree of self-sufficiency.

Input Data for Model Estimation

The input data used in this study deal with several aspects of the fertilizer sector. This includes fertilizer demand projections, production coefficients, capital costs, production conversion costs, import and export prices, and transportation costs and routes.

Fertilizer Demand Projections

As food demand expands, fertilizer demand may increase even at a greater rate. This is because (1) the new land brought under cultivation will be of poor quality and thus will need large amounts of fertilizer to improve its fertility and (2) the existing land will need more fertilizer to maintain fertility as cropping intensity goes up and new crop varieties with large nutrient demand are grown.

The fertilizer nutrient demand by country for the 1979-92 period was estimated using historical time series analyses. For all countries the base period for these projections was time series data set for 14 years from 1964 through 1977. Different types of demand functions were estimated, and for each country the results of the function which gave the best fit were chosen. These functions were then used to make demand projections for the 1981-92 period. However, in the case of Thailand demand projections were adjusted based on an in-country study conducted by IFDC in early 1979. Since the demand projections are based on historical data when fertilizer consumption was rather low, the projections may reflect underestimates.

The breakdown of nutrient consumption by marketing regions for each country (except Thailand, where the country was not divided into market regions) was based partly on information coming directly from representatives of the respective countries and partly on information coming from other knowledgeable sources. With the exception of the Philippines this breakdown was held constant over the whole projection period. For the Philippines slight differences in the regional growth rates in fertilizer consumption were used. These growth rates were determined on the basis of information provided by country representatives.

The estimates for aggregate and regional nutrient consumption forecasts for each of the four 3-year subperiods are reported in Appendix Table A-5. These estimates for fertilizer demand were used as an input in evaluating alternative supply strategies. The past and projected fertilizer consumption by countries is shown in Figure 3.

Production Coefficients

Production coefficients, defining the quantities of raw materials and intermediates required to produce fertilizer products selected for this study, are developed in the Appendix Tables A-6 and A-7.

Capital Cost

The investment cost figures for fertilizer production facilities under construction or in the planning stage are based on IFDC estimates. These estimates are presented in Appendix Table A-1. When available, cost estimate data were considered for specific projects. Specific allowances for infrastructure items and for support facilities located outside the plant site boundary were not included.

The investment estimates are on a 1979 cost basis, including interest during construction (10%/year). A 4-year construction schedule with a disbursement rate of 10%, 30%, 40%, and 20% for fixed capital funds is used. No cost escalation during construction is included. Since the capital costs normally overrun, the actual capital costs may be higher than the estimates used in this study.

Production Conversion Costs

Conversion cost figures used for the calculations are IFDC estimates. These cost estimates are also presented in Appendix Table A-1. They are based on the assumption of a 90% capacity utilization rate for all plants except the following Indonesian plants, which are based on the assumption of 95%: PUSRI II, III, and IV, Aceh, Bontang, and Cikampek. Annual capacity is defined as 330 days of operation at daily design capacity. Thus, a 90% capacity utilization is equivalent to 297 (330 x 0.9) days of operation at daily design capacity. Raw material costs, interest charges on capital, and depreciation are not included in conversion cost estimates but are accounted for separately.

For natural gas feedstock-based plants, the price of natural gas for steam and electricity generation is the same as for feedstock. Cost of fuel oil for steam and electricity generation and other uses was assumed to be world market price. Cost of purchased electricity is assumed to be US $0.030/kWh. Sulfuric acid plants are credited for steam export at US $10/mt of steam. Process plants using the export steam are charged at US $10/mt of steam.

Annual cost of maintenance materials is 3%, and insurance and taxes are 1% of the estimated fixed investment (1979 cost basis), excluding interest during construction. Administration expenses and general overhead are 150% of the estimated cost of wages, salaries, and benefits.

Import and Export Prices

Depending on the respective scenario formulation, the economic environment as reflected by the world markets for fertilizers, intermediates, and raw materials can greatly influence the results of the optimizations. The assumed c.i.f. prices for bulk material, gas, and liquids are reported in Table 6 for mid-1979. Prices for bulk materials and liquid were estimated for seaborne transported materials from the main supplying areas. They are f.o.b. prices, plus sea transport costs and port handling costs at the receiving ports.

Prices for natural gas are accounting prices which were provided by government officials from each country. They were assumed to remain constant throughout the planning period, except for Malaysia, where they were allowed to increase at a 5% annual rate.

Prices for fertilizer exports from the ASEAN region to the world markets are assumed to be 20% lower than the import prices for corresponding fertilizer. This reflects, in general, the transport charges to other main consuming regions in the world. Export potential has been evaluated for the following products: (1) urea which could be delivered from large plants (existing or expansion) in Indonesia, Malaysia, and the Philippines; (2) ammonia

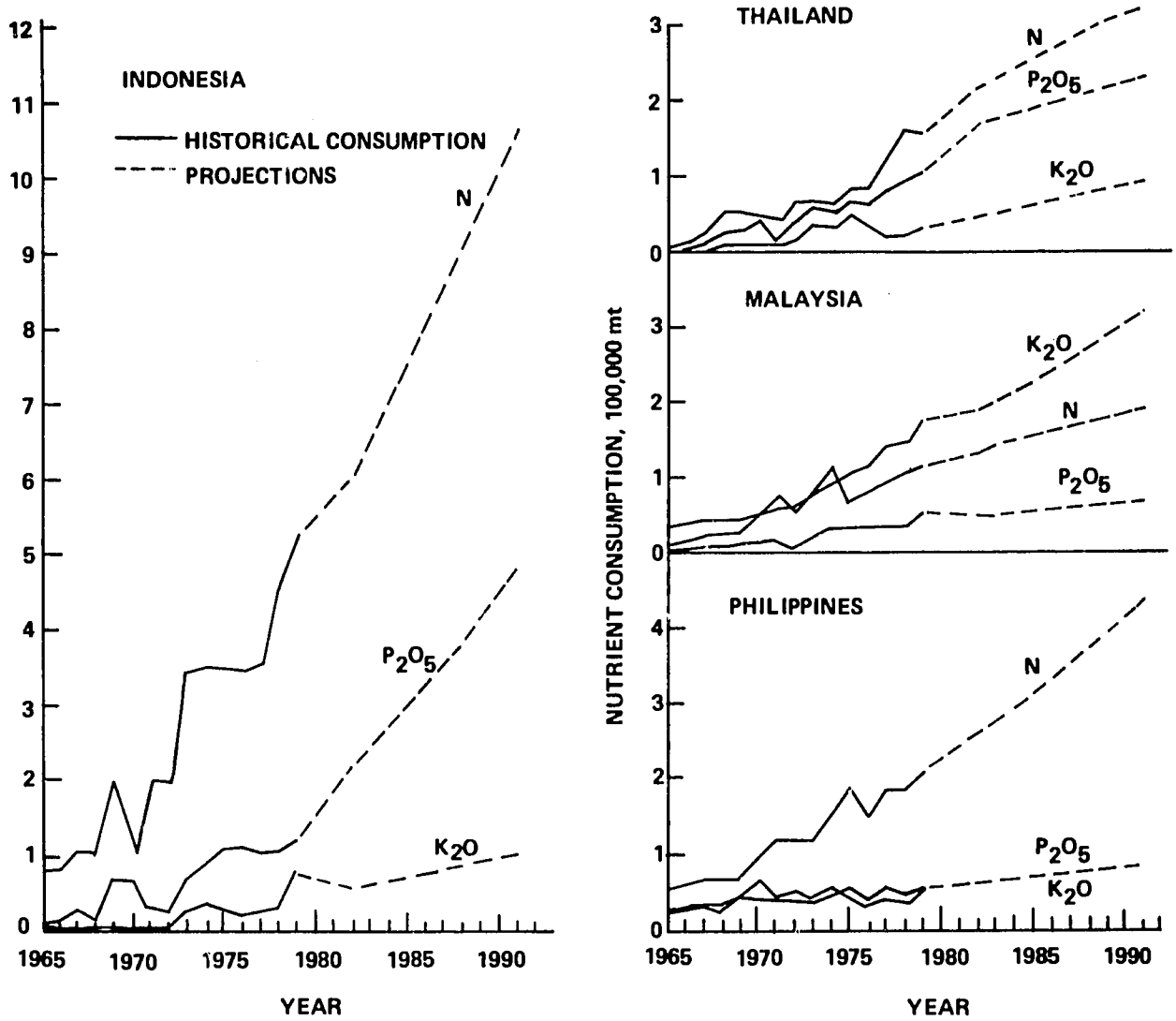

Figure 3. Apparent Historical and Projected Nutrient Consumption for ASEAN Countries.

where excess capacity is available (Bontang and Bintulu); and (3) DAP from Leyte.

Transportation Costs

Transport activities refer to movement of fertilizer from producing locations to receiving ports in consuming regions and transport of intermediates between production sites. Three types of materials are transported. These are: (1) solid materials, (2) ammonia, and (3) phosphoric acid. Transportation of solid fertilizers is much more voluminous than the transportation of ammonia or of phosphoric acid. Due to the geographic situation of the ASEAN countries, only seaborne transportation is considered.

In most cases, bulk terminal or bagging facilities exist at the receiving central ports of the selected market regions. Most of the central ports can be reached by ships that are normally used for the interisland transportation within the region.

The bulk transport freight rates refer to the middle of 1979. For ammonia and especially for phosphoric acid, it is difficult to obtain reasonable information about the actual freight terms because freight rates (long-term contracts) are normally not published. In the case of large-volume contracts, freight rates are often contracted in conjunction with f.o.b. or as part of c.i.f. prices. Therefore, they do not appear explicitly in market price scans.

The freight rates for ammonia and phosphoric acid are based upon personal communications with shipping agents, and rates for bulk materials are based upon published rates reported weekly in Green Markets and Fertilizer International.

For the calculations of transportation costs the following equations have been used:

Bulk material: $C = 8 + (0.005 \times M)$
Ammonia: $C = 10 + (0.005 \times M)$
Phosphoric acid: $C = 7 + (0.006 \times M)$
Where C = transport costs in U.S. dollars per ton of product (mid-1979)
M = distance in nautical miles

Transportation rates are for 1979. These rates are allowed to increase at an annual rate of 8% throughout the planning period.

TABLE 6. PRICES FOR FINISHED FERTILIZERS, INTERMEDIATES, AND NATURAL GAS DURING 1979

Material	Prices
Imported Material[a]	(US $/mt)
Ammonia	190.00
Ammonium chloride	90.00
Ammonium sulfate	118.00
DAP	243.00
MAP (powdered)	225.00
Fuel oil	150.00
Naphtha	260.00
NPK, 15-15-15	147.00
Phosphoric acid (100% P_2O_5)	345.00
60% Potassium chloride	114.00
Rock phosphate, 60% BPL	64.00
Sulfur	98.00
TSP	187.00
Urea	200.00
Natural Gas[b]	(US $/1,000 ft^3)
Indonesia: Bontang & Cikampek	0.85
Aceh & Palembang	0.60
Thailand: Sattahip	0.75
Malaysia: Bintulu	0.70

a. Prices are estimated mid-1979 c.i.f. basis, including port handling cost at receiving port.
b. Refers to accounting prices.

Empirical Results for Alternative Supply Strategies

Selected empirical results for the specified four fertilizer scenarios are discussed with respect to fertilizer production patterns, fertilizer supply patterns, production site fertilizer prices, and fertilizer prices at the market regions. Various assumptions described above need to be kept in mind before interpreting these model results. The results may vary under different assumptions. Consequently, these results serve only as broad guideposts for the fertilizer sector planners.

Fertilizer Production Patterns

The optimum levels of domestic and regional production for nitrogen and P_2O_5 for each subperiod and for the four scenarios are reported in Table 7. The optimum production patterns for each production facility in each study country are provided in Appendix Tables B-1 through B-4.

In general, regional production of nitrogen and phosphate fertilizers increases for each subperiod. In scenario I, production increased from subperiod 1 to subperiod 2 but stayed at that level for the remaining two subperiods. In scenarios II and III regional production increased throughout the planning period. For scenario IV production increased during the first three subperiods and declined slightly during the last subperiod.

Total regional production of nitrogen and phosphate fertilizers, by subperiod, is the lowest for scenario I and the highest for scenario IV. This reflects the crucial role played by constraints on imports and on regional production in the respective scenarios.

Fertilizer production at different plants in Indonesia is reported in Appendix Table B-1. It shows that all existing urea plants operate at maximum capacity for all scenarios and for all subperiods. The only exception to this is the plant at Cikampek which operates at 98% capacity. The Aceh urea plant operates at maximum capacity in all scenarios after it comes on stream. The same applies to the Bontang urea plant, with the exception of scenario IV, where it operates at 88% capacity. The DAP unit of the Gresik plant operates at maximum capacity for all scenarios and for all time periods. The TSP unit at Gresik operates at maximum capacity for all scenarios and for all time periods, except for subperiod 1 of scenario I.

The fertilizer production at different plants in Malaysia is reported in Appendix Table B-2. The expansion site for urea production at Bintulu operates at maximum capacity in all scenarios after it is completed and starts production in subperiod 2. The NPK unit at Petaling Jaya operates at maximum capacity for all scenarios and subperiods. The AS unit at this complex does not operate at all in scenario I and operates only during the first subperiod in the other three scenarios.

The fertilizer production at different plants in the Philippines is reported in Appendix Table B-3. It shows that the old urea plant at Limay is the only old plant that operates at maximum capacity for all scenarios and during all subperiods. The DAP expansion site at Leyte operates at maximum capacity after completion in subperiod 2 for scenarios I, II, and III. However, the DAP production is less than maximum capacity in scenario IV. The new urea plant and the NPK plant at Limay, and the AS plants at Pasig, Toledo City, and Iligan City operate at full capacity during the last three subperiods of scenario IV. For the other scenarios these plants operate sporadically or not at all. The AS plants usually operate only during the first subperiod before expansion projects could be completed.

The fertilizer production at different plants in Thailand is reported in Appendix Table B-4. It shows that the urea unit at Sattahip operates at maximum capacity in scenarios I, II, and III after it is constructed in subperiod 1. In scenario IV, however, this unit operates at maximum capacity only during the last two subperiods. The Mae Moh plant operates at full capacity during all subperiods for scenarios I, II, and III and sporadically for scenario IV. It is interesting to note that in scenario I only the urea plants at Mae Moh and the expansion at Sattahip operate. The NPK production units operate only in scenarios with restrictions.

The Mae Moh urea facility in Thailand produces at full capacity during the entire planning period for all scenarios except IV. The AS plant seldom operates. However, recently all the Mae Moh facilities have been closed for technical reasons. It was assumed for modeling purposes that the facilities would be renovated, but those plans have apparently now been abandoned. Since the total Mae Moh capacity was very low, the permanent closing of the Mae Moh plants has little effect upon the results of this analysis. The mixing-granulation plant near Bangkok was simulated to operate only occasionally in scenario II and to operate with more or less full capacity utilization in scenarios III and IV. At Sattahip, the production of NP and NPK fertilizers is feasible only under the conditions of scenario IV. MAP is not produced as an intermediate for NP fertilizer at Bangkok.

Fertilizer Supply Patterns

The general sources of supply of plant nutrients as finished fertilizers to consuming regions by

TABLE 7. ANNUAL PRODUCTION OF NUTRIENTS UNDER ALTERNATIVE SUPPLY SCENARIOS: MODEL RESULTS

Country/ Region	Nutrient Production, Thousand mtpy							
	Scenario I		Scenario II		Scenario III		Scenario IV	
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
			Subperiod 1 (1981-83)					
Indonesia	941.24	70.84	971.39	174.65	971.39	176.49	941.24	169.74
Malaysia	12.75	12.75	22.95	12.75	22.95	12.75	20.15	12.75
Philippines	40.16	0	67.70	12.75	67.70	12.74	51.82	8.26
Thailand	10.58	0	90.58	72.00	90.58	72.00	88.98	70.40
TOTAL	1,004.73	83.59	1,152.62	272.14	1,152.62	273.98	1,102.19	261.15
			Subperiod 2 (1984-86)					
Indonesia	1,427.00	169.74	1,427.00	169.74	1,427.00	169.74	1,398.02	169.74
Malaysia	217.91	12.75	217.91	12.75	217.91	12.75	217.91	12.75
Philippines	63.20	95.68	63.20	95.68	63.20	95.68	250.90	109.04
Thailand	120.06	0	120.06	0	139.46	19.40	256.31	188.13
TOTAL	1,828.17	278.17	1,828.17	278.17	1,847.57	297.57	2,123.14	479.66
			Subperiod 3 (1987-89)					
Indonesia	1,427.00	169.74	1,427.00	169.74	1,433.75	176.49	1,400.87	172.55
Malaysia	217.91	12.75	217.91	12.75	217.91	12.75	217.91	12.75
Philippines	63.20	95.68	63.20	95.68	66.20	98.48	242.80	88.34
Thailand	120.06	0	120.06	0	192.06	72.00	291.13	212.20
TOTAL	1,828.17	278.17	1,828.17	278.17	1,909.72	359.72	2,152.71	485.84
			Subperiod 4 (1990-92)					
Indonesia	1,427.00	169.74	1,427.00	169.74	1,433.75	176.49	1,398.02	169.74
Malaysia	217.91	12.75	217.91	12.75	217.91	12.75	217.91	12.75
Philippines	63.20	95.68	214.62	95.68	148.76	134.32	240.64	82.82
Thailand	120.06	-	156.46	36.40	215.60	103.03	293.85	200.60
TOTAL	1,828.17	278.17	2,015.99	314.57	2,016.02	426.59	2,150.42	465.91

subperiods and scenarios in each study country are reported in Appendix Tables B-5 through B-8. These results are summarized in Tables 8 and 9. A graphic illustration of the distribution of major raw materials and intermediates is shown in Appendix Figures B-1 through B-4 and are summarized in Table 10. Domestic production of nitrogen accounts for 51%-61%, 62%-65% 60%-69%, and 62%-96% of ASEAN demand for scenarios I, II, III, and IV, respectively, during the planning periods. Domestic production of P_2O_5 accounts for 29%-41% of P_2O_5 demand for scenario I, 34%-48% for scenario II, 35%-46% for scenario III, and 54%-81% for scenario IV. Thus, while increasingly restrictive conditions on nitrogen production requirements increase the proportion of ASEAN demand which is produced in the country of use, only the most restrictive scenario has a significant influence on P_2O_5 production within the countries of use.

For scenarios I, II, and III, the region obtains about 30%-35% of its nitrogen supply and less than 15% of its P_2O_5 supply from the other ASEAN countries. Since no cooperative agreements among ASEAN countries exist in scenario IV, the prices for such trade are world market prices, and fertilizers obtained from other ASEAN countries are reported as obtained from the world market. Generally, less than 10% of N is obtained from outside the ASEAN region for scenarios I, II, and III. However, for scenario IV, Malaysia, the Philippines, and Thailand obtain 85%, 80%, and 60%, respectively, of their nitrogen from the world market (other ASEAN countries and outside the ASEAN region) during subperiod 1. Thereafter only the Philippines imports significant quantities of nitrogen. On the other hand, generally more than 50% of phosphate (P_2O_5) fertilizer is obtained from outside the ASEAN region for scenarios I, II, and III and from 27% to 46% for scenario IV. All potash originates from outside the ASEAN region, but some is transformed into NPKs within a country.

As reported in Table 10, the imports of finished fertilizers from the world market primarily consist of KCl, AS, and MAP. Inter-ASEAN trade in fertilizers is dominated by urea which is supplied by the Indonesian and Malaysian plants. Small quantities of TSP and DAP are traded within the ASEAN region. Low-analysis fertilizers are usually not transported between countries.

Production capacity for nitrogen fertilizers in Indonesia is well in excess of domestic demand throughout the planning period. Nitrogen production capacity in Malaysia is less than demand in subperiod 1, but it exceeds demand through the remainder of the planning period. Nitrogen production capacity in the Philippines is less than demand throughout the planning period. In Thailand, nitrogen production capacity is less than demand in subperiod 1, but it exceeds demand until the end of the planning period when capacity and demand are in balance.

Exports (outside the ASEAN region) of urea and ammonia are shown in Table 11. Export potential to world markets decreases over time during the planning period. The greatest export potential exists for scenario IV, but as mentioned earlier sales to

TABLE 8. SOURCES OF N SUPPLY AS FINISHED FERTILIZERS TO ASEAN MARKET REGIONS: MODEL RESULTS

Country of Use	Supply Sources as Percent of Projected Demand											
	In-Country Scenario				Other ASEAN Countries Scenario				Non-ASEAN Countries Scenario			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Subperiod 1 (1981-83)												
Indonesia	94	95	94	100	0	0	1	0	6	5	5	0
Malaysia	10	17	12	15	82	78	87	0	8	5	1	85
Philippines	15	26	26	20	57	69	69	0	28	5	5	80
Thailand	5	41	41	40	66	55	55	0	29	5	5	60
ASEAN	51	62	60	62	33	33	34	0	15	5	5	38
Subperiod 2 (1984-86)												
Indonesia	93	99	100	100	1	1	0	0	5	0	0	0
Malaysia	19	19	19	100	74	81	81	0	7	0	0	0
Philippines	16	16	12	80	84	84	88	0	0	0	0	20
Thailand	47	47	54	100	25	53	46	0	29	0	0	0
ASEAN	61	64	65	96	31	36	35	0	8	0	0	4
Subperiod 3 (1987-89)												
Indonesia	91	100	99	100	1	0	1	0	8	0	0	0
Malaysia	18	18	19	100	74	82	81	0	8	0	0	0
Philippines	14	14	11	65	86	86	89	0	0	0	0	35
Thailand	41	41	66	100	30	59	34	0	29	0	0	0
ASEAN	59	63	67	92	31	37	33	0	10	0	0	8
Subperiod 4 (1990-92)												
Indonesia	89	99	98	100	1	1	2	0	10	0	0	0
Malaysia	18	18	18	100	74	82	82	0	8	0	0	0
Philippines	12	16	25	55	88	84	75	0	0	0	0	45
Thailand	37	48	66	90	35	52	34	0	28	0	0	10
ASEAN	57	65	69	89	32	35	31	0	11	0	0	11

other ASEAN countries are classified as world market exports in this scenario. The next greatest export potential exists for scenario I. The export potential is at its lowest for scenarios II and III.

Production Site Prices

The estimated fertilizer prices for different products at each plant within countries are reported in Appendix Tables B-9 through B-12. In general, these tables show that fertilizer prices increase as the scenarios become more restrictive and limits are set on the level of imports and/or domestic production. With few exceptions, scenario I has the lowest prices for all products and for all scenarios. In some cases, prices for subperiods 2, 3, and 4 are lower than prices in subperiod 1, mainly because of a decline in production costs as new facilities come on stream.

In scenarios II and III, which require nitrogen self-sufficiency, prices for nitrogen fertilizer during subperiod 1 are influenced by high production from existing facilities. During subperiod 2 and 3 prices decrease slightly because of lower production costs at new plants. For subperiod 4, when ASEAN demand approaches potential, fertilizer prices increase.

Scenarios I and II exhibit the lowest prices for phosphate fertilizers. Since there are no constraints on phosphate fertilizer production in the region and imports can take place, prices are leveled with world market prices. Scenario III, in which 50% of the total phosphate (P_2O_5) fertilizer requirement is to be produced domestically, has higher prices especially for subperiod 1 when less efficient production units must come on stream to meet the requirements.

The fertilizer prices calculated for scenario IV vary widely for all products. For Indonesia and Malaysia, fertilizer prices for this scenario are sometimes lower than for other scenarios. This is the result of excess production above domestic requirements so that in-country equilibrium prices are lowered by export prices to world markets. For the Philippines and Thailand, the fertilizer prices are generally high because they are influenced by the respective in-country high production cost structures. In-country capacities must be used as far as possible even to the point of using inefficient plants. In several cases, prices reflect that domestic production, determined by forcing the use of existing inefficient plants, could be extremely uneconomic. In other words, the cost of avoiding the risk by being dependent on the world market for fertilizer supply is reflected by the price level, which could be very high.

Market Region Prices

The weighted average prices for nitrogen and P_2O_5 in each consuming country are shown in Table 12. These prices can be considered as approximations for the nutrient prices to be expected under the different scenario assumptions. They include the cost of transportation to central points in market regions but do not include transportation costs from central points to farmers.

TABLE 9. SOURCES OF PHOSPHATE (P_2O_5) SUPPLY AS FINISHED FERTILIZERS TO ASEAN MARKET REGIONS: MODEL RESULTS

Country of Use	Supply Sources as Percent of Projected Demand											
	In-Country Scenario				Other ASEAN Countries Scenario				Non-ASEAN Countries Scenario			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
					Subperiod 1 (1981-83)							
Indonesia	57	62	61	77	0	0	3	0	43	38	36	23
Malaysia	30	30	14	30	0	26	35	0	70	44	51	70
Philippines	0	24	24	15	0	9	27	0	100	67	49	85
Thailand	0	44	44	42	0	13	6	0	100	43	50	58
ASEAN	29	48	46	54	0	8	10	0	71	44	44	46
					Subperiod 2 (1984-86)							
Indonesia	57	57	50	57	9	9	0	0	34	34	50	43
Malaysia	26	26	26	26	16	22	24	0	58	52	50	74
Philippines	100	100	50	179[a]	0	0	0	0	0	0	50	0
Thailand	0	0	10	100	0	0	40	0	100	100	50	0
ASEAN	41	41	35	81	6	6	15	0	53	53	50	27
					Subperiod 3 (1987-89)							
Indonesia	45	45	46	45	5	5	4	0	50	50	50	55
Malaysia	24	24	24	24	12	12	26	0	64	64	50	76
Philippines	100	100	50	133[a]	0	0	0	0	0	0	50	0
Thailand	0	0	34	100	0	0	16	0	100	100	50	0
ASEAN	35	35	41	68	4	4	9	0	61	61	50	35
					Subperiod 4 (1990-92)							
Indonesia	35	35	36	35	3	3	14	0	62	62	50	65
Malaysia	21	21	21	21	11	11	29	0	67	67	50	79
Philippines	100	100	50	114[a]	0	0	1	0	0	0	49	0
Thailand	0	15	44	85	0	0	6	0	100	85	50	15
ASEAN	30	34	38	55	2	3	12	0	67	63	50	46

a. In these cases the Philippines is oversupplied with P_2O_5 because domestic production of DAP and NPK products was used to meet the N requirement.

TABLE 10. DISTRIBUTION OF PRINCIPAL RAW MATERIALS AND INTERMEDIATES: MODEL RESULTS[a]

To	From	Raw Material and Intermediates for Scenario			
		I	II	III	IV
Gresik	World market Limay	FO, PR	FO, PR, PA PA	FO, PR, PA, KCl PA	FO, PR, PA
Petaling Jaya	World market Bintulu	PR, KCl	PR, KCl AA	PR, KCl AA	PR, KCl AA
Limay	World market	PR, AS	PR, AS, FO	PR, KCl, FO	FO, PR, AS, KCl
Leyte	World market Bintulu Limay	PA, PR	PR, AA AA	PR AA AA	PR, AA PA, AA
Bangkok	World market		AC, MAP	AC, MAP	AC, MAP
Sattahip	World market				PR, SU, KCl

a. FO = fuel oil, SU = sulfur, PR = phosphate rock, PA = phosphoric acid, AA = ammonia, AS = ammonium sulfate, AC = ammonium chloride, MAP = monoammonium phosphate, KCl = potassium chloride.

TABLE 11. ANNUAL EXPORTS TO WORLD MARKETS OF UREA AND AMMONIA: MODEL RESULTS

Subperiod	Exports, Thousand Metric Tons of Product/Year					
	Palembang	Aceh	Bontang		Bintulu	
	Urea	Urea	Urea	Ammonia	Urea	Ammonia
			Scenario I			
1	0	0	0	0	0	0
2	644	386	39	150	0	10
3	679	359	0	150	0	10
4	0	78	0	150	0	10
			Scenario II			
1	0	0	0	0	0	0
2	438	362	0	150	0	10
3	0	213	0	150	0	10
4	0	0	0	141	0	0
			Scenario III			
1	0	0	0	0	0	0
2	476	367	0	150	0	10
3	52	334	0	150	0	3
4	0	0	0	128	0	0
			Scenario IV			
1	750	0	0	0	0	0
2	1,015	367	115	150	145	13
3	828	333	0	150	106	13
4	488	298	0	150	69	13

The prices of nitrogen and P_2O_5 indicate the direction in which the scenario-specific supply strategies influence the price level of plant nutrients. In general, the lowest prices can be found in the unrestricted scenario I throughout the planning period. In this scenario, prices are influenced by the world market prices or by the in-country production costs, depending on the relationship between them and on the potentially available capacities.

Scenarios II and III have relatively high nitrogen prices during subperiod 1 when the old nitrogen-producing facilities must be used and before new plants come on stream. Scenario III shows very high P_2O_5 prices during subperiod 4. This is because old NPK plants with high production costs are required to operate to meet 50% of the P_2O_5 consumption, imposed as a constraint on the supply system.

Scenario IV results are highly influenced by the country-specific relative needs. In some cases, especially in Thailand, the prices of P_2O_5 are very high. This indicates a situation in which NP fertilizers are produced at old and relatively inefficient plants.

For scenario IV in the Philippines, the P_2O_5 prices for subperiods 2, 3, and 4 are close to zero. This is an indication that the fertilizer type structure does not fit the nutrient demand structure. Specifically, the supply of nitrogen is partially satisfied by DAP which results in a surplus of P_2O_5 coming into the Philippines' consuming regions. Since the urea plants are operating at maximum capacity, the only other alternative to satisfy nitrogen demand from domestic production is to produce more DAP. However, DAP is not an adequate source of nitrogen since its P_2O_5 content is much higher than its nitrogen content. This apparent problem of high nitrogen prices and low P_2O_5 prices can be corrected by calculating weighted average nutrient price using nutrient contents as weights.

Economic Evaluation of Alternative Supply Strategies

The economic implications of alternative fertilizer supply strategies are discussed in terms of capital requirements, variable production costs, contribution to profits, return on investments, and total costs of supply strategies. As mentioned earlier, however, all figures are presented in 1979 constant U.S. dollars. The derived costs and returns taken collectively reflect the relative economic advantage of one supply strategy over the other.

Capital Requirements

Capital requirements are discussed in terms of investment costs for facilities to be constructed during the planning period. In Indonesia and Malaysia, all urea plants which were considered as potential new facilities are constructed during subperiod 1 in all scenarios and start production in subperiod 2. The same applies for the planned DAP plant in the Philippines and for the tentative urea facility at Sattahip in Thailand. The planned urea plant at Limay operates only in subperiod 4 of scenarios II and III and subperiods 2-4 of scenario IV. The NPK plant at Sattahip does not operate at all in scenarios I and II, very little in subperiod 4 of scenario III, and at less than full capacity in subperiods 2-4 in scenario IV.

TABLE 12. WEIGHTED AVERAGE PRICES FOR NUTRIENTS BY COUNTRY: MODEL RESULTS

	Average Prices, 1979 US $/mt[a]							
	Indonesia		Malaysia		Philippines		Thailand	
Subperiod	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
				Scenario I				
1	425	362	426	364	434	355	427	361
2	368	381	367	381	373	370	372	382
3	369	385	368	385	374	374	373	382
4	374	381	373	383	380	371	376	381
				Scenario II				
1	768	401	767	404	776	402	768	407
2	356	403	367	403	373	393	372	405
3	371	406	369	406	375	396	374	407
4	503	405	502	406	510	396	507	406
				Scenario III				
1	762	404	762	409	772	707	763	411
2	368	535	367	536	373	526	372	540
3	369	703	368	703	374	691	373	706
4	471	1,247	470	1,242	476	1,214	475	1,246
				Scenario IV				
1	371	412	619	359	674	603	606	358
2	368	412	368	424	1,411	0	125	1,403
3	369	664	369	426	1,319	2	356	1,364
4	370	412	369	426	1,318	2	546	1,082

a. Price for K_2O is always US $190 (1979) in each market region.

If all potentially planned facilities are realized, capital requirements are: US $588 million for Indonesia, US $270 million for Malaysia, US $503 million for the Philippines, and US $505 million for Thailand. This results in a total of US $1,866 million as capital required for investment to establish the new fertilizer facilities in the ASEAN region.

Variable Production Costs

Variable production costs at existing facilities are equal to raw material costs plus conversion costs. In the case of new facilities, however, the investment costs per unit of output are also added. Variable production costs for a given fertilizer, from a specified plant, are constant in terms of 1979 U.S. dollars throughout the planning period and for all scenarios. Natural gas prices were assumed to remain nominally constant at 1979 levels for all countries except Malaysia where an annual increase of 5% was assumed. These estimates were made on the basis of information provided by country representatives in 1978. This results in declining 1979 present values for natural gas and in declining variable production costs, as indicated in the bottom line of Appendix Tables B-13 through B-16. The highest cost is for subperiod 1, and the lowest cost is for subperiod 4. Costs of other raw materials are assumed to be the world market prices and were presented earlier in Table 6.

In Indonesia variable production cost for urea ranges from US $69 to US $72 at Palembang Unit I, from US $47 to US $50 at Palembang Unit II, and from US $44 to US $47 at Palembang Unit III and IV. The estimated variable costs for urea in Malaysia and Thailand are also within this range, but in the Philippines these costs for urea are US $112-$116/mt at both the existing and new plants at Limay.

The estimated variable production costs for AS in the Philippines range from US $78/mt at Toledo City to US $127/mt at Iligan City. Variable production cost of NPK is estimated to be US $185/mt in the Philippines, US $175/mt in Indonesia, and US $121/mt in Malaysia. The costs for DAP are US $229/mt in the Philippines and US $224/mt in Indonesia. The estimated variable production cost of TSP is US $157/mt in Indonesia. At the mixing/granulation plant in Thailand, the estimated cost for 20-20-0 varies from US $173 to US $183/mt. Variable production costs for the NP and NPK fertilizers at Sattahip were equal to US $170/mt for MAP, US $121/mt for 25-34-0, and US $120/mt for 22-29-7, respectively.

Contribution to Profits

The contribution to profits was calculated by subtracting the variable production cost from the fertilizer price at the production site. Since prices are used to estimate contributions to profits, the estimates are valid only under conditions of economic equilibrium. The accuracy of the estimates depends to a large degree upon the deviation of prices from real prices. Thus, they only indicate a potential for the contribution to profits. The estimated contributions are reported in Appendix Tables B-13 through B-16.

Negative values on these tables indicate that production costs exceed the estimated fertilizer price. Since prices are determined based on production costs, all products being produced have variable

costs equal to or less than the price but never higher. Negative values are shown to indicate the magnitude of financial loss, on a per-ton basis, if production occurs at those places. Since the objective is to minimize costs, those production facilities which contribute the greatest amount to profits are selected first for fertilizer production.

The results reported in these tables indicate that, in general, the urea facilities of the region are highly economical, especially those located in Indonesia. Among the possible new urea production sites, Aceh, Bontang, Bintulu, and Sattahip contribute around US $100/mt of urea toward profits. The new facility at Limay contributes enough profit to justify construction only in scenario IV and subperiod 4 of scenarios II and III.

On the other hand, the uncompetitive position of ammonium sulfate and NP/NPK is shown for nearly all cases. Some exceptions occur during subperiod 1 with its high prices. The TSP production facility at Gresik is in a rather good position. Diammonium-phosphate production at a possible plant at Limay gives a low contribution to profit. An exception is found in the case of Thailand at Sattahip. The whole multinutrient and urea complex seems to be economical only in scenario IV and in subperiod 4 of scenario III. In the remaining scenarios only the urea facility of this plant seems economical.

Return on Investment

The return on investment (ROI) is calculated by dividing the plant specific total contribution to profits (product specific contribution to profits per ton times tons produced) by the initial investment. The ROI is used mainly for comparisons of different investments. It reflects the rate of return on an investment that can be achieved under equilibrium conditions.

On the basis of the possible contribution to profits and considering the investment to be made for each new plant, an assessment of the ROI was made. Table 13 shows ROI figures for plants that are under construction and for potential new plants which are considered.

The figures indicate that the potential urea facilities in Indonesia and Malaysia have a high ROI. With respect to relative profitability, these facilities appear to have economic advantage over the urea and DAP facilities that are planned to be built near Limay and on Leyte in the Philippines. Furthermore, the tentative facilities at Sattahip also show a positive ROI. However, the ROI is valid only for the ammonia-urea plant, except for scenario IV and subperiod 4 of scenario III when the NP and NPK facilities are also built and operated.

The urea plant at Limay has the highest ROI in scenario IV. This is due partially to high prevailing nitrogen prices in the Philippines for this scenario and partially to the fact that it uses fuel oil as raw material. The Leyte urea plant exhibits a very low ROI in scenarios I, II, and IV and a high ROI in scenario III. Even though the ROI is low for these scenarios, operating this plant is part of the scheme that minimizes total fertilizer supply cost to the region.

Costs for Supplying Regional Requirements

In considering the costs of supplying the fertilizer demands of the entire ASEAN region, two cost categories are used. These categories are "total expenses" and "avoidable costs."

Total expenses represent the total value that the countries and region would pay for fertilizers delivered to consuming regions over the entire planning period at market prices. Total expenses are calculated by adding the value of products at central points of market regions. These values are shown for individual nutrients by subperiods and scenarios in Appendix Tables B-17 through B-20. However, the total expenses are summarized in Table 14.

Scenario I is the lowest total expense supply alternative for each country. Other scenarios have mixed effects among the different countries. The most expensive scenario for Indonesia and Malaysia is scenario III while for the other two countries scenario IV is the most expensive. One factor which reduces the cost of scenario IV for Indonesia and Malaysia compared with that of other countries is the value of exports at world market prices. This increases total revenue from the sale of nitrogen fertilizers. The greatest contribution to the increased expenditure for scenario III for Malaysia and Indonesia is the increased expense for production of P_2O_5. In the Philippines scenario IV expenses are considerably greater than those of other scenarios because of the greatly increased expense for production of nitrogen. In Thailand expenses increase gradually from scenario I through IV, and the greatest increase is due to the expense of supplying P_2O_5.

On the other hand, avoidable costs represent the minimum total costs of production, imports, exports, transportation, and construction activities. They do not include capital costs of facilities operating at the beginning of the planning period. Those capital costs are no longer decision parameters for plant managers. In other words, sunken costs are not included.

The differences between avoidable costs for various scenarios indicate the extent to which formulated supply strategies could lead to different total costs to meet fertilizer needs for the whole ASEAN region. Avoidable costs for the region are shown for each scenario in Table 14. Scenario I, which contains fewer constraints to supply possibilities, allows the lowest cost supply of fertilizer to meet the needs of the whole ASEAN region. Scenario IV represents the most expensive supply strategy.

The total expenses, which also represent the total value of production, of the whole ASEAN region exceed the avoidable costs by 100%-150%. This represents the realized ROI of activities associated with supplying the fertilizer needs of the whole region.

Suggested Improvement and Applications

Because complex fertilizer sector planning models are seldom free from some shortcomings, there is always a scope for further improvements. The present study can be improved in three different but related areas. First, the structural and behavioral aspects of the planning model itself can be improved by adding new activities, constraints, and behavior rules to represent uncertainty and expectations. Second, some of the simplifying assumptions with respect to fertilizer sector, planning horizon, and the planning region can be modified. Third, the input

TABLE 13. ESTIMATED RETURN ON INVESTMENT AT EXPANSION SITES: MODEL RESULTS

Subperiod	Aceh Urea	Bontang Urea	Bintulu Urea	Leyte DAP	Limay Urea	Sattahip NP, Urea
	Return on Investment, %					
			Scenario I			
1	0	0	0	0	0	0
2	21	19	19	0	0	13
3	21	20	19	0.3	0	13[a]
4	21	20	19	0.3	0	14[a]
			Scenario II			
1	0	0	0	0	0	0
2	21	19	19	3	0	13[a]
3	21	20	19	3	0	13[a]
4	33	30	29	9	11	20[a]
			Scenario III			
1	0	0	0	0	0	0
2	21	19	19	18	0	13[a]
3	21	20	19	37	0	13[a]
4	30	28	27	104	3	16
			Scenario IV			
1	0	0	0	0	0	0
2	21	19	19	4	55	26
3	21	20	19	0	50	39
4	21	20	19	0	50	37

a. Only ammonia/urea plant built.

TABLE 14. ESTIMATED TOTAL EXPENSES AND AVOIDABLE COSTS TO SUPPLY FERTILIZERS TO THE ASEAN REGION DURING 1981-92: MODEL RESULTS

Scenario	Indonesia	Malaysia	Philippines	Thailand	Total Supply Expenses	Total Avoidable Costs
	Estimated Total Expenses					
	(millions of 1979 US dollars)					
I	5,499	1,539	2,046	2,294	11,376	5,809
II	6,614	1,764	2,504	2,846	13,728	6,019
III	8,198	1,967	2,718	3,565	16,448	6,164
IV	5,824	1,637	5,317	4,087	16,865	7,328

data can be further updated and refined. The quality of data used in empirical estimation determines, to a great extent, the reliability of the model results. This problem can be partly removed by conducting sensitivity analysis with respect to key parameters and policy variables.

Complex mathematical programming models, being normative in nature, cannot be validated with respect to their predictability by using standard statistical tests. However, despite some obvious shortcomings the model appears to have performed extremely well in simulating the general features of the fertilizer sector in the ASEAN region.

Despite attempts to realistically portray the fertilizer economy in the ASEAN region, some simplifying assumptions with respect to data can be removed or modified. For example, the input prices and costs were developed at the beginning of the steep price increase of 1979. The level and structure of input prices, costs, and output prices have since changed. However, despite these changes, the technical and economic structure of the ASEAN fertilizer industry has not changed very much. The general implications of the model appear valid in providing guidelines to the planners in the region for fertilizer sector development, individually or in cooperation with each other. The economic decisions, with respect to the ASEAN fertilizer sector, and on the basis of the results of this model, appear logical and better than those decisions which might be based on pure descriptive analysis or political considerations.

The model results are very instructive in providing some guidelines to the planners in the region with respect to broad economic implications of alternative supply strategies. However, the planners must keep in mind the idealistic character of the model results. This is especially true with respect to the interpretation of fertilizer prices, contribution to profits, and return on investments. Furthermore, this study evaluates only four fertilizer supply strategies which were considered appropriate for the ASEAN region. However, depending on the data availability, computation facilities, time, and planning objectives, the model can be adapted to evaluate any number of alternative fertilizer strategies.

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APPENDIX A

Selected Model Input Data

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Appendix Table A-1. Selected Characteristics of Existing and Potential Fertilizer Plants in the ASEAN Region

Site	Product	Plant Status[a]	Capacity (mt/day)	Raw Material or Intermediates	Conversion Cost[b] 1979 US $/mt	Capital Investment[c] 1979 US $ million Facilities	Working
				Indonesia			
Gresik	Ammonia	OPR (1972)	240	Fuel Oil	115	-	-
	AS	OPR (1972)	450	Sulfur	23	-	-
	Sulfuric acid	OPR (1972)	340	Phosphate rock	-1	-	-
	TSP	OPR (1979)	1,200	Potash			
	DAP	OPR (1979)	d 1,800	d Phosphoric acid	11/9/7	-	-
	NPK	OPR (1979)	1,800	Ammonia			
Cikampek	Ammonia	OPR (1979)	1,000	Natural gas	47	-	-
	Urea	OPR (1979)	1,700		25	-	-
Palembang							
I	Ammonia	OPR (1963)	180	Natural gas	60	-	-
	Urea	OPR (1963)	300		30	-	-
II	Ammonia	OPR (1974)	700	Natural gas	45	-	-
	Urea	OPR (1974)	1,150		17	-	-
III	Ammonia	OPR (1976)	1,000	Natural gas	41	-	-
	Urea	OPR (1976)	1,700		16	-	-
IV	Ammonia	OPR (1977)	1,000	Natural gas	41	-	-
	Urea	OPR (1977)	1,700		16	-	-
Aceh	Ammonia	CTN (1981)	1,000	Natural gas	47	160	3
	Urea	CTN (1981)	1,725		19	100	5
Bontang	Ammonia	PLN	1,500	Natural gas	45	200	5
	Urea	PLN	1,725		23	100	15
				Malaysia			
Pt. Dickson	Ammonia	OPR (1966)	150	Naphtha or ref. gas	115	-	-
Petaling Jaya	Sulfuric acid	OPR (1970)	150	Sulfur	9	-	-
	Nitric acid	OPR (1966)	80	Ammonia from Pt. Dickson	28		
	AS	OPR (1970)	180		30	-	-
	NPK	OPR (1966)	800	Potash	30	-	-
Bintulu	Ammonia	CON	1,000	Natural gas	46	160	5
	Urea	CON	1,500		28	90	15

(Continued)

Appendix Table A-1. Selected Characteristics of Existing and Potential Fertilizer Plants in the ASEAN Region (Continued)

Site	Product	Plant Status[a]	Capacity (mt/day)	Raw Material or Intermediates	Conversion Cost[b] 1979 US $/mt	Capital Investment[c] 1979 US $ million Facilities	Capital Investment[c] 1979 US $ million Working
				Philippines			
Limay	Ammonia	OPR (1965)	270	Ref. gas	100	-	-
	Urea	OPR (1965)	190		48	-	-
	Sulfuric acid	OPR (1965)	620	Pyrites	-1	-	-
	Phosphoric acid P_2O_5	OPR (1965)	210[f]	Phosphate rock	66	-	-
	NPK	OPR (1965)	730	Potash	30	-	-
Pasig	Sulfuric acid	OPR (1966)	180	Sulfur	5	-	-
	AS	OPR (1966)	90	Ammonia	37	-	-
Toledo City	Phosphoric acid	OPR (1958)	30[f]	Phosphate rock	g	-	-
	Sulfuric acid	OPR (1958)	250	Pyrites	3	-	-
	AS	OPR (1958)	250	Ammonia	27	-	-
	NP/NPK	OPR (1958)	200	Potash	45	-	-
Iligan City[e]	Ammonia	OPR (1966)	80	Naphtha	135	-	-
	Sulfuric acid	OPR (1954)	120	Pyrites	10	-	-
	AS	OPR (1966)	150		31	-	-
Limay (expansion)	Ammonia	CON (1982)	600	Naphtha or	102	130	10
				fuel oil	92	175	10
	Urea	CON (1982	1,000		46	75	20
Leyte	Phosphoric acid P_2O_5	CON (1982)	350[f]	H_2SO_4 from Cu smelter	59	42	5
	DAP	CON (1982)	700	Ammonia	29	26	10
				Thailand			
Mae Moh	Ammonia	OPR (1966)	82	Lignite	130	-	-
	Urea	OPR (1975)	76		60	-	-
	Sulfuric acid	OPR (1975)	300	Sulfur	2	-	-
	AS	OPR (1975)	175		30	-	-
Bangkok	NP/NPK	OPR (1975)	400	Ammonium chloride Diammonium phosphate	40	-	-
	NP/NPK	OPR (1978)	800	Potash	30	-	-

(Continued)

Appendix Table A-1. Selected Characteristics of Existing and Potential Fertilizer Plants in the ASEAN Region (Continued)

Site	Product	Plant Status[a]	Capacity (mt/day)	Raw Material or Intermediates	Conversion Cost[b] 1979 US $/mt	Capital Investment[c] 1979 US $ million	
						Facilities	Working
				Thailand (Continued)			
Sattahip	Ammonia	CON	1,200	Natural gas	45	191	5
	Urea crystals	CON	1,200		15	61	3
	Urea granular	CON	800		6	21	7
	Phosphoric acid	CON	700[f]	Phosphate rock	22	61	5
	Sulfuric acid	CON	2,000	Sulfur	8	56	3
	Powdered MAP	CON	350		5	6	4
	NP (22-29-7) + (25-34-0)	CON	1,500	Potash	9	59	23

a. OPR--operational, CTN--under construction, PLN--being planned, CON--to be constructed. The number in parentheses indicates startup year.
b. Do not include raw materials, depreciation, and interest. Based on 95% capacity utilization, except for PUSRI I and Gresik plants which are based on 90%.
c. IFDC cost estimates for projects under construction or in planning stages. Estimates do not include escalation during construction.
d. Maximum capacity if one fertilizer type is produced.
e. Iligan City production facilities to be phased out in 1985.
f. Capacity is in terms of quantity of P_2O_5.
g. Not estimated--Limay estimate taken.

Appendix Table A-2. Production, Imports, and Exports of Fertilizer in the ASEAN Region, 1970-79

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
	Production or Trade, thousand mt									
					N Production					
Indonesia	39.3	45.3	48.2	59.9	85.2	165.9	207.5	184.2	396.1	736.0
Malaysia	31.0	26.0	42.5	40.0	46.2	37.0	34.0	38.7	37.7	37.4
Philippines	53.5	47.7	58.6	55.4	53.5	53.4	62.1	48.4	37.9	45.7
Thailand	8.0	11.5	10.3	7.7	7.4	6.7	4.3	6.9	8.9	3.5
TOTAL	131.8	130.5	159.6	163.0	192.3	263.0	307.9	281.5	485.9	822.6
					N Imports					
Indonesia	107.6	99.0	214.7	244.9	293.0	611.0	159.0	103.0	9.9	17.1
Malaysia	30.5	33.9	44.3	38.3	55.6	75.2	44.9	73.4	66.0	103.0
Philippines	47.9	71.4	94.0	51.0	94.6	239.4	44.1	63.2	141.6	117.5
Thailand	41.0	36.0	52.0	55.0	52.9	73.1	74.6	129.7	151.2	178.9
TOTAL	227.0	240.3	405.0	389.2	496.1	998.7	322.6	369.3	368.7	416.5
					N Exports					
Indonesia	0	0	0	0	0	0	0	0	184.1	106.0
Malaysia	0	1.4	2.8	5.3	5.7	5.8	5.5	0	0	0
Philippines	0	3.0	1.2	0	0	0	0	0	4.5	1.2
Thailand	0	0	0	0	0	0	0	0	0	0
TOTAL	0	4.4	6.0	5.3	5.3	5.8	5.5	0	188.6	107.2
					P_2O_5 Production					
Indonesia	0	0	0	0	0	0	0	0	0	0
Malaysia	23.5	22.9	21.2	26.0	24.3	0	20.9	22.0	25.3	28.8
Philippines	39.0	41.0	41.7	41.8	41.0	42.1	31.2	31.0	29.3	36.1
Thailand	0	0	0	0	0	0	0	0	0	0
TOTAL	62.5	63.9	62.9	67.8	65.3	42.1	52.1	53.0	54.6	64.9

(Continued)

Appendix Table A-2. Production, Imports, and Exports of Fertilizer in the ASEAN Region, 1970-79 (Continued)

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
	Production or Trade, thousand mt									
	P_2O_5 Imports									
Indonesia	62.6	18.0	21.6	96.0	85.0	34.8	81.9	7.9	44.2	121.5
Malaysia	17.0	22.9	12.5	10.8	16.0	18.3	12.7	19.3	17.0	75.0
Philippines	25.0	0.8	5.2	2.1	6.5	47.7	0.6	0	0	8.2
Thailand	45.0	23.5	43.3	55.9	51.4	70.4	62.2	80.3	132.6	125.0
TOTAL	149.6	65.2	82.6	164.8	158.9	171.2	157.4	107.5	183.8	329.7
	P_2O_5 Exports									
Indonesia	0	0	0	0	0	0	0	0	0	0
Malaysia	0	0	0	5.3	4.8	0	0	0	0	0
Philippines	0	2.9	1.3	0	1.6	0	0	0	5.6	1.5
Thailand	0	0	0	0	0	0	0	0	0	0
TOTAL	0	2.9	1.3	5.3	6.4	0	0	0	5.6	1.5
	K_2O Imports									
Indonesia	8.2	6.8	4.7	29.9	40.3	33.2	13.4	30.0	40.0	77.2
Malaysia	56.1	75.7	74.9	80.8	89.3	102.9	118.7	143.4	173.2	190.0
Philippines	37.7	36.4	36.6	45.0	46.6	86.3	44.0	48.0	42.8	53.9
Thailand	20.6	15.0	22.8	42.0	38.4	50.9	39.1	20.5	29.8	34.0
TOTAL	122.6	133.9	139.0	197.7	214.6	273.3	215.2	241.9	285.8	355.1

Source: FAO, Fertilizer Yearbook, various issues.

Appendix Table A-3. Nutrient Consumption in ASEAN Countries, 1970-79

Country	Consumption, thousand mt										Average Annual Compound Growth Rate, %
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
					N						
Indonesia	105.5	201.7	196.3	347.4	350.0	345.0	341.9	351.2	465.2	524.0	19.5
Malaysia	52.4	66.4	66.6	80.8	112.2	68.9	77.6	83.5	96.8	106.9	8.2
Philippines	101.4	119.2	122.0	114.5	151.9	177.4	144.1	177.2	174.2	205.4	8.2
Thailand	49.0	42.5	62.0	62.0	60.2	79.8	78.9	136.3	160.1	153.5	13.5
TOTAL	308.3	429.8	446.9	604.7	674.3	671.1	642.5	748.2	896.3	989.8	13.8
					P_2O_5						
Indonesia	62.6	28.9	23.1	66.8	85.0	114.1	116.5	106.7	108.2	123.5	7.8
Malaysia	17.0	22.9	12.0	25.6	35.2	29.1	28.3	36.4	16.0	52.4	13.3
Philippines	64.0	44.0	50.0	39.9	51.0	47.8	34.0	40.0	40.4	49.8	-2.7
Thailand	45.3	23.5	43.3	55.9	51.4	70.4	62.2	80.3	90.0	104.4	9.7
TOTAL	188.9	119.3	128.4	188.2	222.6	261.4	241.0	263.4	254.6	330.1	6.4
					K_2O						
Indonesia	8.2	6.5	4.7	29.9	40.3	33.0	25.0	30.0	25.4	75.4	28.0
Malaysia	56.1	75.7	76.8	80.8	89.3	102.9	113.7	141.1	150.8	172.7	13.3
Philippines	30.0	40.0	37.7	38.8	55.6	60.0	48.8	51.5	45.9	56.6	7.3
Thailand	10.8	15.0	22.8	42.0	38.4	50.9	39.1	20.5	25.0	30.0	12.0
TOTAL	105.1	137.2	140.0	191.5	223.6	246.8	246.8	243.1	247.1	334.7	13.7

Source: FAO, Fertilizer Yearbook, various issues.

Appendix Table A-4. Selected Fertilizer Raw Material Reserves in the Southeast Asian Region

Region	Main Port	Lignite	Crude Oil	Natural Gas	Pyrites	Rock Phosphates	Potash Salts
North Thailand	Bangkok	Mae Moh: 80 million mt Li: 15 million mt	Fang: oil quantity not exactly known Li: oil shale Thailand reserves: 140,000 bbl	Total Thailand: $8,000 \times 10^9$ ft^2		Total Thailand: 50,000 mt of P_2O_5	In excess of 10×10^6 mt of K_2O
South Thailand	Plukeit	Krabi: 100 million mt					
North Sumatra	Aceh		Indonesian reserves: $9,600 \times 10^6$ bbl, reserves obviously are not a limiting factor at any of the locations mentioned	Indonesian reserves: $24,000 \times 10^9$ ft^3, reserves obviously are not a limiting factor at one of the locations mentioned		500,000 mt rock, exploitation not probable in larger scale	
South Sumatra West Java	Palembang						
East Kalimantan	Bontang or Balikpapan						
Brunei	Kuala - - Belait		$1,800 \times 10^6$ bbl	$7,700 \times 10^9$ ft^3			
Malaysia Peninsula	-		Malaysian reserves: $2,800 \times 10^6$ bbl	Malaysian reserves: $17,000 \times 10^9$ ft^3		100,000 mt rock, exploitation not probable	
Malaysia Sabah	-						
Malaysia Sarawak	-						
Philippines	-		25×10^6 bbl		60×10^6 mt	454,000 mt rock, small-scale exploitation	

Sources: International Petroleum Encyclopedia, 1980, and unpublished IFDC information.

Appendix Table A-5. Nutrient Demand Projections by Market Region (1981-92)[a]

Country	Market Region	Central Demand Point (Port)	1981-83			1984-86			1987-89			1990-92		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
			(thousand mt of nutrients/year)											
Indonesia	Kalimantan, East	Balikpapan	18	7	0.6	22	9	0.7	27	11	1	32	14	1
	Kalimantan, West	Pontianak	6	2	0.6	7	3	0.7	9	4	1	11	5	1
	Sulawesi	Ujung Pandang	30	11	0.6	37	15	0.7	45	19	1	54	24	1
	East Java	Surabaja	167	62	7	207	83	9	250	107	11	298	133	13
	Central Java	Cilacap	143	53	3	177	71	3.5	215	92	4	256	116	5
	West Java	Jakarta	155	58	7	192	77	9	232	100	11	276	126	13
	South Sumatra	Palembang	18	7	0.6	22	9	0.7	27	11	1	32	14	1
	Central Sumatra	Padang	24	9	0.6	30	12	0.7	36	15	1	43	19	1
	North Sumatra	Belawan	35	13	35	44	17	45	54	23	56	63	29	67
	TOTAL		596	222	55	738	296	70	895	382	87	1,065	480	103
Malaysia	West Malaysia (Penisula W.)	Port Dickson	92	28	128	102	33	159	114	37	193	126	42	228
	West Malaysia (Penisula E.)	Kuantan	28	9	38	31	10	47	34	11	58	37	12	69
	Sarawak	Bintulu	9	3	7	10	4	9	12	4	10	13	4	12
	Sabah	Kota Kinabalu	5	3	9	8	3	10	9	3	11	10	3	13
	TOTAL		134	43	182	151	50	225	169	55	272	186	61	322
Philippines	North Philippines	Manila	110	23	26	126	24	26	150	27	27	176	29	29
	Central Philippines	Iloilo	99	21	23	132	26	28	157	28	29	184	31	31
	South Philippines	Cagayan de Oro	51	11	12	56	11	12	67	12	12	78	13	13
	TOTAL		260	55	61	314	61	66	374	67	68	438	73	73
Thailand	TOTAL	Bangkok	222	165	47	256	188	57	291	212	67	326	236	77
GRAND TOTAL			1,212	485	345	1,459	595	418	1,729	716	494	2,015	850	575

a. For the midpoint of the years indicated.

Appendix Table A-6. Input Requirements for Intermediates and Fertilizer Products

Product	Input Requirement per mt
Ammonia	22,700 ft^3 of natural gas or 22,900 ft^3 of refinery gas/mt or 0.75 mt of fuel oil or 0.56 mt of naphtha or 2.62 mt of lignite/mt
Nitric acid	0.283 mt of ammonia/mt
Sulfuric acid	0.72 mt of pyrite or 0.344 mt of sulfur/mt
Phosphoric acid	3.10 mt of phosphate rock plus 2.62 mt of sulfuric acid/mt
Ammonium sulfate	0.27 mt of ammonia plus 0.75 mt of sulfuric acid/mt
Urea	0.60 mt of ammonia/mt
Triple superphosphate	0.36 mt of P_2O_5 as phosphoric acid plus 0.41 mt of phosphate rock/mt
Diammonium phosphate	0.25 mt of ammonia plus 0.46 mt of phosphoric acid/mt
Monoammonium phosphate	0.60 mt of ammonia plus 0.53 mt of phosphoric acid/mt

Appendix Table A-7. Input Requirements for Selected Compound Fertilizer Grades

Inputs	Quantity of Inputs, mt/mt of Product					
	Philippines	Indonesia	Malaysia	Thailand		
	14-14-14	15-15-15	15-15-15	20-20-0	25-34-0	22-29-7
Ammonia	0.045	0.048	0.110	-	0.170	0.150
Ammonium chloride	-	-	-	0.610	-	-
Ammonium sulfate	0.464	0.362	0.030	-	-	-
Nitric acid	-	-	0.280	-	-	-
Urea	0.017	0.081	-	-	0.270	0.235
Phosphoric acid	0.140	0.150	-	-	0.350	0.300
Phosphate rock	-	-	0.500	-	-	-
Triple superphosphate	0.059	0.080	-	-	-	-
KCl (60%)	0.234	0.250	0.250	-	-	0.130
Diammonium phosphate	-	-	-	0.390	-	-

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Appendix Table B-1. Fertilizer Production in Indonesia

Subperiod	Fertilizer Production, thousand mt of product/year									
	Existing Plants								Expansion Sites	
	Gresik				Cikampek	Palembang			Aceh	Bontang
	AS	DAP	15-15-15	TSP	Urea	I Urea	II Urea	III + IV Urea	Urea	Urea
					Scenario I					
1	0	72	0	82	523	89	361	1,045	0	0
2	0	72	0	297	523	89	361	1,045	523	533
3	0	72	0	297	523	89	361	1,045	523	533
4	0	72	0	297	523	89	361	1,045	523	533
					Scenario II					
1	117	72	45	293	523	89	361	1,045	0	0
2	0	72	0	297	523	89	361	1,045	523	533
3	0	72	0	297	523	89	361	1,045	523	533
4	0	72	0	297	523	89	361	1,045	523	533
					Scenario III					
1	117	72	45	297	523	89	361	1,043	0	0
2	0	72	0	297	523	89	361	1,045	523	533
3	0	72	45	297	523	89	361	1,041	523	533
4	0	72	45	293	523	89	361	1,045	523	533
					Scenario IV					
1	0	72	0	297	523	89	361	1,045	0	0
2	0	72	0	297	523	89	361	1,045	523	470
3	0	72	19	297	521	89	361	1,045	523	470
4	0	72	0	297	523	89	361	1,045	523	470
	Effective Capacity, thousand mt product/year									
	134	72	45	297	534	89	361	1,066	533	533

Appendix Table B-2. Fertilizer Production in Malaysia

Subperiod	Fertilizer Production, thousand mt of product/year		
	Existing Plant		Expansion Site
	Petaling Jaya		Bintulu
	AS	15-15-15	Urea
	Scenario I		
1	0	85	0
2	0	85	446
3	0	85	446
4	0	85	446
	Scenario II		
1	51	85	0
2	0	85	446
3	0	85	446
4	0	85	446
	Scenario III		
1	51	85	0
2	0	85	446
3	0	85	445
4	0	85	446
	Scenario IV		
1	37	85	0
2	0	85	446
3	0	85	446
4	0	85	446
	Effective Capacity, thousand mt of product/year		
	54	85[a]	446[b]

a. Total capacity is equal to 238,000 mtpy, but nitric acid capacity limits NPK production to 85,000 mtpy.
b. Excess capacity of ammonia of 145,000 mtpy.

Appendix Table B-3. Fertilizer Production in the Philippines

	Fertilizer Production, thousand mt of product/year							
	Existing Plants						Expansion Sites	
	Limay		Pasig	Toledo City		Iligan City	Leyte	Limay
Subperiod	14-14-14	Urea	AS	AS	14-14-14	AS	DAP	Urea
				Scenario I				
1	0	56	0	72	0	0	0	0
2	0	56	0	0	0	0	208	0
3	0	56	0	0	0	0	208	0
4	0	56	0	0	0	0	208	0
				Scenario II				
1	91	56	27	74	0	45	0	0
2	0	56	0	0	0	0	208	0
3	0	56	0	0	0	0	208	0
4	0	56	0	74	0	0	208	297
				Scenario III				
1	91	56	27	74	0	45	0	0
2	0	56	0	0	0	0	208	0
3	20	56	0	0	0	0	208	0
4	217	56	0	0	59	0	208	102
				Scenario IV				
1	0	56	27	47	59	15	0	0
2	217	56	27	74	0	45	171	293
3	217	56	27	74	0	45	126	293
4	217	56	27	74	0	45	114	293
	Effective Capacity, thousand mt of product/year							
	217	56	27	74	59	45	208	297

Appendix Table B-4. Fertilizer Production in Thailand

	Fertilizer Production, thousand mt of product/year						
	Existing Plants			Expansion Site			
	Mae Moh		Bangkok	Sattahip			
Subperiod	AS	Urea	20-20-0	11-54-0[a]	25-34-0	22-29-7	Urea
				Scenario I			
1	0	23	0	0	0	0	0
2	0	23	0	0	0	0	238
3	0	23	0	0	0	0	238
4	0	23	0	0	0	0	238
				Scenario II			
1	40	23	360	0	0	0	0
2	0	23	0	0	0	0	238
3	0	23	0	0	0	0	238
4	0	23	182	0	0	0	238
				Scenario III			
1	40	23	360	0	0	0	0
2	0	23	97	0	0	0	238
3	0	23	360	0	0	0	238
4	0	23	360	0	0	107	238
				Scenario IV			
1	40	23	352	0	0	0	0
2	0	0	360	0	223	139	213
3	0	11	360	0	223	222	238
4	30	23	360	0	223	182	238
	Effective Capacity, thousand mt of product/year						
	52	23	360	104	223	223	238

a. MAP is to be produced only to use as intermediate in Bangkok plant.

Appendix Table B-5. Sources of Supply of Plant Nutrients as Finished Fertilizers to Market Regions in Indonesia

	Quantity of Plant Nutrients, thousand mtpy											
	In Country			Other ASEAN Countries			Non-ASEAN Countries			Total		
Subperiod	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
					Scenario I							
1	559	127	0	0	0	0	37	95	55	596	222	55
2	689	170	0	10	26	0	39	100	70	738	296	70
3	812	170	0	8	22	0	75	190	87	895	382	87
4	945	170	0	6	16	0	114	294	103	1,065	480	103
					Scenario II							
1	566	137	7	0	0	0	30	85	48	596	222	55
2	729	170	0	9	24	0	0	102	70	738	296	70
3	891	170	0	4	22	0	0	190	87	895	382	87
4	1,059	170	0	6	16	0	0	294	103	1,065	480	103
					Scenario III							
1	559	134	7	7	7	7	30	81	41	596	222	55
2	738	148	0	0	0	0	0	148	70	738	296	70
3	889	175	7	6	16	0	0	191	80	895	382	87
4	1,040	175	7	25	65	0	0	240	96	1,065	480	103
					Scenario IV							
1	596	170	0	0	0	0	0	52	55	596	222	55
2	738	170	0	0	0	0	0	126	79	738	296	79
3	895	172	3	0	0	0	0	210	84	895	382	87
4	1,065	170	0	0	0	0	0	310	103	1,065	480	103

Appendix Table B-6. Sources of Supply of Plant Nutrients as Finished Fertilizers to Market Regions in Malaysia

	Quantity of Plant Nutrients, thousand mtpy											
	In Country			Other ASEAN Countries			Non-ASEAN Countries			Total		
Subperiod	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
					Scenario I							
1	13	13	13	110	0	0	11	30	169	134	43	182
2	28	13	13	112	8	0	11	29	212	151	50	225
3	31	13	13	124	7	0	14	35	259	169	55	272
4	33	13	13	137	7	0	16	41	309	186	61	322
					Scenario II							
1	23	13	13	104	11	0	7	19	169	134	43	182
2	28	13	13	123	11	0	0	26	212	151	50	225
3	31	13	13	138	7	0	0	35	259	169	55	272
4	33	13	13	153	7	0	0	41	309	186	61	322
					Scenario III							
1	16	6	6	116	15	0	2	22	176	134	43	182
2	29	13	13	122	12	0	0	25	212	151	50	225
3	32	13	13	137	15	0	0	27	259	169	55	272
4	34	13	13	152	17	2	0	31	307	186	61	322
					Scenario IV							
1	20	13	13	0	0	0	114	30	169	134	43	182
2	151	13	13	0	0	0	0	37	212	151	50	225
3	169	13	13	0	0	0	0	42	259	169	55	272
4	186	13	13	0	0	0	0	48	307	186	61	320

Appendix Table B-7. Sources of Supply of Plant Nutrients as Finished Fertilizers to Market Regions in the Philippines

	Quantity of Plant Nutrients, thousand mtpy											
	In Country			Other ASEAN Countries			Non-ASEAN Countries			Total		
Subperiod	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
					Scenario I							
1	40	0	0	147	0	0	73	55	61	260	55	61
2	50	61	0	264	0	0	0	0	66	314	61	66
3	52	67	0	322	0	0	0	0	68	374	67	68
4	54	73	0	384	0	0	0	0	73	438	73	73
					Scenario II							
1	68	13	13	179	5	0	13	37	48	260	55	61
2	51	61	0	263	0	0	0	0	66	314	61	66
3	52	67	0	322	0	0	0	0	68	374	67	68
4	69	73	0	369	0	0	0	0	73	438	73	73
					Scenario III							
1	68	13	13	179	15	0	13	27	48	260	55	61
2	38	31	0	276	0	0	0	30	66	314	61	66
3	41	34	3	333	0	0	0	33	65	374	67	68
4	108	35	35	330	2	2	0	36	36	438	73	73
					Scenario IV							
1	52	8	8	0	0	0	208	47	53	260	55	61
2	251	109	30	0	0	0	63	0	36	314	109[a]	66
3	243	89	30	0	0	0	131	0	38	374	89[a]	68
4	241	83	30	0	0	0	197	0	43	438	83[a]	73

a. In these cases an oversupply of P_2O_5 exists because DAP was produced to meet the N requirements.

Appendix Table B-8. Sources of Supply of Plant Nutrients as Finished Fertilizers to Market Regions in Thailand

	Quantity of Plant Nutrients, thousand mtpy											
	In Country			Other ASEAN Countries			Non-ASEAN Countries			Total		
Subperiod	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
					Scenario I							
1	10	0	0	147	0	0	65	165	47	222	165	47
2	120	0	0	63	0	0	73	188	57	256	188	57
3	120	0	0	88	0	0	83	212	67	291	212	67
4	120	0	0	114	0	0	92	236	77	326	236	77
					Scenario II							
1	90	72	0	121	22	0	11	71	47	222	165	47
2	120	0	0	136	0	0	0	188	57	256	188	57
3	120	0	0	171	0	0	0	212	67	291	212	67
4	156	36	0	170	0	0	0	200	77	326	236	77
					Scenario III							
1	90	72	0	121	10	0	11	83	47	222	165	47
2	139	19	0	117	75	0	0	94	57	256	188	57
3	192	72	0	99	34	0	0	106	67	291	212	67
4	215	103	8	111	15	0	0	118	69	326	236	77
					Scenario IV							
1	89	70	0	0	0	0	133	95	47	222	165	47
2	256	188	10	0	0	0	0	0	47	256	188	57
3	291	212	16	0	0	0	0	0	51	291	212	67
4	293	201	13	0	0	0	33	35	64	326	236	77

Appendix Table B-9. Estimated Fertilizer Prices at Production Sites in Indonesia

Subperiod	Fertilizer Prices, 1979 US $/mt of Product									
	Gresik				Cikampek	Palembang			Aceh	Bontang
	AS	DAP	15-15-15	TSP	Urea	I Urea	II Urea	III + IV Urea	Urea	Urea
					Scenario I					
1	77	233	138	157	186	185	185	185	0	0
2	72	232	133	165	162	160	160	160	160	160
3	72	234	133	167	162	160	160	160	160	160
4	72	234	134	166	164	162	162	162	160	163
					Scenario II					
1	146	312	195	174	344	342	342	342	0	0
2	100	242	162	175	162	160	160	160	160	160
3	101	244	137	177	162	161	161	161	160	161
4	97	268	157	177	225	222	222	222	220	222
					Scenario III					
1	145	313	195	176	342	340	340	340	0	0
2	84	302	157	235	161	160	160	160	160	160
3	101	380	181	313	162	160	160	160	160	160
4	109	649	278	564	210	207	207	207	205	207
					Scenario IV					
1	66	246	141	179	162	160	160	160	0	0
2	66	245	161	178	161	160	160	160	160	160
3	109	362	175	295	162	160	160	160	160	160
4	109	246	137	179	163	160	160	160	160	160

Appendix Table B-10. Estimated Fertilizer Prices at Production Sites in Malaysia

Subperiod	Fertilizer Prices, 1979 US $/mt of Product		
	Petaling Jaya		Bintulu
	AS	15-15-15	Urea
		Scenario I	
1	93	138	-
2	101	133	160
3	102	133	160
4	101	133	163
		Scenario II	
1	145	196	-
2	101	136	160
3	102	137	161
4	106	156	222
		Scenario III	
1	144	196	-
2	65	156	160
3	66	183	160
4	106	278	207
		Scenario IV	
1	113	165	-
2	106	137	160
3	106	137	160
4	106	137	160

Appendix Table B-11. Estimated Fertilizer Prices at Production Sites in the Philippines

	Fertilizer Prices, 1979 US $/mt of Product							
	Limay		Pasig	Toledo City		Iligan City	Leyte	Limay
Subperiod	14-14-14	Urea	AS	AS	14-14-14	AS	DAP	Urea
				Scenario I				
1	129	192	79	78	128	79	-	-
2	123	164	86	86	122	86	228	171
3	124	165	87	86	123	86	230	171
4	124	167	87	86	123	86	230	167
				Scenario II				
1	182	349	147	146	183	147	-	-
2	126	164	116	66	125	66	239	164
3	132	165	87	86	113	93	241	165
4	146	226	94	93	188	94	265	226
				Scenario III				
1	182	347	146	146	183	146	-	-
2	166	164	86	66	151	86	300	172
3	168	165	88	66	169	67	377	173
4	254	212	110	108	255	108	643	212
				Scenario IV				
1	198	301	126	126	196	127	-	-
2	215	640	274	274	270	275	246	640
3	202	598	255	255	203	256	229	598
4	202	597	255	255	211	256	229	597

Appendix Table B-12. Estimated Fertilizer Prices at Production Sites in Thailand

	Fertilizer Prices, 1979 US $/mt of Product						
	Mae Moh		Bangkok	Sattahip			
Subperiod	AS	Urea	20-20-0	11-54-0	25-34-0	22-29-7	Urea
			Scenario I				
1	75	186	147	-	-	-	-
2	64	161	140	134	215	198	163
3	64	161	141	135	215	198	163
4	65	163	141	136	216	199	165
			Scenario II				
1	143	343	225	-	-	-	-
2	64	161	145	147	227	205	163
3	65	162	146	217	224	205	167
4	91	223	173	216	257	237	225
			Scenario III				
1	143	341	225	-	-	-	-
2	64	161	173	216	268	244	163
3	64	161	205	217	325	292	163
4	85	208	334	764	534	471	210
			Scenario IV				
1	111	268	183	-	-	-	-
2	15	47	296	221	500	440	49
3	61	154	334	217	544	479	156
4	99	241	315	216	496	439	243

Appendix Table B-13. Estimated Variable Production Costs and Contribution to Profits in Indonesia

Subperiod	Gresik AS	Gresik DAP	Gresik 15-15-15	Gresik TSP	Palembang Cikampek Urea	Palembang I Urea	Palembang II Urea	Palembang III + IV Urea	Aceh Urea	Bontang Urea
	Contribution to Profits, 1979 US $/mt of Product									
						Scenario I				
1	-32	9	-37	0	123	113	135	138	-	-
2	-37	8	-42	8	101	89	111	114	108	103
3	-37	10	-42	10	103	90	112	115	109	104
4	-37	10	-41	9	106	93	115	118	110	108
						Scenario II				
1	37	88	20	17	281	270	292	295	-	-
2	-9	18	-13	18	101	89	111	114	108	103
3	-8	20	-38	10	103	91	113	116	109	105
4	-12	44	-18	10	167	153	175	178	170	167
						Scenario III				
1	36	89	20	19	279	268	390	293	-	-
2	-25	78	-18	78	100	89	111	114	108	103
3	-8	156	6	156	103	90	112	115	109	104
4	0	425	103	407	152	138	160	163	155	152
						Scenario IV				
1	-43	22	-34	22	99	88	110	113	-	-
2	-43	21	-14	21	100	89	111	114	108	103
3	0	138	0	138	103	90	112	115	109	104
4	0	22	-46	22	105	91	113	116	110	105
	Variable Production Cost, 1979 US $/mt of Product									
	109	224	175	157	63-58	72-69	50-47	47-44	52-50	57-55

Appendix Table B-14. Estimated Variable Production Costs and Contribution to Profits in Malaysia

Subperiod	Contribution to Profits, 1979 US $/mt of Product: Petaling Jaya AS	Petaling Jaya 15-15-15	Bintulu Urea
		Scenario I	
1	-20	17	-
2	-12	12	96
3	-11	12	97
4	-12	12	100
		Scenario II	
1	32	75	-
2	-12	15	96
3	-11	16	98
4	-7	35	159
		Scenario III	
1	31	75	-
2	-48	35	96
3	-47	62	97
4	-7	157	144
		Scenario IV	
1	0	44	-
2	-7	16	96
3	-7	16	97
4	-7	16	97
	Variable Production Cost, 1979 US $/mt of Product		
	113	121	64-63

Appendix Table B-15. Estimated Variable Production Costs and Contribution to Profits in the Philippines

Subperiod	Limay 14-14-14	Limay Urea	Pasig AS	Toledo City AS	Toledo City 14-14-14	Iligan City AS	Leyte DAP	Limay Urea
	Contribution to Profits, 1979 US $/mt of Product							
				Scenario I				
1	-40	76	-37	0	-57	-48	-	-
2	-45	50	-30	8	-63	-41	0	46
3	-44	52	-29	8	-62	-41	1	46
4	-44	55	-29	8	-62	-41	1	42
				Scenario II				
1	13	233	31	68	-2	20	-	-
2	-42	50	0	-12	-60	-61	10	39
3	-36	52	-29	8	-72	-34	12	40
4	-22	114	-22	15	3	-33	36	101
				Scenario III				
1	13	231	30	68	-2	19	-	-
2	-2	50	-30	-12	-34	-41	71	47
3	0	52	-28	-12	-16	-60	148	48
4	86	100	-6	30	70	-19	414	87
				Scenario IV				
1	29	185	10	48	11	0	-	-
2	46	525	158	196	85	146	17	524
3	33	484	161	177	18	129	0	482
4	33	485	161	177	26	129	0	481
	Variable Production Costs, 1979 US $/mt of Product							
	169	116-112	116	78	185	127	229	116

Appendix Table B-16. Estimated Variable Production Costs and Contribution to Profits in Thailand

Subperiod	Contribution to Profits, 1979 US $/mt of Product							
	Mae Moh		Bangkok 20-20-0		Sattahip			
	AS	Urea	Old	New	11-54-0	25-34-0	22-29-7	Urea
				Scenario I				
1	-24	32	-36	-26	-	-	-	-
2	-35	7	-43	-33	-34	97	81	124
3	-35	7	-42	-32	-33	98	81	125
4	-34	9	-42	-32	-30	100	83	128
				Scenario II				
1	44	189	42	52	-	-	-	-
2	-35	7	-38	-28	-21	109	88	124
3	-34	8	-37	-27	50	106	88	126
4	-8	69	-10	0	50	141	121	188
				Scenario III				
1	44	187	42	52	-	-	-	-
2	-35	7	-10	0	48	150	127	124
3	-35	7	22	32	50	208	175	125
4	-14	54	151	161	598	418	355	173
				Scenario IV				
1	12	114	0	10	-	-	-	-
2	-84	-107	113	123	51	379	320	0
3	-38	0	151	161	47	423	359	106
4	0	87	132	142	46	375	319	193
	Variable Production Costs, 1979 US $/mt of Product							
	99	154	183	173	170	121	120	50

Appendix Table B-17. Estimated Total Expenses to Supply Plant Nutrients in Indonesia

Subperiod	Equilibrium Expenses, 1979 US $ x 10^6			
	N	P_2O_5	K_2O	Total
		Scenario I		
1	759	240	30	1,029
2	816	339	39	1,194
3	990	435	51	1,476
4	1,194	549	57	1,800
TOTAL	3,759	1,563	177	5,499
		Scenario II		
1	1,373	267	31	1,671
2	788	356	40	1,184
3	996	465	50	1,511
4	1,607	583	58	2,248
TOTAL	4,764	1,671	179	6,614
		Scenario III		
1	1,362	269	31	1,662
2	815	475	40	1,330
3	991	806	50	1,847
4	1,505	1,796	58	3,359
TOTAL	4,673	3,346	179	8,198
		Scenario IV		
1	663	274	31	968
2	815	366	40	1,221
3	991	761	50	1,802
4	1,182	593	58	1,833
TOTAL	3,651	1,994	179	5,824

Appendix Table B-18. Estimated Total Expenses to Supply Plant Nutrients in Malaysia

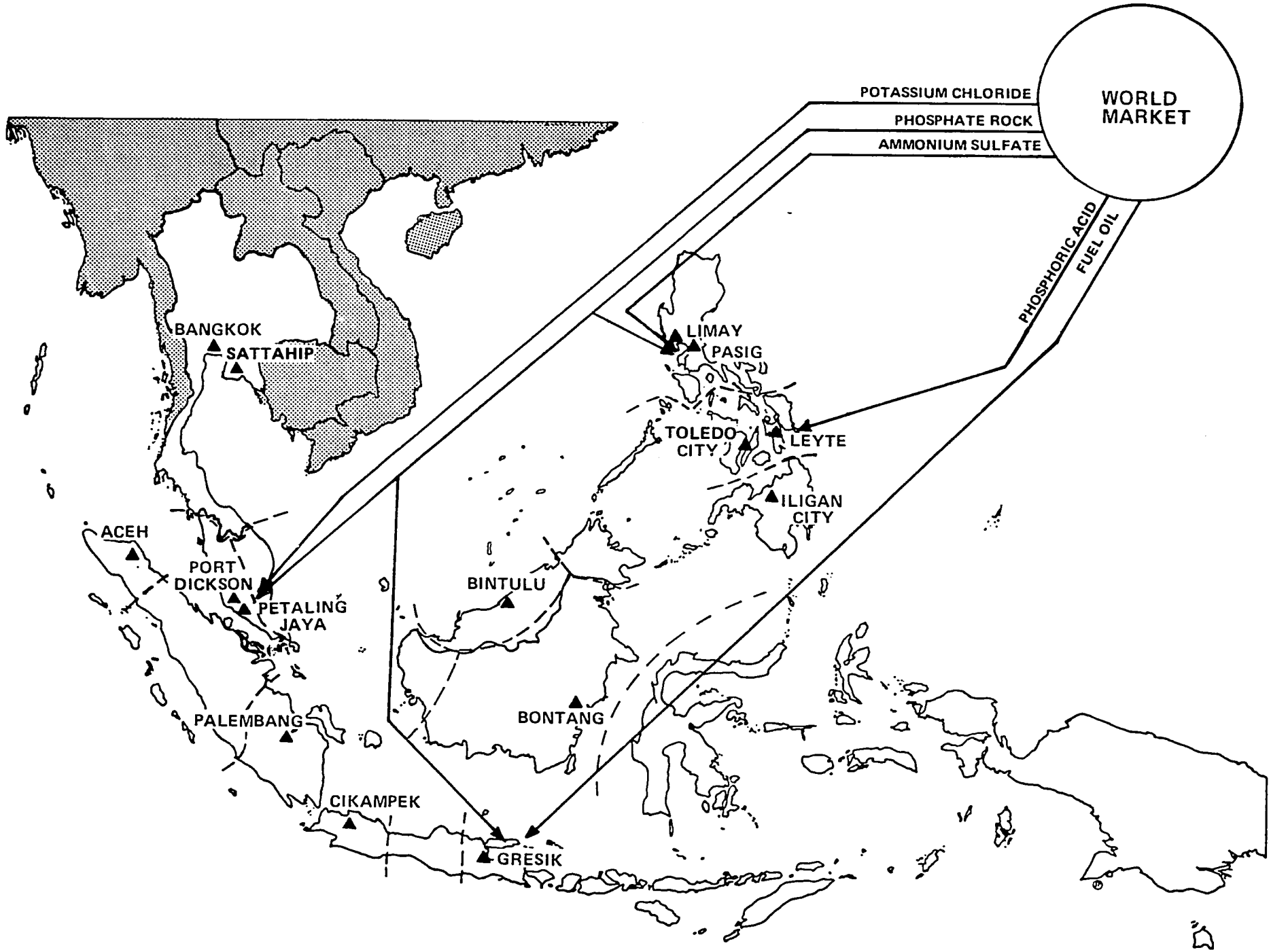
Subperiod	Equilibrium Expenses, 1979 US $ x 10^6			
	N	P_2O_5	K_2O	Total
		Scenario I		
1	171	48	105	324
2	165	57	129	351
3	186	63	156	405
4	207	69	183	459
TOTAL	729	237	573	1,539
		Scenario II		
1	308	52	104	464
2	166	60	128	354
3	187	67	155	409
4	280	74	183	537
TOTAL	941	253	570	1,764
		Scenario III		
1	306	53	104	463
2	166	80	128	374
3	187	116	155	458
4	262	227	183	672
TOTAL	921	476	570	1,967
		Scenario IV		
1	249	46	104	399
2	167	64	128	359
3	187	70	155	412
4	206	78	183	467
TOTAL	809	258	570	1,637

Appendix Table B-19. Estimated Total Expenses to Supply Plant Nutrients in the Philippines

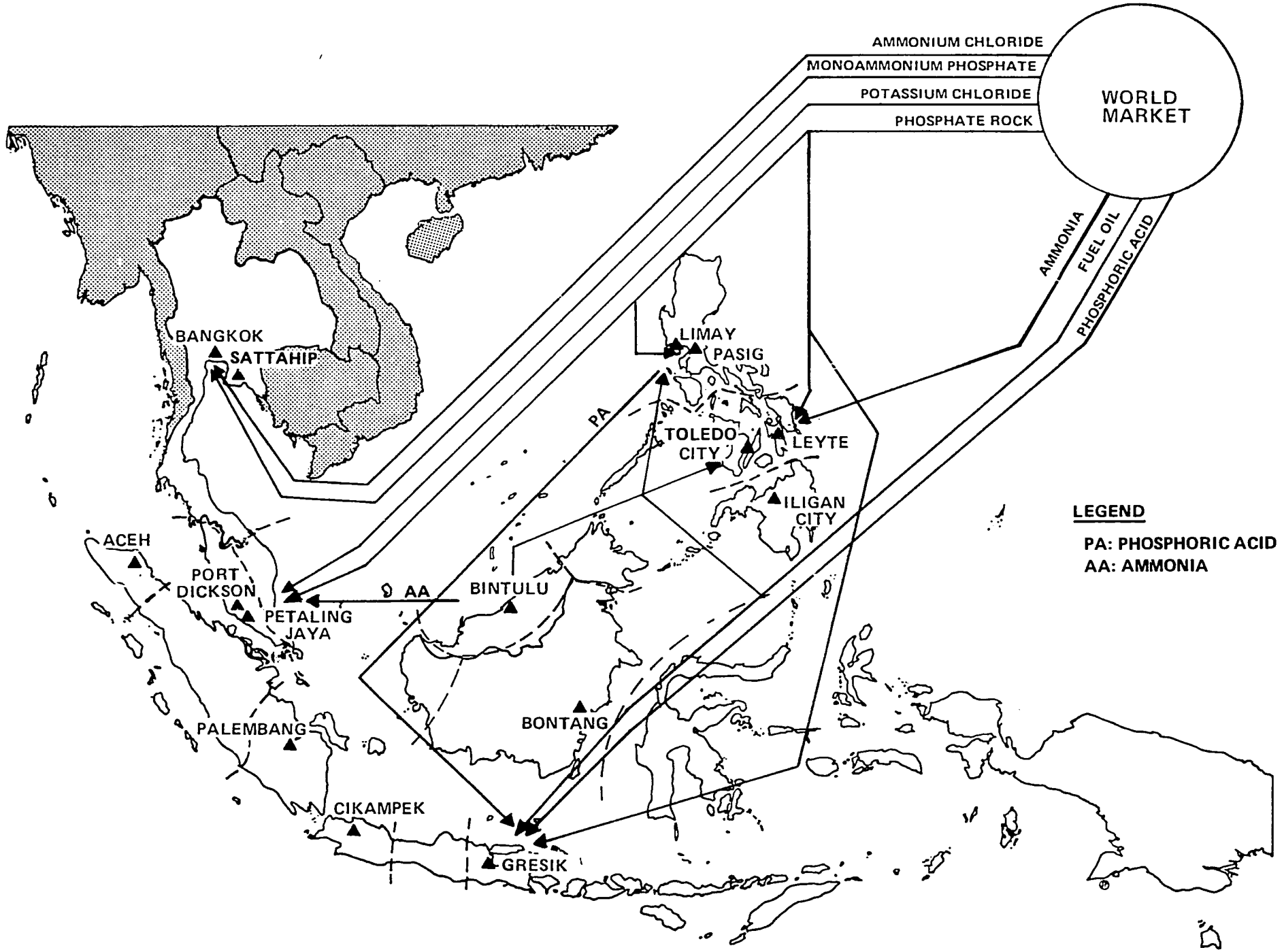
Subperiod	Equilibrium Expenses, 1979 US $ x 10^6			
	N	P_2O_5	K_2O	Total
		Scenario I		
1	339	60	36	435
2	351	69	36	456
3	420	75	39	534
4	498	81	42	621
TOTAL	1,608	285	153	2,046
		Scenario II		
1	605	66	35	706
2	351	72	37	460
3	421	80	39	540
4	670	87	41	798
TOTAL	2,047	305	152	2,504
		Scenario III		
1	602	67	35	704
2	351	96	37	484
3	420	139	39	598
4	625	266	41	932
TOTAL	1,998	568	152	2,718
		Scenario IV		
1	526	99	35	660
2	1,329	0	37	1,366
3	1,480	0	38	1,518
4	1,732	0	41	1,773
TOTAL	5,067	99	151	5,317

Appendix Table B-20. Estimated Total Expenses to Supply Plant Nutrients in Thailand

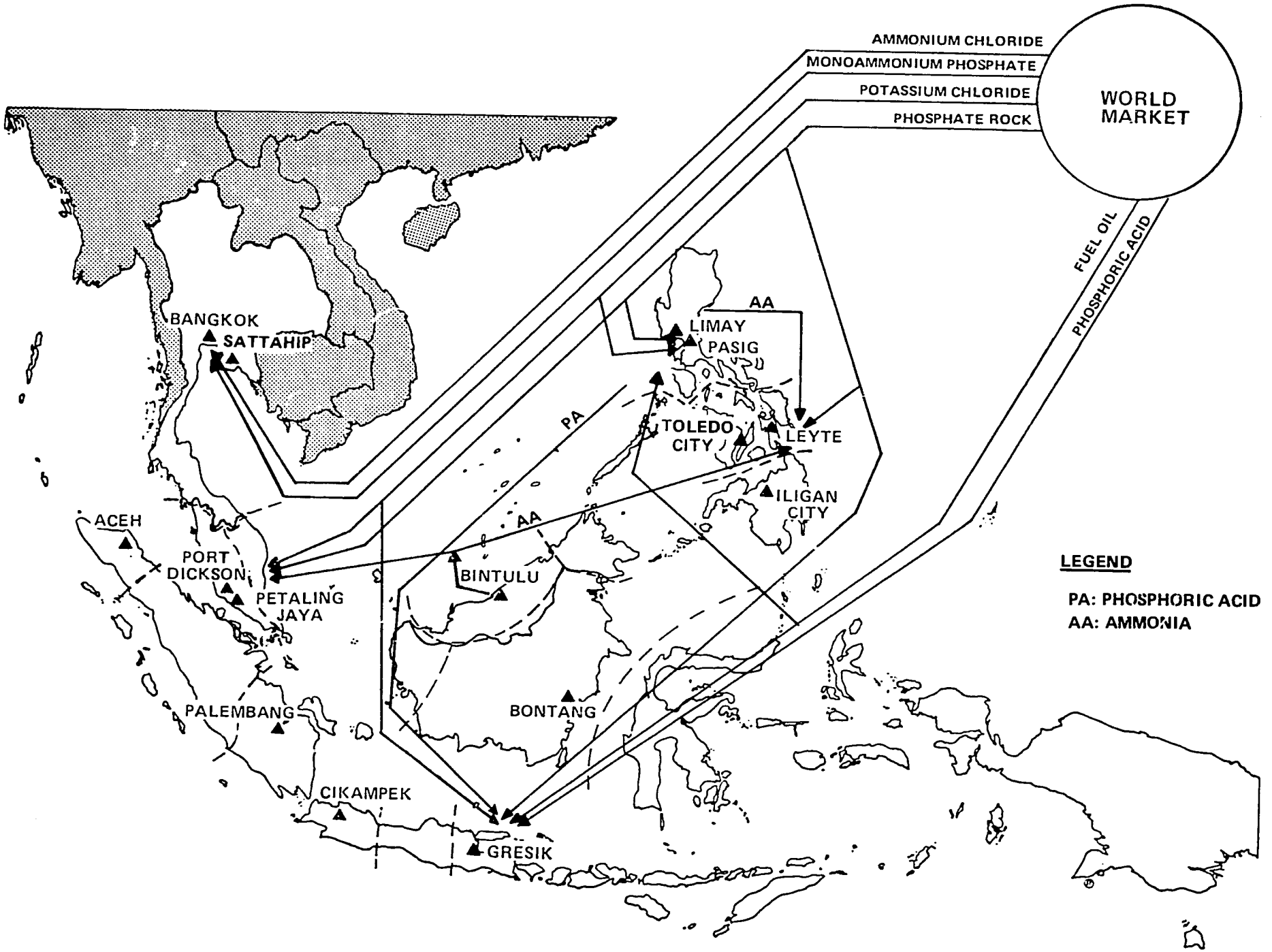
Subperiod	Equilibrium Expenses, 1979 US $ x 10^6			
	N	P_2O_5	K_2O	Total
		Scenario I		
1	284	179	25	488
2	286	215	29	530
3	326	243	32	601
4	368	270	35	673
TOTAL	1,264	907	121	2,292
		Scenario II		
1	511	201	27	739
2	286	228	32	546
3	327	259	38	624
4	496	397	44	937
TOTAL	1,620	1,085	141	2,846
		Scenario III		
1	508	203	27	738
2	286	305	32	623
3	326	449	38	813
4	465	882	44	1,391
TOTAL	1,585	1,839	141	3,565
		Scenario IV		
1	404	177	26	607
2	96	791	32	919
3	311	868	38	1,217
4	534	766	44	1,344
TOTAL	1,345	2,602	140	4,087



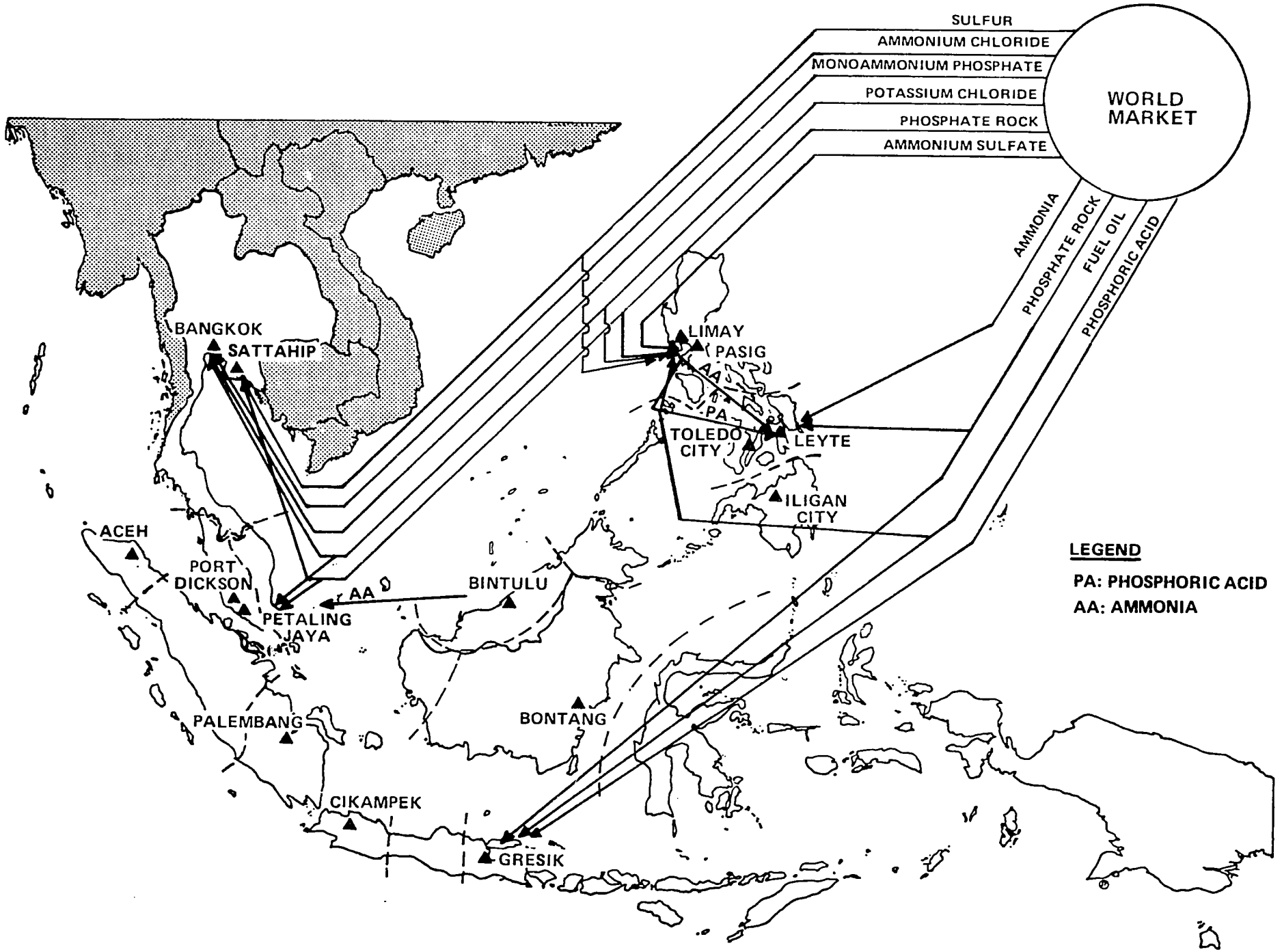
Appendix Figure B-1. Distribution of Principal Raw Materials and Intermediates for Scenario I.



Appendix Figure B-2. Distribution of Principal Raw Materials and Intermediates for Scenario II.



Appendix Figure B-3. Distribution of Principal Raw Materials and Intermediates for Scenario III.



Appendix Figure B-4. Distribution of Principal Raw Materials and Intermediates for Scenario IV.

APPENDIX C

Mathematical and Schematic Formulations of the Linear Programming Model

Mathematical Formulation of the Dynamic Linear Programming Model

Objective Function

$$\text{Minimize} \quad \sum_{d=1}^{D} \sum_{i=1}^{I} \sum_{t=1}^{T} r_t \cdot \Bigg\{ \Bigg(\sum_{u=1}^{U} \sum_{p=1}^{P} ct_{u,i,d,p,t} \cdot T_{u,i,d,p,t} \Bigg) + \left(cm_{i,d,t} \cdot M_{i,d,t} \right) - \left(ce_{i,d,t} \cdot E_{i,d,t} \right) + \left(cp_{i,d,t} \cdot P_{i,d,t} \right) - \Bigg(\sum_{c=1}^{C} cs_{i,c,d,t} \cdot S_{i,c,d,t} \Bigg) + \Bigg[\sum_{m=1}^{M} \Big(cx_{i,d,m,t} \cdot X_{i,d,m,t} + cb_{i,d,m,t} \cdot cr_{i,t} \cdot I_{i,d,m,t} \Big) \Bigg] \Bigg\}$$

Constraints

1. $$\sum_{i=1}^{I} an_{i,n} \cdot F_{i,d,t} \geqq DN_{n,d,t}$$

   for each n,d,t combination (n = 1,2,...,N; d = 1,2,...,D; t = 1,2,...,T)

2. $$\sum_{i=1}^{I} an_{i,n} \cdot M_{i,d,t} \leqq pct_{n,d,t} \cdot DN_{n,d,t}$$

   for each n,d,t combination (n = 1,2,...,N; d = 1,2,...,D; t = 1,2,...,T)

3. $$-F_{i,d,t} + \sum_{u=1}^{U} \sum_{d=1}^{D} \sum_{p=1}^{P} (T_{u,i,d,p,t} - T_{u,i,p,d,t}) + M_{i,d,t} - E_{i,d,t} + P_{i,d,t} - \sum_{c=1}^{C} ac_{ic} \cdot (S_{i,c,d,t} + D_{i,c,d,t}) + \sum_{m=1}^{M} X_{i,d,m,t} - \sum_{i=1}^{I} \sum_{m=1}^{M} ah_{j,m} \cdot X_{i,d,m,t} = 0$$

   for each i,d,t combination (i = 1,2,...,I; d = 1,2,...,D; t = 1,2,...,T)

4. $$X_{i,d,m,t} - \sum_{s=1}^{T-1} C_{i,d,m,t} \leqq CA_{i,d,m,t}$$

for each i,d,m,t combination ($i = 1,2,\ldots,I$; $d = 1,2,\ldots,D$; $m = 1,2,\ldots,M$; $t = 1,2,\ldots,T$)

(s = first possible time period for plant construction)

5. $$\sum_{i=1}^{I} \sum_{m=1}^{M} cb_{i,d,m,t} \cdot r_t \cdot cr_{i,t} \cdot I_{i,d,m,t} \leqq CIE_{d,t}$$

for each d,t combination ($d = 1,2,\ldots,D$; $t = 1,2,\ldots,T$)

6. $$\sum_{m=1}^{M} C_{i,d,m,t} \leqq RA_{i,d,t}$$

for each i,d,t combination ($i = 1,2,\ldots,I$; $d = 1,2,\ldots,D$; $t = 1,2,\ldots,T$)

7. $$-C_{i,d,m,t} + sm_{i,m,t} \cdot I_{i,d,m,t} \geqq 0$$

for each i,d,m,t combination ($i = 1,2,\ldots,I$; $d = 1,2,\ldots,D$; $m = 1,2,\ldots,M$; $t = 1,2,\ldots,T$)

8. $$\sum_{m=1}^{M} \sum_{t=1}^{T} I_{i,d,m,t} \leqq 1$$

for each i,d, combination ($i = 1,2,\ldots,I$; $d = 1,2,\ldots,D$)

9. $$F_{i,d,t} \geqq DF_{i,d,t}$$

For each i,d,t combination ($i = 1,2,\ldots,I$; $d = 1,2,\ldots,D$; $t = 1,2,\ldots,T$)

10. $$T_{u,i,d,p,t} \leqq CT_{u,i,d,p,t}$$

for each u,i,d,p,t combination ($u = 1,2,\ldots,U$; $i = 1,2,\ldots,I$; $d = 1,2,\ldots,D$; $p = 1,2,\ldots,P$; $t = 1,2,\ldots,T$)

11. $$M_{i,d,t} \leqq IM_{i,d,t}$$

12. $$E_{i,d,t} \leqq EX_{i,d,t}$$

13. $$P_{i,d,t} \leqq AB_{i,d,t}$$

14. $$S_{i,c,d,t} \leqq MC_{i,c,d,t}$$

for each i,d,t combination ($i = 1,2,\ldots,I$; $d = 1,2,\ldots,D$; $t = 1,2,\ldots,T$)

for each i,c,d,t combination ($i = 1,2,\ldots,I$; $c = 1,2,\ldots,C$; $d = 1,2,\ldots,D$; $t = 1,2,\ldots,T$)

15. $I_{i,d,m,t} = 0$ or 1 for all i,d,m,t

Definition of Symbols

C = the number of coproducts per material

D = the number of model regions (destinations in case of transport activities)

I = the number of model materials (raw materials, intermediates, and fertilizers)

M = the number of production technologies

N = the number of model nutrients

P = the number of model regions in case of transport activities (origins)

T = the number of model time periods

U = the number of transportation technologies

ct = unit transportation cost ($/ton)

cm = unit import cost ($/ton)

ce = unit export prices ($/ton)

cp = byproduct unit purchase cost ($/ton)

cs = unit sales price of coproduct ($/ton)

cx = unit production cost ($/ton)

cb = plant construction cost ($)

an = tons of nutrient per ton of fertilizer

pct = % of nutrient demand that may be imported

ac = tons of material required per ton of coproduct produced

ah = tons of material required per ton of material produced

sm = maximum plant expansion capacity

DN = nutrient demand (tons)

CA = initial production capacity (tons/model time period)

CIE = capital available from external and internal origin

RA = tons of raw material from indigenous reserve available per model time period

DF = tons of fertilizer demand

CT = maximum allowable volume of transports (tons)

IM = maximum tons available for import

EX = maximum volume which may be exported (tons)

AB = material available for purchase as byproduct (tons)

MC = maximum sales possible for coproduct (tons)

$T_{u,i,d,p,t}$ = material interregional transport activity by transportation technology u, of material i, from region d to region p in time period t

$M_{i,d,t}$ = import activity - material i, region d, time period t

$E_{i,d,t}$ = export activity - material i, region d, time period t

$P_{i,d,t}$ = byproduct purchase activity - material i, coproduct c, region d, time period t

$S_{i,c,d,t}$ = coproduct sales activity - material i, coproduct c, region d, time period t

$X_{i,d,m,t}$ = material production activity - material i, region d, production technology m, time period t

$I_{i,d,m,t}$ = plant construction activity for material i, region d, production technology m, time period t

$F_{i,d,t}$ = fertilizer supply activity - material i, region d, time period t

$D_{i,c,d,t}$ = coproduct disposal activity - material i, coproduct c, region d, time period t

$C_{i,d,m,t}$ = production capacity expansion activity - material i, region d, production technology m, time period t

Discounting Factor

$$r_t = \prod_{j=1}^{t} (1 + \rho_j)^{-q_j} \quad ; \text{ with}$$

ρ_j = rate of interest in time period j, and

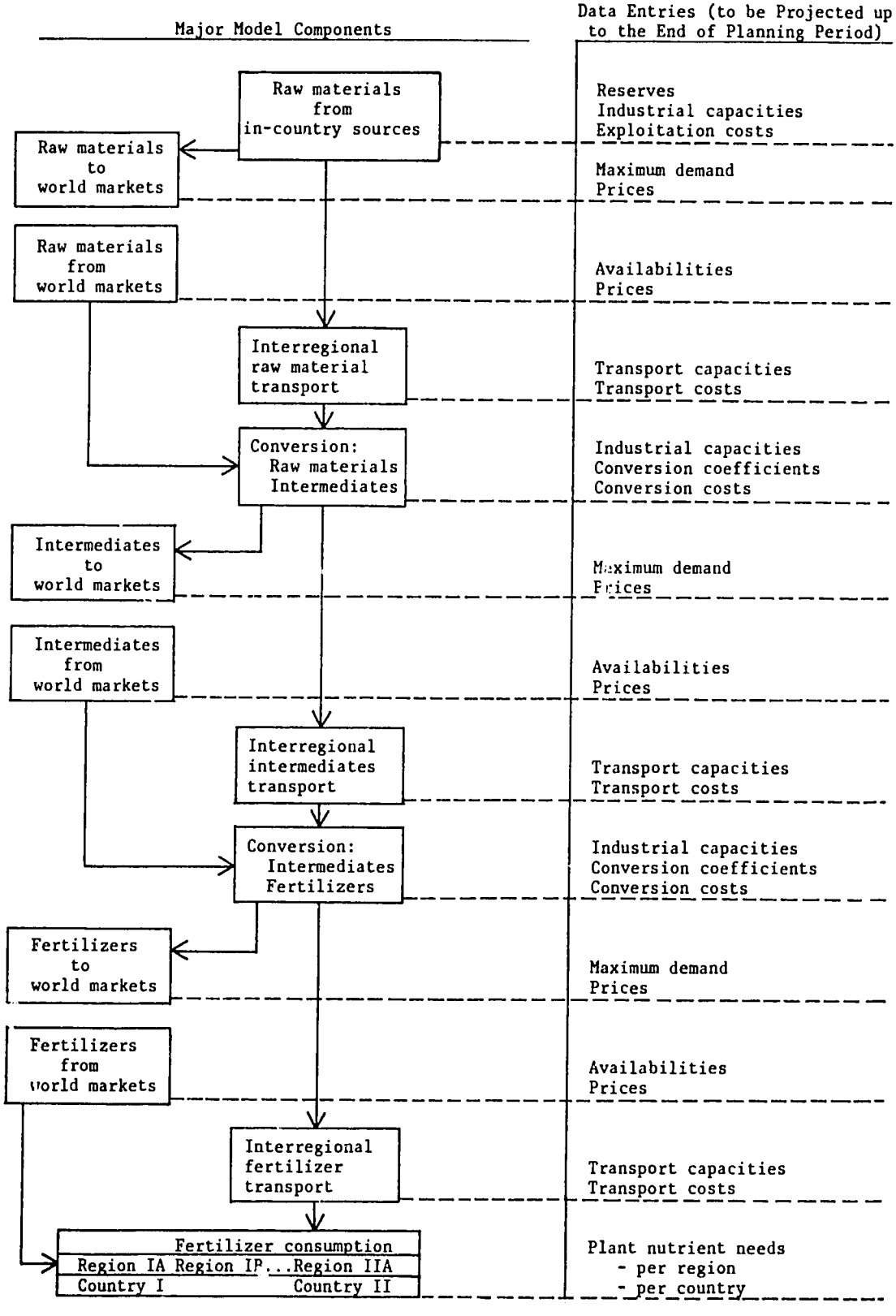
q_j = number of years in time period j

Capital Recovery Factor

$$cr_{i,t} = \frac{\rho_t}{-1 + (1 + \rho_t)^{N_t}} + \rho t$$

ρ_t = rate of interest in time period t, and

N_t = number of years expected lifetime for a plant producing material i



Appendix Figure C-1. Data Requirements and Schematic Representation of Model Components and Interrelationships.