AN ECONOMIC ANALYSIS OF FERTILIZER ALLOCATION AND IMPORT POLICIES IN SYRIA

Volume I

By

Maurice Emile Saade

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1991

ABSTRACT

AN ECONOMIC ANALYSIS OF FERTILIZER ALLOCATION AND IMPORT POLICIES IN SYRIA

By

Maurice Emile Saade

The main objective of this dissertation is to develop a national economic decision model to be used as a tool by Syrian policy makers to plan more economically efficient allocations of the limited fertilizer supplies in Syria. The model also serves as the main framework for analyzing the economic implications of the current constraints on fertilizer supplies. These constraints are mainly the result of government restrictions on fertilizer imports in an attempt to reduce foreign exchange expenditures. The model was formulated in terms of a separable linear programming model, based on the results of fertilizer experiments undertaken between 1965 and 1989 on the most important crops in Syria.

Compared to the current government fertilizer allocation strategy, the results indicated that a strategy based on the proposed model would significantly increase national and farm incomes and aggregate crop output, and would reduce the government's foreign exchange and general budget deficits. The main effect of the current constraints on fertilizer supplies is a substantial reduction in fertilizer use on rainfed cereals, particularly barley. Thus, a policy of importing all the fertilizer needed to satisfy total requirements would substantially increase aggregate crop output. Compared to the current situation, this policy would increase national income by 2.4 billion Syrian Liras (SL),

a 4.2% increase in the agricultural Gross Domestic Product (GDP). This would also result in a decline of 54 million $US in net crop imports, which would more than offset the 41 million $US needed to import the additional fertilizer.

Given the current heavily subsidized fertilizer prices, such a policy would require up to 800 million SL in additional fertilizer subsidies. The results showed that a 7% to 15% increase in the price of nitrogen and 45% to 60% in that of phosphorus would allow the government to satisfy total fertilizer requirements without increasing its current expenditures on subsidies. Farmers' unlimited access to fertilizers would allow them to increase their output, which would lead to higher revenues that would offset any increase in fertilizer costs. Compared to the current situation of subsidized but limited fertilizer supplies, farmers' income would increase by an average of 1.5 billion SL, in spite of higher fertilizer costs.

to Lamia

ACKNOWLEDGMENTS

This dissertation is based on a collaborative research project between the Soils Directorate of the Syrian Ministry of Agriculture and Agrarian Reform, and the International Center for Agricultural Research in the Dry Areas (ICARDA). Many people from both institutions contributed to the success of this project, to whom I wish to express my appreciation and gratitude.

From the Soils Directorate, I am especially grateful to Mr. Khazzaa El-Hajj for sharing with me his valuable time, in-depth knowledge, and long experience, which were instrumental in the writing of this dissertation. Ms. Lina Meda helped with the tedious task of data entry and analysis. Mr. Adeeb Safi, Ms. Bdour Al-Bunni, and Ms. Widad Al-Shahadeh helped in compiling the results of fertilizer experiments.

From ICARDA, my deepest thanks are to Dr. Thomas Nordblom for his crucial support, encouragement and contribution to this research, and for his, and his family's, warm friendship. Mr. Ahmad Mazid and Drs. Peter Cooper, Abdallah Matar, Elizabeth Bailey and Michael Jones provided insightful comments at many points throughout this project.

I am grateful to the Ford Foundation who provided funding for this dissertation, and the efforts of Dr. David Nygaard in supporting it are greatly appreciated.

I am especially thankful to my advisor, Dr. Stephen Harsh, for taking the time to visit me in Syria during my stay there, for his insightful comments, and for the long hours he spent with me before this dissertation was completed. My deepest appreciation is to my graduate program supervisor and thesis committee member, Dr. John Staatz, for his numerous valuable comments on the dissertation, and for his encouragement and practical wisdom which were of great help throughout my graduate program at Michigan State University. I am also thankful to Drs. Eric Crawford and Roy Black, members of the thesis committee, for their useful comments.

Finally, I wish to thank my mother, Béatrice Dagher, for her love and patience throughout my graduate studies, and for her faith that, somehow, one day I will finally end up getting a "real job" as a result of this long and tedious endeavor. I dedicate this dissertation to my wife and best friend, Lamia El-Fattal, for her emotional and moral support, and for her faith in me, which provided me with all the strength and patience in writing this dissertation.

TABLE OF CONTENTS

APPEN

APPEN

APPEN

BIBL

LIST OF TABLES

Table

Table

Tabl

Tab

Tabl

Table

Table

Table

Table

Tabl

Tabl

Tab

APPENDIX TABLES:

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background and Problem Definition

The access of farmers to fertilizers is one of the most important factors affecting the productivity of Syrian agriculture and its ability to meet current and future food and fiber needs for domestic consumption and for exports. Chemical fertilizers were first commercially used in Syria in the early 1950's, with the rapid expansion in cotton cultivation. Since then, fertilizer use has grown dramatically, especially during the past two decades. Fertilizer use per hectare of arable land increased from 6.7 kg of plant nutrients in 1970 to 32 kg in 1984 (World Bank, 1987, p. 213). Between 1974 and 1978 alone, the use of nitrogen fertilizer doubled and that of phosphate fertilizer quadrupled (Nixon, 1979, p. 17).

Faced with the rapid growth in fertilizer consumption and imports, the Syrian government has invested heavily in expanding production capacity. These investments were encouraged by the discovery in the late 1960's of substantial deposits of rock phosphate, oil, and natural gas that can be used as raw materials for fertilizer production. The major expansion in production capacity in the early 1980's had the goal of making Syria self-sufficient in fertilizer production and being able to sell fertilizer on the export market. This expansion was also part

of a broader fertilizer policy that included heavy subsidies to encourage farmers to rapidly increase their fertilizer use.

Throughout the 1980's fertilizer production levels remained much lower than the planned capacity due to a multitude of technical and managerial problems. These problems, in conjunction with the rapid increase in consumption, resulted in continued importation of substantial quantities of fertilizer. These import levels could not be sustained for a long time, especially in light of the severe foreign exchange crisis facing Syria since the mid 1980's. In response to this crisis, the government has resorted to reducing all imports, including that of fertilizers. As a result, the quantities of fertilizer demanded by farmers, given current subsidized prices, have often exceeded the total available supplies, leading to a situation of chronic shortages.

In an attempt to address the problem of frequent shortages, the government introduced a fertilizer rationing system. According to this system, each farmer is allocated a quantity of fertilizer based on the type of crops grown and the area planted to each crop. There are several potential problems associated with such a rationing policy. These include: (1) the economic rationale of fertilizer allocation strategies, (2) the accuracy of information in a centrally planned allocation system, and (3) the economic implications of restrictions on fertilizer imports.

1. <u>Economic rationale of fertilizer allocation strategies:</u>

The fertilizer rationing and allocation system is a centrally planned and managed system. In other words, government planners decide the fertilizer rates to be allocated to each crop in each agro-climatic zone, given the limited supplies available for distribution to farmers. Thus, an important potential problem related to this system is the underlying assumptions upon which the allocation decisions are made.

The main purpose of the rationing system is to allocate the limited supplies to various crops so as to maximize net returns from fertilizer use. At the same time, this system attempts to incorporate policy concerns about food self-sufficiency and balance of trade deficit. Thus, every effort is made to ensure that "strategic crops" receive their ideal rates, i.e., those maximizing net returns to fertilizer application. These crops are defined as those providing substantial export earnings (e.g., cotton) and crops that substitute for the main food imports (e.g., wheat and sugar).

Another important factor influencing allocation decisions is whether crops are irrigated or rainfed. The general rule is that irrigated crops should receive their ideal fertilizer rates. This is because net economic returns to fertilizer use on rainfed crops, especially in the drier areas, are lower and more risky than on irrigated crops. Given the existing constraints on fertilizer supplies, the practical implications of the above allocation strategies are that irrigated crops and rainfed wheat in the high rainfall zones usually receive most if not all of their ideal rates, with very limited fertilizer left for rainfed barley. In fact, the first time that fertilizer was allocated to barley was in 1986/87, but even then only in the wetter areas (above 250 mm average annual rainfall).

The above policy priorities may conflict with the initial objective of maximizing net returns from the limited quantities of fertilizer available. Maximizing net returns from fertilizer use under rationing conditions requires that marginal revenues be equal across all crops (equimarginal rule). Thus, if aggregate fertilizer supplies decline, the rates on all crops would need to be reduced in such a way as to maintain the equality between marginal revenues. The above priority system implies that the fertilizer rates on high-priority crops are kept constant, or slightly reduced, while the rates on low-priority crops are reduced drastically. This would lead to a situation where marginal revenues from fertilizer application on low-priority crops are larger than those on high-priority crops resulting in an economically inefficient allocation of the limited fertilizer resources. Therefore, an allocation strategy based on the above priorities may result in a decline in aggregate net returns to fertilizer use, compared to net returns potentially obtained if the equimarginal rule was used as the basis for allocation.

Concerns about potential inefficiencies in the current allocation strategy have been reinforced by results from recent fertilizer experiments in northern Syria. These experiments suggest that barley fertilization in the drier areas might be much more profitable and less risky than was previously thought (Soils Directorate/ICARDA, 1990). Other research findings also suggest that the current fertilizer rates, specifically phosphate rates, on rainfed wheat are excessive. This is due to the buildup of soil phosphate as a result of years of continuous application (Soils Directorate/ICARDA, 1989). Such findings suggest that it may be more economical to reallocate some fertilizer from wheat to barley grown in the drier areas.

2. <u>Accuracy of information in a centrally planned allocation system:</u>

Another potential problem with the current fertilizer allocation system is the approach used in deciding the rates to be allocated to each crop in each agro-climatic zone, given the limited supplies available. The most common approach currently used by Syrian planners in computing these rates is to reduce the recommended fertilizer rates by a given percentage, depending on the total amounts of fertilizer available. Thus, the economic efficiency of the current allocation system depends to a large extent on whether the current recommendations reflect the economically optimum fertilizer rates.

The fertilizer recommendations for approximately 80 crops and crop categories are included in a "fertilizer requirement schedule". Given the limited number of fertilizer experiments undertaken in Syria, most of these rates are based on recommendations from other countries, especially in the case of newly introduced crops and fruit trees and vegetables. However, recommended rates for the most economically important crops are based on fertilizer experiments undertaken in Syria. Most of these experiments were implemented during the 1970's. Although some of these rates have been modified in light of new research findings, most of the recommendations in the current fertilizer requirement schedule have not been adjusted since the mid 1970's.

Given the rapidly changing physical and economic environments of the 1980's, the need for a systematic revision and adjustment of fertilizer recommendations has become more urgent. The fertilizer experiments of the 1970's were performed on research and farm plots not previously fertilized. Consequently, the calculated rates for the most part reflect initial low soil fertility. By the late 1980's, after two decades of fertilizer use by farmers, there is clear evidence of substantial buildup of soil nutrients, especially phosphorus, resulting in a reduced response to fertilizer (ICARDA/FRMP, 1988, pp. 10-13). Also, most of the current recommended rates are based on calculations of economic optima based on fertilizer and crop prices prevailing during the 1970's. These prices have changed drastically, both domestically and internationally. Therefore, the current rates most likely do not reflect the economically optimum fertilizer rates.

3. Economic implications of the restrictions on fertilizer imports:

The main objective of the current policy of limiting fertilizer imports is to reduce both the government's foreign exchange deficit and the balance of trade deficit in general. Such an objective is attainable only if domestic fertilizer production is increased to substitute for any decline in imports. This could be achieved by solving some of the technical and managerial problems facing fertilizer production, and/or by a further expansion in production capacity. However, the recent downward trends in fertilizer production clearly suggest that production problems will probably continue to hamper the Syrian fertilizer industry for the next few years. Also, any planned expansion in production capacity would require several years to implement and would still be subject to the same foreign exchange constraints facing fertilizer imports.

Therefore, the option of increasing fertilizer production levels would be feasible only in the medium or long run. In the meantime, any reduction in fertilizer imports would lead to lower use by farmers. This may result in reduced aggregate crop production, particularly of export crops and/or crops that substitute for major food imports. Such potential declines in net crop exports may offset any savings in foreign exchange from lower fertilizer imports. Therefore, the net result of a policy of reduced fertilizer imports may be to further exacerbate the balance of trade deficit and the government's foreign exchange deficit.

1.2 Objectives

The potential problems associated with the policy of fertilizer rationing in Syria indicate the need for a systematic analysis of two basic aspects of this policy. First, problems associated with the centrally planned implementation of fertilizer rationing need to be addressed. This includes an evaluation of the current fertilizer allocation strategies, in contrast to a strategy based on equating marginal revenues across all crops. Furthermore, in order to implement any fertilizer allocation strategy properly, a systematic review of current fertilizer recommendations needs to be undertaken for the most important crops grown in Syria.

Second, the economic rationale of the policy of limited fertilizer imports needs to be analyzed, especially in light of the short- to medium-term constraints on any increase in fertilizer production. This requires an assessment of the economic implications of this policy in comparison to alternative policies based on importing all the fertilizer needed to fill the gap between domestic production and aggregate requirements.

Consequently, the main goal of this dissertation is to develop an analytical framework for estimating the efficient allocation of limited fertilizer supplies in Syria. This framework will be formulated in terms of a fertilizer allocation decision model based on the equimarginality principle. Such a model would allow to achieve three basic objectives: (1) it can serve as a tool to be used by Syrian planners to assist them in formulating economically efficient annual fertilizer allocation plans; (2) it will allow the evaluation of alternative fertilizer allocation strategies; and (3) it will provide the basis for estimating the economic implications of the current policy of limited fertilizer imports.

An important prerequisite for the proper formulation and implementation of this proposed framework is a systematic review of the current fertilizer recommendations for the major crops in Syria. Therefore, the specific objectives of this dissertation can be summarized as follows:

1. To review current fertilizer recommendations for the major crops in Syria.
2. To develop a decision model to be used by Syrian government planners in formulating annual plans for the allocation of fertilizer among alternative uses.
3. To analyze the economic impact of alternative fertilizer allocation strategies under different fertilizer availability constraints, and to make recommendations regarding more appropriate strategies.

4 - To analyze the economic implications of the current policy of limited fertilizer imports, in comparison with alternative policy options.

5 - To identify areas in which future research would be useful.

1.3 Dissertation Outline

The dissertation includes seven chapters, including this introductory chapter. Chapter 2 presents an overview of the current fertilizer situation in Syria. This includes recent trends in fertilizer consumption, production, imports, prices and marketing, a discussion of the institutional setting for planning fertilizer allocation policies, and a brief discussion of the fertilizer strategies used by farmers in Syria.

In chapter 3, the research approach used in this study is presented. This includes a discussion of the conceptual approach and its underlying assumptions, and an outline of the main steps in the specification of the fertilizer allocation model. Chapter 4 presents the procedures and assumptions for estimating the financial and economic prices of the crops and fertilizers included in this study. Also included in this chapter are estimates of net taxes (or subsidies) and net foreign exchange earnings (or expenditures) associated with each unit of crop produced or fertilizer used.

In chapter 5, the main results related to fertilizer recommendations for the main crops in Syria are presented. These results are based on the ideal situation of unlimited fertilizer supplies, given the prevailing prices. The chapter includes a summary of the estimated production functions, which constitute the basis for calculating the economically optimum fertilizer rates. The economic feasibility of these proposed rates and their aggregate economic impact are then compared to the current recommended rates.

Chapter 6 addresses the issues of fertilizer allocation under limited fertilizer supplies. Given the constrained optimization nature of the problem, most of the analyses in this chapter are based on the fertilizer allocation model discussed in chapter 3. The results of the model are used to determine the economic impact of the current constraints on fertilizer supplies and to compare alternative fertilizer allocation strategies.

The concluding chapter 7 includes a summary of the main findings and their policy implications, followed by recommendations for future research.

CHAPTER 2

THE PRESENT FERTILIZER SITUATION [1]

This chapter gives an overview of the fertilizer situation in Syria. Its purpose is to put the specific research objectives of this study into the broader context of recent developments in the fertilizer sub-sector in Syria. The chapter begins with a brief description of current cropping patterns in the various agroclimatic regions of Syria. This is followed by an overview of recent trends in fertilizer consumption, production, imports, and prices. Next, the institutional setting for planning fertilizer allocation policies is discussed. This is followed by a section on fertilizer marketing, including a brief discussion of the role of the parallel market. The chapter concludes with a discussion of the available information on some of the fertilizer strategies used by farmers in Syria.

2.1 Land Use and Crop Mix

Syria occupies an area of 18.5 million ha, the majority of which is situated in the dry and semi-dry regions. The area of arable land is 6.1 million ha, representing 33% of total area. Only 5.6 million ha are

---

[1] Unless otherwise mentioned, all the information referred to in this chapter is based either on personal communications with officials from the Soils Directorate, the Agricultural Cooperative Bank, and the General Fertilizer Company, or on unpublished internal documents from the above institutions. See also El-Hajj (1985b).

actually cultivated, representing 92% of total arable land. Water resources are very limited in Syria, with 695 thousand ha irrigated land representing 11.4% of total arable land (Annual Agricultural Statistical Abstracts, 1989). Hence, rainfed agriculture is the predominant type in Syria and it is characterized by great fluctuations in annual yields due to the variability in rainfall.

Syria is subdivided into five agroclimatic regions or Agricultural Stability Zones, based on average seasonal rainfall (see Figure 1). The first region is further divided into two sub-zones (ICARDA/FSR, 1979, p.41):

Zone 1a: Average rainfall over 600 mm. A wide range of crops may be grown here. Fallowing is not necessary.

Zone 1b: Average rainfall between 350 and 600 mm, with at least 300 mm in two thirds of the years surveyed. The main crops are wheat, food legumes, and summer crops.

Zone 2: Average rainfall between 250 and 350 mm, with at least 250 mm in two thirds of the years surveyed. Barley, wheat, food legumes, and summer crops are grown.

Zone 3: Average rainfall over 250 mm, with this level achieved in at least half the years surveyed. Barley is the principal crop but some food legumes also produced.

Zone 4: Average rainfall between 200 and 250 mm, and at least 200 mm during half the years surveyed. Barley is the predominant crop. This area is also used for grazing.

Zone 5: Covers the rest of the country. This steppe land is not suitable for rainfed agriculture but parts of it can be used for winter pasturing.

The above system of Agricultural Stability Zones was introduced in 1975. This is part of the overall effort by the government to regulate agricultural production better through medium- and long-term planning of the agricultural sector. This central planning effort involves a

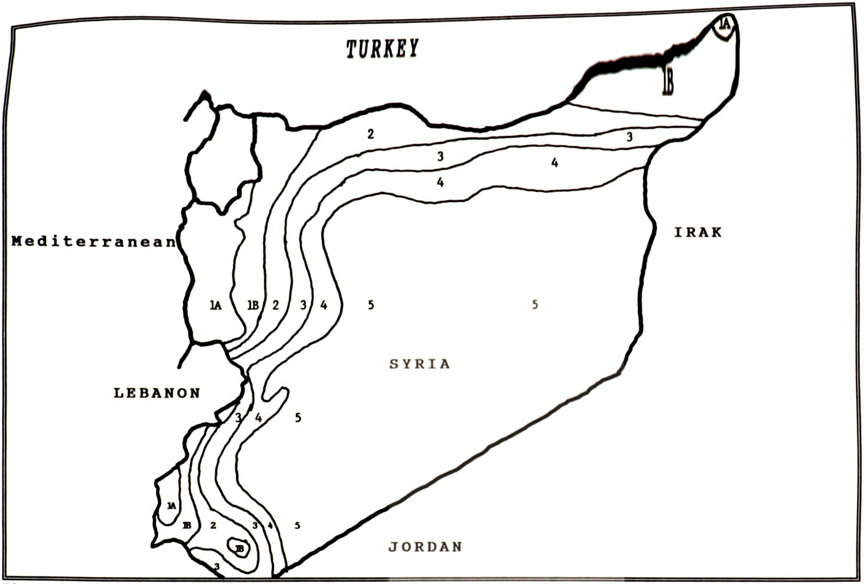

Figure 1: Agricultural Stability Zones in Syria
Source: ICARDA/FSR, 1979, p. 43

comprehensive annual Agricultural Plan specifying the crops that farmers should grow and the area planted to each crop in each of the Agricultural Stability Zones and administrative units.

The main objective of the plan is to provide farmers with adequate and stable incomes and, at the same time, to ensure adequate aggregate production of "strategic crops". These are crops that provide substantial export earnings, such as cotton, or crops that substitute for food imports, such as wheat and sugar beets. Soil conservation is also a main concern of the plan. The plan specifies the crop rotations that farmers should follow (including fallowing), and prohibits any rainfed cultivation in Zone 5 in order to preserve natural pastures (this latter restriction, however, was recently modified to allow for some barley cultivation in Zone 5). The plan also includes stipulations for providing farmers with agricultural inputs (most of them subsidized) and subsidized credit. In return, farmers have to sell to the government their entire production (except for seeds and home consumption) of the main grain (e.g., wheat, barley, food legumes) and industrial crops (e.g., cotton, sugar beets, tobacco) at official prices set by the plan (see MAAR, 1981).

After a period of rapid expansion during the 1940's and 1950's, the growth in total cultivated areas slowed significantly. Most of the arable land had been put into production. By the 1980's, the small increase in cultivated areas was largely due to the gradual decline in fallowing. Thus, between 1984/85 and 1988/89, total cultivated areas increased by 12.9% (10.3% increase in irrigated land and 13.6% in rainfed cultures) (see Appendix A, Table A.1). However, in an attempt to increase the production of cereals by expanding total cultivated area, the government abolished fallowing. This is based on the decision of the Prime Minister, who is also Chairman of the Higher Council on Agriculture (Decision number 55, 20 September 1988), stipulating that:

> ...fallowing will be abolished in all the areas of Agricultural Stability Zones 2, 3, and 4 which will be entirely cultivated with cereals (wheat and barley) and food grain legumes, and all the requirements in fertilizers, seeds, credit, and other inputs will be made available.

Hence, in 1989/90, the total cultivated area is expected to increase by 41.2% compared to the 1984/85 level (15.5% increase in irrigated areas and 47.1% increase in rainfed areas). The total area planned for crop production in 1989/90 is 5 million ha, of which only 768 thousand ha are irrigated. The data in Table 2.1 provide a summary of land allocation between the main crop categories and by Stability Zones (see Appendix A, Table A.2, for more details).

Cereals are the predominant crops, accounting for 82% of total crop area (45% of irrigated land and 89% of rainfed areas). Following in importance are food grain legumes (4.99%), industrial crops (4.36%), and vegetables (3.89% of total area). Total areas in each of the Agricultural Stability Zones are as follows: Zone 1, 17.7%; Zone 2, 34.1%; Zone 3, 17.5%; Zone 4, 20.6%; and Zone 5, 10.1%.

2.2 Evolution of Fertilizer Consumption

2.2.1 Consumption Trends

Chemical fertilizers were first used in Syria in the early 1950's, with the rapid expansion in cotton cultivation. Since then, fertilizer use has grown dramatically, especially during the past two decades (Table 2.2). Total nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O)

Table 2

Table 2.1: *PLANNED CROPPING PROGRAM: Syria, 1989/90 Season*

Crop Category	Irrigated Area (ha)	Irrigated %	Rainfed, by Agricultural Stability Zones (ha) Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	TOTAL	%	GRAND TOTAL (ha)
Cereals:	342,564	44.6	465,778	1,282,073	728,146	879,231	429,912	3,785,140	88.7	4,127,704
Food Grain Legumes:	12,076	1.6	158,687	75,238	3,985	--	--	238,000	5.6	250,076
Feed Grain Legumes:	3,067	0.4	19,604	18,309	6,272	--	--	44,185	1.0	47,252
Forage Crops:	48,718	6.3	18,975	33,470	3,733	261	--	56,439	1.3	105,157
Industrial Crops:	208,150	27.1	11,350	--	--	--	--	11,350	0.3	219,500
Oil Crops:	47,514	6.2	12,296	15,276	4,000	--	--	31,572	0.7	79,086
Vegetables:	104,623	13.6	61,849	29,292	--	--	--	91,141	2.1	195,764
Misc. Crops:	1,148	0.2	5,184	2,240	1,500	--	--	8,924	0.3	10,072
Total Field Crops:	767,860	100.0	753,723	1,455,988	747,636	879,492	429,912	4,266,751	100.0	5,034,611
% :	15.3		15.0	28.9	14.8	17.5	8.5	84.7		100

Source: Ministry of Agriculture and Agrarian Reform, the 1989/90 Agricultural Production Plan.

Table 2.2: EVOLUTION OF FERTILIZER USE (TONS)
Syria, 1954/55 to 1989/90

Season	N	P_2O_5	K_2O
1954/55	3,410	1,170	67
1955/56	4,100	1,275	107
1956/57	5,160	1,880	177
1957/58	4,980	1,300	165
1958/59	6,000	2,580	230
1959/60	6,560	3,000	300
1960/61	5,680	2,190	290
1961/62	9,520	3,700	335
1962/63	8,480	4,280	380
1963/64	10,000	5,000	350
1964/65	12,100	4,350	340
1965/66	12,900	4,450	200
1966/67	12,274	4,770	389
1967/68	16,912	5,525	163
1968/69	22,760	6,680	1,075
1969/70	20,150	7,812	901
1970/71	26,100	12,880	1,465
1971/72	34,900	17,028	1,273
1972/73	32,876	14,916	1,085
1973/74	33,257	7,471	1,797
1974/75	37,671	13,440	1,576
1975/76	47,198	21,638	1,613
1976/77	51,939	24,962	1,315
1977/78	62,135	30,990	1,802
1978/79	65,670	37,368	1,914
1979/80	79,190	44,865	3,540
1980/81	79,780	44,088	3,462
1981/82	83,101	50,061	5,149
1982/83	95,915	53,527	5,765
1983/84	109,481	63,728	5,721
1984/85	126,297	74,263	5,687
1985/86	136,994	85,588	6,182
1986/87	143,911	95,530	6,806
1987/88	158,391	99,774	9,405
1988/89	160,604	109,271	10,547
1989/90	153,565	91,593	4,358

Source: Annual Agricultural Statistical Abstracts, various years.

consumption quadrupled between 1970 and 1980, increasing from 29 to 128 thousand tons. This growth rate slowed during the 1980's with total consumption reaching 280 thousand tons in 1989. This still represents a 120% increase over the 1980 level.

These growth patterns seem consistent with the growth in fertilizer use observed in other developing countries. The Tennessee Valley Authority (TVA) identifies three phases that characterize the growth in consumption of fertilizer in a specific country or region: "Phase one represents the rapid increases that occur in the early stages of development. Phase two represents the transition period between rapid growth and a mature market. Phase three is the mature market in which decreasing rates of increase in consumption occur" (Shields, 1976, p. 334). The consumption data shown in Figure 2 seem to suggest that growth in fertilizer use in Syria during the 1980's represents the transition period (phase two). Although consumption declined slightly during 1989/90, it is very unlikely that this is an indication of a maturing market. This recent decline is a reflection of the severe constraints on fertilizer supplies which have reduced the availability of fertilizers to farmers, especially during the latter half of the 1980's.

Although data on the evolution of fertilizer use by individual crops in Syria are not available, some generalizations can be made about trends during the past two decades based on discussions with officials from the Soils Directorate. The growth of fertilizer use was the fastest on irrigated crops, with more than 90% of total irrigated areas estimated to be currently fertilized. Fertilizer use on rainfed crops

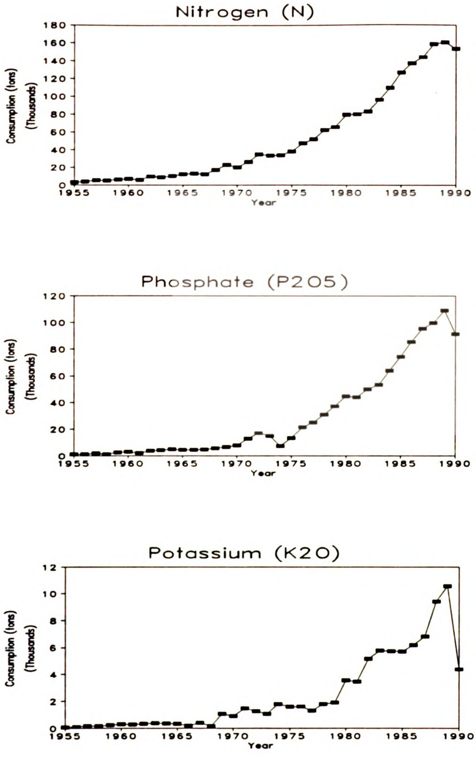

Figure 2: **Fertilizer Consumption: Syria, 1955 to 1990**

in Zone 1 also increased rapidly and at a faster rate than in Zone 2. However, most of the fertilizer has been applied to wheat, with much lower fertilizer use on food legumes. In Zone 3, where barley is the predominant crop, fertilizer use is rather limited. Recent surveys indicate that less than 15% of farmers use any fertilizer on barley (ICARDA/FRMP, 1988, p. 148), while no fertilizer is used in Zones 4 and 5 due to very low rainfall levels. These past consumption trends are expected to change in the future. However, the exact nature of these changes is difficult to predict. Based on discussions with officials from the Soils Directorate, the following possible trends were identified:

1. <u>Expansion in Irrigation</u>: The expansion in irrigated areas is expected to continue as a result of existing and new government irrigation schemes. These ambitious schemes are expected to increase total irrigated area by at least 400 thousand hectares by the year 2010, from the current level of 768 thousand hectares. This would translate into approximately 50% increase in fertilizer use by irrigated crops. Furthermore, the expected increase in the use of supplementary irrigation on wheat from well drilling on private farms will also substantially increase fertilizer use.

2. <u>Fertilizer Use on Feed Crops and Pastures</u>: Another factor is the expected major increase in the demand for feed crops, forages, and pastures due to the growth in demand for animal products. This demand growth will cause the price of feed products to become high enough to justify the use of fertilizer on most barley areas in Zone 3 and in Zone 4 to a lesser extent, and even on natural pastures. Although the rates per hectare used are likely to be relatively low, the area is

sufficiently large (2 to 3 million ha) that the potential increase in fertilizer demand would contribute an additional 20 to 30% increase in total fertilizer use.

3. <u>Fertilizer Use on Fruit Trees</u>: The current low rate of fertilizer use on fruit trees is likely to change in the future. The continued increase in the price of animal manure is expected to push more farmers who have traditionally relied on manuring (such as olive growers) to shift to chemical fertilizers. Such a development would have its major impact on the consumption of K_2O fertilizers since potassium is an important nutrient needed in fruit production.

2.2.2 Estimating Future Consumption

In order to predict potential consumption of fertilizers in the next decade, one needs to estimate equations for the quantities of fertilizer demanded, which would ideally incorporate the previously discussed factors affecting past and future demand[1]. There exists extensive literature on the estimation of fertilizer demand equations for individual countries, groups of countries, or for the world as a whole. Time series analysis is the predominant method used in studies estimating the quantities of fertilizer demanded. Most of these studies include the price of fertilizer as a key dependent variable (see, for example, Grilliches, 1958; Heady and Yeh, 1959; Hayami, 1964; Parikh, 1965; Sung, Dahl, and Shim, 1973; and Timmer, 1974 and 1976).

In the case of Syria, past fertilizer prices are not available. Therefore, the estimation of fertilizer demand equations becomes

---

[1] The theory of input demand is presented in a number of sources. For one presentation, see Henderson and Quandt (1971, pp. 69-70).

difficult. However, based on the historical data presented in Table 2.2, it is possible to estimate a trend equation that can be used to project future fertilizer consumption. However, such an approach assumes that whatever factors that influenced past trends will also have the same effect in the future.

John T. Shields (1976) reviewed the main methods used in the literature in estimating fertilizer trend equations. Most of these methods use one of four functional forms: linear; quadratic; square root; and log forms (Shields, p.335). These four models were fitted to the data in Table 2.2. The best fit was obtained when the log functional form was used based on the following simple model:

$$F = ab^T$$

Where F is total nutrient consumption
T is time (years)
a and b are the estimated model's coefficients

$$\text{or} \quad \log F = A + BT \tag{2.1}$$

Where $A = \log a$
$B = \log b$

A major drawback from using the above model is its assumption of a constant annual rate of increase in fertilizer consumption (the term B in eq. 2.1). Hence, if the above model is applied to the 1955-1990 time series, three different trend equations are estimated:

$$\log N = 3.524 + \underset{(0.0009)^{***}}{0.0502}\, T \qquad R^2 = 0.990 \tag{2.2}$$

$$\log P = 3.023 + \underset{(0.0016)^{***}}{0.0584}\, T \qquad R^2 = 0.976 \tag{2.3}$$

$$\log K = 1.975 + \underset{(0.0027)^{***}}{0.0567}\, T \qquad R^2 = 0.928 \tag{2.4}$$

(Significance levels: *** = 1%; ** = 5%; * = 10%;
NS= not significant; figures in brackets are the standard errors of the coefficients)

The above estimated equations imply an average annual growth rate in consumption between 5 and 6%. However, for the purpose of estimating future consumption, it would be more realistic to limit the analysis to the past decade. Hence, when the analysis is limited to the 1980-1990 series, the following equations are obtained:

$$\log N = 4.851 + \underset{(0.0031)^{***}}{0.0358}\,T \qquad R^2 = 0.938 \qquad (2.5)$$

$$\log P = 4.592 + \underset{(0.0043)^{***}}{0.0423}\,T \qquad R^2 = 0.915 \qquad (2.6)$$

$$\log K = 3.575 + \underset{(0.0114)NS}{0.0304}\,T \qquad R^2 = 0.441 \qquad (2.7)$$

The above equations give more realistic estimates of 3 to 4% annual increase in the use of N and P. However, the equation for K has a relatively low R^2 which sheds some doubts on its accuracy to predict future consumption. Assuming that these growth rates will not change for the next decade, future fertilizer consumptions can be estimated as shown in Table 2.3. By the year 2000, N consumption in Syria is expected to reach 400 thousand tons and that of P_2O_5 would exceed 300 thousand tons, or 160% and 230% increase over 1990 levels, respectively.

Table 2.3: ACTUAL AND PREDICTED FERTILIZER CONSUMPTION
Syria, 1980 to 2000.

Year		1980	1985	1990	1995	2000
				(Thousand tons)		
N	Actual	79.2	126.3	153.6	na	na
	Predicted[1]	77.1	116.5	176.0	266.0	401.8
P_2O_5	Actual	44.9	74.3	91.6	na	na
	Predicted[1]	43.1	70.3	114.5	186.5	303.9
K_2O	Actual	3.5	5.7	4.4	na	na
	Predicted[1]	4.0	5.7	8.1	11.5	16.4

1/ Based on equations 2.5, 2.6, and 2.7

2.3 Domestic Fertilizer Production

Faced with the rapid growth in fertilizer consumption the Syrian government has invested heavily into expanding fertilizer production capacity. These investments were encouraged by the discovery in the late 1960's of substantial deposits of rock phosphate, oil, and natural gas that can be used as raw materials for fertilizer production. Currently, three fertilizer plants are operating at a complex near the city of Homs in central Syria:

1. A plant (originally built in 1972) producing Calcium Ammonium Nitrate (CAN) with 26% N, was upgraded in 1984 to produce 30% N. The maximum capacity of the CAN plant is 36,000 tons of N per year.
2. A urea plant, operating since 1981, has a maximum capacity of 267,750 tons urea or 123,165 tons N per year.
3. A Triple Superphosphate (TSP) plant, operating since 1981, has a maximum capacity of 315,000 tons TSP or 144,900 tons P_2O_5 per year.

Table 2.4: FERTILIZER PRODUCTION CAPACITY AND ACTUAL PRODUCTION LEVELS Syria, 1981/82 to 1988/89.

Year[1]	CAN		Urea		TSP	
	Tons N	% of Capacity	Tons N	% of Capacity	Tons P_2O_5	% of Capacity
1981/82	22,535	61.7	14,443	11.7	59,511	41.1
1982/83	27,224	74.6	51,779	42.0	45,752	31.6
1983/84	30,572	83.8	73,725	59.9	69,515	48.0
1984/85	30,561	83.7	88,366	71.7	70,997	49.0
1985/86	31,031	85.0	88,406	71.8	86,477	59.7
1986/87	32,883	90.1	71,171	57.8	79,019	54.5
1987/88	22,376	61.3	12,122	9.8	57,779	39.9
1988/89	34,690	95.0	46,573	37.8	30,005	20.7
Capacity:	36,500		123,165		144,900	

1/ Fertilizer year: from July 1st to June 30th.
2/ Sources: Soils Directorate internal documents.

These plants have the potential of covering all the domestic N and P_2O_5 needs and to be able to export P_2O_5. However, a multitude of design, technical, and managerial problems and shortages in spare parts have lead to total production much lower than maximum capacity. As shown in Table 2.4, only the CAN plant has maintained relatively high production levels, with actual production representing more than 80% of capacity after the upgrading of the plant in 1984. The one exception was 1987/88, when the ammonia/urea unit was being modified to operate on natural gas instead of naphtha.

After a relatively slow start, production at the urea plant rapidly increased to reach a peak of 72% of production capacity in 1984/85. Technical problems prevented higher production levels and the shift from naphtha to natural gas in 1987/88 caused a further, though temporary, decline in production. Hence, total N production (CAN plus urea) declined from a peak level of around 75% of production capacity in 1985/86 to 21.7% in 1987/88. In 1988/89, after the modifications in the ammonia/urea unit were completed, total N production recovered somewhat but total production figures were still very low, 51.1% of total N capacity.

Technical problems at the TSP plant emerged shortly after it began operating in 1982. These serious problems prevented actual production levels from exceeding 60% of production capacity. They have become more serious in recent years leading to frequent shutdowns of the TSP plant for prolonged periods of time. This is clearly implied by the gradually declining production figures presented in Table 2.4, with actual production declining to a mere 30 thousand tons of P_2O_5 (20% of capacity) in 1988/89.

2.4 Fertilizer Imports

Prior to the dramatic expansion in domestic fertilizer production capacity in the early 1980's, Syria depended on imports for a large proportion of its fertilizer needs. The construction of the urea and TSP plants had the goal of making Syria self-sufficient in fertilizer production and being able to sell fertilizer on the export market. In fact, in 1983 Syria exported 6,000 tons of urea to Burma, 5,700 tons of urea to Jordan, and 15,500 tons of TSP to Iran (Fertilizer International, No. 220, 13 Feb. 1986, pp. 13 to 17). The following year urea exports increased, with 6,000 tons shipped to Burma and India and 19,200 tons to Iran, while TSP exports were negligible.

Table 2.5: FERTILIZER IMPORTS: Syria, 1984/85 to 1988/89

	N			P_2O_5		
Year[1]	Use (tons)	Imports (tons)	Imports as % of use	Use (tons)	Imports (tons)	Imports as % of use
1984/85	126,279	16,415	13.0	74,263	4,324	5.8
1985/86	136,994	15,235	11.1	85,588	13,064	15.3
1986/87	143,911	29,912	20.8	95,530	--	--
1987/88	158,391	154,409	97.5	99,774	51,036	51.2
1988/89	160,604	71,161	44.3	109,271	92,678	84.8

1/ Fertilizer year: from July 1st to June 30th.
2/ Differences between use and imports do not necessarily correspond to production figures because of inventories.
3/ Sources: Soils Directorate, internal documents.

These export figures were far below Syria's ambitious plans to export 60,000 tons of fertilizer in 1984, because of technical production problems and the growth in Syrian fertilizer consumption. By 1985 Syria had reverted to importing substantial amounts of fertilizer.

In 1984/85, fertilizer imports accounted for 13% of total N and 5.8% of total P_2O_5 use. By 1988/89, these percentages had increased to 44.3% for N and 84.8% for P_2O_5 (Table 2.5).

2.5 Fertilizer Prices

Fertilizer producer prices for the entire country are set by the government. In spite of high annual rates of inflation (approximately 60% in 1987[1]), fertilizer official (nominal) prices remained unchanged throughout the period 1984/85 to 1986/87 (see Table 2.6). Thus, the government covered the growing gap between the cost of production (or import costs) and sales prices. Starting in 1987/88 the government decided to gradually increase fertilizer prices with the aim of reaching the true costs of production in the near future. Official prices of crops were also increased to offset the higher fertilizer prices.

The data in Table 2.6 show that, between 1986/87 and 1989/90, the nominal price of calcium ammonium nitrate (30% N) increased by 405% and ammonium nitrate (33.5% N) increased by 398%. Also, the nominal prices of urea, TSP and potassium sulfate increased by 516%, 520% and 810%, respectively. However, when measured in real terms, all fertilizer prices in 1988/89 were still below their 1984/85 levels. In 1989/90 the substantial increases in nominal prices and the decline in inflation rates resulted in real fertilizer prices being above their 1984/85 levels. In 1989/90, the real prices of ammonium nitrates were about 5% higher than their 1984/85 levels, while the real prices of urea and TSP increased by about 35% during that period. The largest increase was in

---

[1] Unofficial sources claimed a 100% rate was more realistic (Cowitt, 1991, p. 769).

Table 2.6: FERTILIZER OFFICIAL PRICES
Syria, 1984/85 to 1989/90

	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
	(Syrian Liras per ton)					
- Local Ammonium Nitrate (30% N):						
Nominal:	840	840	840	1500	2300	3400
Real[1]:	985	840	617	691	788	1045
- Imported Ammonium Nitrate (33.5% N):						
Nominal:	955	955	955	1600	2500	3800
Real[1]:	1120	955	702	737	856	1168
- Urea (46% N):						
Nominal	950	950	950	1800	2800	4900
Real[1]:	1114	950	698	829	959	1506
- Di-Ammonium Phosphate (DAP) (18% N, 46% P_2O_5):						
Nominal:	--	--	--	--	4345	7100
Real[1]:	--	--	--	--	1488	2183
- Triple Super Phosphate (TSP) (46% P_2O_5):						
Nominal:	1000	1000	1000	2000	3000	5200
Real[1]:	1172	1000	735	922	1027	1599
- Potassium Sulfate (50% K_2O):						
Nominal:	950	950	950	2000	3000	7700
Real[1]:	1114	950	698	922	1027	2367
Consumer Price Index:	85.3	100	136.1	217.0	292.0	325.3

1/ Constant 1985 prices.
2/ Sources: Official fertilizer prices from internal documents of the Agricultural Cooperative Bank. Consumer Price Index from International Financial Statistics, April 1991.

the real price of potassium sulfate, with an increase of 112% between 1984/85 and 1989/90.

Despite these substantial increases in nominal prices, and minor increases in real prices (except for potassium sulfate), government subsidies continue to represent a significant proportion of the true costs of fertilizer. In 1989/90, these subsidies accounted for 30% of the true cost of urea, 49% for TSP, and 40% for Potassium Sulfate.

2.6 Planning Aggregate Fertilizer Requirements

2.6.1 Institutional Setting

The main agency responsible for planning annual fertilizer requirements in Syria is the Soils Directorate (SD). SD is one of several directorates under which the activities of the Ministry of Agriculture and Agrarian Reform (MAAR) are organized. The mandate of the SD is fairly broad, covering such diverse activities as conducting research, and formulating and implementing policy.

While most agricultural research activities are conducted by the Directorate of Agricultural and Scientific Research (DASR)[1], the SD specializes in soils-related research including soil mapping and classification; fertilizer trials; soil conservation methods; and soil chemistry and physics. In addition to its advisory function related to agricultural policy formulation in general, the SD's role is especially involved in the formulation and implementation of fertilizer policies. This includes not only estimating annual fertilizer needs, but also

---

[1] Refer to Peterson (1980), Zahlan (1984, p. 1) and ISNAR (1990), for a more detailed discussion of the organization of agricultural research in Syria.

making policy recommendations regarding fertilizer allocation, imports, production, distribution, and pricing. Moreover, the SD acts as a supervisor and coordinator of the activities of other agencies involving fertilizer policies.

The Soil Fertility and Plant Nutrition section of the SD is responsible for estimating annual fertilizer requirements. Based on these requirements, fertilizer production and import targets are recommended for the annual agricultural plan. These recommendations are submitted for approval to a committee that includes representatives of parties concerned with agricultural input provision. These include the Ba'ath Arab Socialist Party (the ruling political party in Syria); the General Peasant Union (GPU); the Ministry of Agriculture and Agrarian Reform (MAAR); the General Establishment for Chemical Industries; the General Fertilizer Company; the Establishment for Foreign Trade in Chemical and Food Products (GEZA); and the Agricultural Cooperative Bank (ACB). The committee is chaired by the Deputy Minister of Agriculture and Agrarian Reform.

The fertilizer requirements plan, which specifies the requirements of winter and summer crops and fruit trees, is reviewed by the above committee. It is then submitted to the Minister of Agriculture and Agrarian Reform and later to the Prime Minister for final approval. The Prime Minister is responsible for ensuring that the production and import targets set by the plan are implemented.

The official fertilizer requirement plan for the 1989/90 season is presented in Table 2.7. According to this plan, total fertilizer needs would amount to 306 thousand tons of N, 210 thousand tons of P_2O_5, and 23 thousand tons of K_2O.

Table 2.7 THE OFFICIAL FERTILIZER REQUIREMENT PLAN
Syria, 1989/90

	N	P_2O_5	K_2O
		(Thousand tons)	
REQUIREMENTS			
- Winter Season (July 1 to Dec. 31 1989):	181.0	151.0	13.0
- Summer Season (Jan. 1 to June 30 1990):	125.0	60.0	10.0
Total Requirements:	306.0	209.0	23.0
SUPPLIES			
- ACB[1] Stocks (July 1 1989):	35.3	27.1	4.9
- Domestic Production:	146.4	64.4	---
- Imports:	124.3	117.5	18.1
Total Supplies:	306.0	209.0	23.0

1/ Agricultural Cooperative Bank.
Sources: The Agricultural Plan for the 1989/90 Season, Ministry of Agriculture and Agrarian Reform (Unpublished).

Based on these requirements, the following fertilizer production and import targets were set:

Production: 120,000 tons of Calcium Ammonium Nitrate (30% N)
240,000 tons of Urea (46% N)
140,000 tons of Triple Superphosphate (46% P_2O_5)

Imports: 257,400 tons of Urea (46% N)
279,400 tons of Triple Superphosphate (46% P_2O_5)
35,280 tons of Potassium Sulfate (50% K_2O)

2.6.2 Estimation of Aggregate Requirements

The procedure currently used by the SD in estimating fertilizer requirements involves two types of estimates: Ideal and Planned requirements. Ideal fertilizer requirements assume "best scenario" conditions including: (a) all areas planted are fertilized; (b) farmers will apply the fertilizer rates recommended by the SD; and (c) farmers will have access to fertilizers.

Estimation of fertilizer requirements is usually made before the general agricultural plan, which specifies the areas to be planted to each crop, is finalized. Hence, the estimation of total area per crop is based on the previous season's agricultural plan. Fertilizer recommended rates on all crops are included in a "fertilizer requirement schedule". This schedule has recommendations for approximately 80 different crop categories grouped into three main classes, winter crops, summer crops, and fruit trees (see Appendix B).

Given the limited number of fertilizer trials undertaken in Syria, most of these rates are based on recommendations used in other countries. This is especially true in the case of newly introduced crops (e.g., soybeans), and fruit trees and vegetables. However, for the most economically important crops grown in Syria (e.g., wheat, cotton, barley, sugar beets, potatoes, corn, lentils, chickpeas) the recommended rates tend to be based on fertilizer trials undertaken in Syria during the past three decades. New results from fertilizer trials are used to adjust these rates periodically.

Ideal aggregate fertilizer requirements are estimated by summing the recommended fertilizer rates for each crop multiplied by the area planted to that crop. These estimates are affected by any increase in total cropped area, changes in the cropping plan, and adjustments in fertilizer recommendations.

In 1984/1985, the SD estimated ideal aggregate fertilizer requirements at 240 thousand tons N, 200 thousand tons P_2O_5, and 60 thousand tons K_2O (El-Hajj, 1985, p. 3). Actual fertilizer used during that year represented 53% of the ideal requirements for N, 37% for P_2O_5, and only 10% for K_2O. Based on these estimates of ideal requirements, the SD recommended a target of 20% annual growth rate in fertilizer use for the 1985-1990 five-year plan. If this target was achieved, ideal N levels were expected to be reached by 1988/89, and ideal P_2O_5 levels by 1990/91 (ibid., p. 18).

Based on the above goals, estimation of planned fertilizer requirements for the following year were based on actual fertilizer sales during the current year plus 20 percent. This figure is further adjusted by adding 15% to allow for enough contingency stocks to handle the possibility for increased demand during good seasons and to address possible shortfalls in production or delays in imports. Hence, the following general rule was used:

Planned Requirements including contingency stocks
= (Current season's sales + 20% annual growth rate) * 1.15
= 138% of current season's sales

According to the above rule, given 126,297 tons of actual N sales and 74,262 tons of P_2O_5 sales in 1984/85, the planned N requirements for 1985/86 were estimated at 174,200 tons (i.e., 126,297 x 1.38) and that of P_2O_5 at 102,500 tons. Starting in 1987/88, the above rule was modified. Instead of basing the estimates on previous season's sales, the current approach is based on satisfying the ideal N and P_2O_5 requirements of all field crops, 33% of ideal K_2O requirements, and 75% of N and P_2O_5 requirements for fruit trees. Thus, for the 1989/90 season, the ideal requirements were estimated at 328 thousand tons of N, 222 thousand tons of P_2O_5, and 70 thousand tons of K_2O. In contrast, the planned requirements were 306 thousand tons of N, 210 thousand tons of P_2O_5, and 23 thousand tons of K_2O (Table 2.8).

Table 2.8: ESTIMATION OF PLANNED FERTILIZER REQUIREMENTS
Syria, 1989/90

	N	P_2O_5	K_2O
Ideal Requirements[1] (tons):			
Crops:	237,900	172,927	17,358
Fruit trees:	90,407	48,713	52,484
Total:	328,307	221,641	69,843
Planned Requirements (tons):			
Crops:	237,900	172,927	5,728
Fruit trees:	67,805	36,535	17,320
Total:	305,705	209,462	23,048

1/ See Appendix B for detailed estimation of ideal fertilizer requirements for 1989/90.

The shift to this new system, in conjunction with the reduced levels of domestic production and constraints on imports, has led to a growth in planned requirements while at the same time actual use has declined. Discrepancies between planned and actual fertilizer use have become more accentuated in recent years. The percentage of the planned N requirements actually used declined steadily from 91% in 1984/85 to 50% in 1989/90 (Table 2.9). A similar trend was also observed for P_2O_5 (89% in 1984/85 as compared to 44% in 1989/90). In the case of K_2O, the drop was not as sharp. The percentage of planned requirements actually achieved declined from 69% in 1984/85 to 47% in 1988/89. In 1989/90, the cancellation of all potassium import contracts drastically limited the distribution of potassium fertilizers, with supplies coming from existing stocks.

Table 2.9: PLANNED AND ACTUAL FERTILIZER REQUIREMENTS
Syria, 1984/85 to 1989/90.

N REQUIREMENTS

Year[1]	Planned (tons)	% Increase	Actual (tons)	% Increase	Actual as % of Planned
1984/85	138,500	--	126,297	--	91.2
1985/86	174,200	25.8	136,994	8.5	78.6
1986/87	187,900	7.9	143,911	5.0	76.6
1987/88	240,000	27.7	158,391	10.1	66.0
1988/89	290,000	20.8	160,604	4.6	55.4
1989/90	306,000	5.5	153,565	-4.4	50.2

P_2O_5 REQUIREMENTS

Year	Planned (tons)	% Increase	Actual (tons)	% Increase	Actual as % of Planned
1984/85	83,500	--	74,262	--	88.9
1985/86	102,500	22.7	85,588	15.2	83.5
1986/87	118,100	15.2	95,530	11.6	80.9
1987/88	147,000	24.5	99,774	4.4	67.9
1988/89	205,000	39.5	109,271	9.5	53.3
1989/90	210,000	2.4	91,593	-16.2	43.6

K_2O REQUIREMENTS

Year	Planned (tons)	% Increase	Actual (tons)	% Increase	Actual as % of Planned
1984/85	8,200	--	5,678	--	69.4
1985/86	8,200	0.0	6,182	8.9	75.4
1986/87	9,250	12.8	6,806	10.1	73.6
1987/88	18,000	94.6	9,405	38.2	52.2
1988/89	22,250	23.6	10,547	12.1	47.4
1989/90	23,000	3.4	4,358	-58.7	18.9

1/ Fertilizer year: from July 1st to June 30th.
Sources: Soils Directorate internal documents.

It should be noted that the above mentioned drastic decline occurred in spite of a gradual increase in actual total fertilizer use (see Table 2.9). Thus, the widening gap between planned and actual use was partly due to the rapid increase in planned requirements. This is especially true in 1987/88 and 1988/89 because of the change in procedures to estimate fertilizer requirements.

2.7 Fertilizer Rationing and Allocation Strategies

2.7.1 Fertilizer Availability

The Soils Directorate defines fertilizer availability as the amount of fertilizer, domestically produced or imported, which is available for distribution to farmers. Availability is usually expressed in terms of the percentage of planned requirements actually available for distribution. In general the figures on fertilizer availability overestimate the true capabilities of the Agricultural Cooperative Bank (ACB) to satisfy the quantities demanded by farmers. This is because production and imports are not always available to meet the demand of peak periods.

Reduced fertilizer availability has become a chronic problem that Syrian policy makers are faced with almost every year. These problems have tended to be much more serious for fertilizer use on winter crops (primarily wheat, barley, food legumes, and fall-planted sugar beets and potatoes). The peak period of fertilizer demand for winter crops, especially phosphate, occurs very early in the season (October-December). Thus, any delays in importing fertilizers and/or any early disruptions in domestic production would cause serious reductions in fertilizer use for the fall-planted winter crops.

In fact, for the past few years the impact of fertilizer shortages was mostly felt during the winter season, whereas summer crops usually receive all their fertilizer requirements. This situation is partly caused by the delays in the development of the annual agricultural plan, which is rarely finalized before the end of August. Thus, officials are usually left with only one month to plan all the details for fertilizer distribution to fall-planted crops. For instance, in the 1989/90 season the total amounts of N fertilizer expected to be available for the winter season was estimated at 127 thousand tons. This is only 73% of the 175 thousand tons planned for the winter season. The situation for P_2O_5 was even more serious, with only 97.5 thousand tons available, representing 61% of the planned needs for the winter season.

2.7.2 Fertilizer Allocation

Given the centrally planned nature of fertilizer marketing and the highly subsidized official prices, the government has relied on fertilizer rationing to address chronic fertilizer shortages. Each farmer is issued a quantity of fertilizers based on the type of crops grown and total area planted to each crop. The per hectare allocation for each crop is determined by the SD, and it varies from year to year depending on the total amounts of fertilizer available at the beginning of the season.

Estimations of fertilizer requirements for the coming season are usually finalized in July of every year. Actual fertilizer applications on fall-planted crops usually begin with the sowing of rainfed cereals starting in October. Thus, to ensure that farmers have timely access to fertilizers, allocation and distribution decisions for fall-planted crops have to be finalized by early October. At that time the officials at the SD have acquired sufficient information to make realistic predictions about the actual amounts of fertilizer likely to be available for the winter season. These predictions are based on existing stocks, on the most recent production figures from the fertilizer plants, and on procurement contracts signed with international fertilizer suppliers.

Having relatively accurate estimates of the actual fertilizer available at the beginning of the winter season, the next issue is how to allocate the limited fertilizer resources to the various winter crops. Fertilizer allocation strategies adopted by the SD tend to vary from year to year. However, one principle that seems to be common in these strategies is to meet the fertilizer requirements for the "strategic crops", i.e., either those that provide substantial export earnings (such as cotton) or those substituting for the major food imports (such as wheat). Whether crops are irrigated or rainfed is another important factor influencing fertilizer allocation decisions. Generally irrigated crops have their fertilizer requirements met because the economic returns to fertilizer use by rainfed crops are lower and more risky than for irrigated crops.

The impact of the above strategies for fertilizer allocation to winter crops is that irrigated crops, including irrigated wheat, usually receive all their fertilizer requirements. As for rainfed crops, the first priority goes to high-yielding (HYV) wheat varieties. Of lower priority are local (LYV) wheat varieties and food legumes, with barley having the lowest priority. Given the general fertilizer shortfall for the winter crops, fertilizer is rarely allocated to barley. In fact, the first time fertilizer was allocated to barley was in the 1986/87 season. However, this allocation excluded barley in Zone 3.

2.8 Fertilizer Marketing

2.8.1 Official Channels

The Agricultural Cooperative Bank (ACB) is the sole legal distributor of chemical fertilizers in Syria. Based on instructions from the SD, the ACB issues individual licenses specifying the amounts of fertilizer allocated to each farmer based on the type of crops grown, area planted to each crop, whether these crops are irrigated or rainfed, and the Agricultural Stability Zone where the farm is located. All fertilizer purchases are made based on interest-free short-term loans by the ACB, with re-payment after harvest.

The ACB operates a network of 68 local branches covering most of the agricultural regions in Syria. The government provides the required facilities to open up needed branches. Fertilizer and other input stocks at the ACB branches are monitored on a weekly basis and sales on a monthly basis. The data are entered in a central computer at the ACB headquarters in Damascus. This allows the ACB to direct the flow of fertilizers towards the branches with the highest demand. The ACB has also expanded its network of warehouses. The total storage space is 93.2 thousand square meters, with a capacity of 233 thousand tons. They are used for various agricultural inputs distributed by the ACB (fertilizers, seeds, pesticides, bags, and so forth), with fertilizers being the largest user of space (196,535 tons in October 1989). The ACB can lease extra storage space if the need for storage arises.

2.8.2 The Parallel Market

Private trade in fertilizers is illegal in Syria. However, discussions with farmers clearly indicate that a large number of farmers purchase part of their fertilizer needs from the local or regional parallel market. Very little information is available regarding the parallel market sources of supply. However, based on informal interviews with farmers and local traders, it was possible to identify the following possible sources of supply:

1. Senior ACB officials, especially in the provincial branches, have enough discretionary power to divert some of the fertilizer under their authority to be sold in the parallel market. A typical arrangement would involve a provincial ACB senior official selling the fertilizer to a local influential notable or politician. The latter would then use his influence to protect the corrupt official. Another variant is the practice of local traders who bribe officials to obtain licenses allowing them to receive very large quantities of fertilizer at the official price.

2. Junior ACB employees are able to issue farmers only a portion of their fertilizer entitlements and sell the rest on the parallel market. This practice is facilitated by the illiteracy of many farmers and their inability to understand the complex fertilizer distribution system.

3. Heads of agricultural cooperatives: Another reportedly major "leakage" in official distribution channels takes place at the agricultural cooperative level. Cooperatives are treated as a single unit by the ACB. Thus, the entire fertilizer ration is received by the head of the cooperative who would then allocate it among the other

members and in the process be able to sell some fertilizer on the parallel market.

4. Farmers: There is enough evidence to indicate that at least some farmers also sell part of their fertilizer rations on the parallel market. Given the inaccuracy of fertilizer allocation procedures, it is very likely that many farmers would receive rations in excess of the amounts they had intended to apply. Thus, they may sell the rest on the market or to neighboring farmers. However, interviews with farmers suggest that they would prefer to store any excess fertilizer for future use rather than selling it. Moreover, the use of the parallel market prices as the base of fertilizer transactions between farmers is viewed by most farmers as highly unethical. Hence, most of these transactions tend to be in the form of barter exchange or short-term borrowing. Therefore, the available evidence suggests that fertilizer sales by farmers represent only a minor source of supplies to the parallel market.

In summary, two factors seem to be the most important determinants of fertilizer supply in the parallel market. The first factor is the total quantity of fertilizer available for distribution by the ACB. Since the majority of market supplies are suspected to originate from the ACB, it can be assumed that only a certain proportion finds its way to the market. It is virtually impossible to estimate the magnitude of this "leakage". However one can assume there is a positive relationship between the two. Thus, for a given level of quantity demanded, an increase in fertilizer availability would translate into an increase in parallel market supplies and, hence, would result in lower market prices. The second important factor is the degree of government monitoring and enforcement of the distribution activities of the ACB. Therefore, if the government decides to increase its vigilance, the proportion of total fertilizer sold on the parallel market would decline.

Information on fertilizer prices of the parallel market is limited and sketchy, with figures ranging from 15% to 35% above official prices. One of the most important factors affecting market prices is rainfall. With higher rainfall farmers' demand for fertilizer increases. During exceptionally good years, such as in 1987/88, market prices were 50 to 100% higher than official prices. In Contrast, the margins between market and official prices were less than 10% in dry years (e.g., 1988/89). During the 1989/90 season, after two consecutive dry years, farmers reduced their fertilizer use to such an extent that very few of them had to buy additional fertilizer from the parallel market. Thus, the parallel market was virtually non-existent during that year.

Another important determinant of the quantity of fertilizer demanded from the parallel market is fertilizer availability from the official channels. Since market demand represents aggregate excess demand, any increase in fertilizer availability would reduce fertilizer shortages at the farm level and, hence, would reduce market demand Finally, it is important to mention that any increase in agricultural product prices (official or market prices) would also increase farmers' demand for fertilizers. This would be reflected into increased market demand and higher market prices.

2.9 Farmers' Fertilizer Strategies

Very little information is available on farmers' decision making in relation to fertilizer use. Some information is available from farmers' surveys in northern Syria undertaken by ICARDA since the late 1970's. These surveys were mostly designed to analyze farmers' cultural practices in general, with some questions directed towards fertilizer use. More recently, a detailed study by Meri Whitaker (1990) focused on farmers' fertilizer strategies in northern Syria. This case study focused on nitrogen fertilization on rainfed wheat. The following discussion will rely heavily on Whitaker's results, in addition to personal discussions with farmers and officials from the Soils Directorate.

First, it is important to note that although fertilizer allocations are based on the assumption that farmers will actually apply the SD recommended rates for each crop, the majority of farmers make their fertilization decisions independently of the SD or the local extension agent. Some policy makers have seriously considered making it compulsory for farmers to apply the recommended rates. Such a proposal was briefly discussed in a meeting by the Higher Council on Agriculture (HCA) in 1985. However, it was rejected due to opposition by the General Peasant Union representative (El-Hajj, 1985, pp. 19,20). Moreover, although most wheat farmers surveyed have used fertilizer for 10 to 15 years, most of them had little information about the recommended rates or the official fertilizer allocations for each crop. They take whatever is allocated to them and rely on their own experiences, and others, to decide on what fertilizer strategies to employ.

When farmers have to make decisions about fertilizer use they need to address the allocation of fertilizer between crops, the number of applications per crop, in addition to the rates, timing, and method of applications. All of these decisions are made under a highly uncertain environment characterized by wide year-to-year variations in rainfall levels and in seasonal distribution.

Whitaker identified several fertilizer strategies adopted by rainfed wheat farmers in northern Syria. First, practically all farmers surveyed have indicated that they applied P_2O_5 only once, at the time of planting (mid-November to early December). Average rates used in the wetter areas (Zone 1) are almost twice as large as the rates applied in the drier regions (Zones 2 and 3). These rates vary very little from year-to-year given that P_2O_5 is applied at the beginning of the growing season, when future rainfall is unknown.

Unlike with P_2O_5 application, farmers have greater flexibility with N application. This allows them to modify their strategies based upon rainfall levels. Wheat farmers in Zone 1 generally apply two N applications. The first application is done at planting, while the second one is applied around tillering time (end of February). As with P_2O_5 rates, N rates at planting time show relatively little variation.

The rates of N for the second application depend essentially on rainfall levels during the first half of the growing season (October to February). If prior rainfall is considered normal, then farmers usually apply a rate twice as large as the first N application. This rate may be cut by one third if rainfall is below average, or increased by up to 50% in a wet year. This depends essentially on the level of previous rains and on farmers' expectations about rainfall during the second half of the growing season (early March to early May).

In the drier zones, farmers are less likely to apply N at planting than in Zone 1, and they tend to use much lower rates. This is a sensible strategy considering uncertain weather. During the growing season, farmers usually apply one to two additional N applications. The number of N applications during the growing season and the rates used per application represent the most important variables that farmers can manipulate to adjust to the amount of rain received. In a normal year, most farmers reported applying at least one additional N application around the end of January. But if the year was dry, two thirds of the farmers would not apply additional N during the growing season. In a wet year, more than 80% of survey farmers reported applying the same rate of N applied in normal years. However, more than half added a third application, about a month later.

Therefore, in the case of rainfed wheat (and rainfed crops in general), rainfall levels and seasonal distribution constitute the main determinant of fertilizer strategies adopted by farmers. In addition to weather uncertainty, uncertainty about government fertilizer policy also plays an important role in shaping farmers' strategies. Delays in fertilizer distribution and the size of the allocations are two important factors that influenced farmers' strategies. One of the most frequently stated complaint is that they often have to delay sowing their cereals or to plant without fertilization due to delays in fertilizer distribution. Delays also occur during the growing season. In fact many farmers have reported that they would increase the rates and/or the number of N applications during the growing season if the second distribution of fertilizer (allocations for fruit trees and summer crops) was done earlier. A number of farmers also mentioned that they seldom receive their full allocation. Thus, they often resort to diverting fertilizer from other crops (e.g., olives) or to buying from the parallel market.

CHAPTER 3

THE RESEARCH APPROACH

The main objective of this research is the development of a model for determining economically optimum allocations of limited fertilizer supplies in Syria. The model also will be used to compare alternative fertilizer allocation strategies and to assess the economic impact of limited supplies on national and farm incomes. The purpose of this chapter is to present the conceptual framework for this model and to outline the main steps in the research approach.

The chapter starts with a presentation of the basic microeconomic models of unconstrained and constrained optimization at the farm level. This is followed by a discussion of the main issues related to the extension of the farm-level approach to the problem of fertilizer allocation at the national level. Finally, the last section outlines the main steps in the specification of the fertilizer allocation model and its underlying assumptions.

3.1 Optimum Fertilizer Rates at the Farm Level

3.1.1 Unconstrained Optimization

The basic problem of how much fertilizer a farmer should apply to a given crop can be presented based on the standard neoclassical static model of profit maximization. This model assumes that the only criterion guiding the farmer's decision is that of maximizing profits, or net returns, from the use of fertilizers. The model also assumes that the farmer is risk-neutral and has perfect knowledge about input and output prices and about the relationship between the level of fertilizer applied and yield. Such a relationship describes the rate at which fertilizers are transformed into crop output, and it is often referred to as a yield response function or production function (Doll and Orazem, 1984, p. 20).

Assuming a yield response function to nitrogen (N) and phosphorus (P) fertilizer applications[1], this function can be written in the following general form:

$$Y = F(N, P, X, Z) \tag{3.1}$$

where Y is the per ha yield;
N and P are the per ha fertilizer application rates;
X refers to other variable inputs;
Z refers to environmental factors;

Based on this production function, the farmer's net returns to fertilizer application can be expressed as

$$NR = P_y * (Y - Y^0) - (W_n * N) - (W_p * P) - (TVC - TVC^0)$$

where NR are net returns to fertilizer use per ha;
Y^0 is the per ha yield of the unfertilized treatment;
P_y is output price;
W_n and W_p are fertilizer prices;
TVC are total variable costs other than fertilizer costs;
TVC^0 are total variable costs in the unfertilized treatment;

Assuming that TVC and TVC^0 are equal, these two terms can then be dropped from the net return equation to give

$$NR = P_y * (Y - Y^0) - (W_n * N) - (W_p * P) \tag{3.2}$$

[1] Potassium is not included in the analysis given its limited use in Syria.

Such an assumption may not be realistic given that fertilizer use is often accompanied by an increase in other variable costs such harvesting and transfer costs associated with the additional output due to fertilizer application. Such variable costs that are proportional to yield can be implicitly incorporated into the net returns equation by adjusting output prices to reflect these costs. A detailed discussion of these cost adjustments is presented in chapter 4.

Although eq. 3.2 is the simplest form for modeling farmers' decision making, it is not the most accurate. This is particularly true if the carry-over effect of the applied fertilizers is significant enough to affect the decision making process. A more accurate modeling of the net return equation needs to incorporate this carry-over effect, particularly in the case of phosphate and potassium fertilizers. Such fertilizer carry-over models were suggested by Kennedy et al. (1973), Stauber, Burt, and Linse (1975), Dillon (1977), Taylor (1983), Smith and Umali (1984), Kennedy (1986 and 1988), Lanzer, Paris, and Williams (1987), and Segara et al. (1989).

Although these models would greatly improve the accuracy of the results, they require more detailed biological data such as the content and availability of soil nutrients before planting and the patterns of nutrient uptake by the crop during the growing season. Such data are very limited in Syria and their quality is questionable given the inaccuracy of the soil testing procedures. Therefore, the analysis throughout this dissertation will be essentially based on the simple profit maximization model given by eq. 3.2.

To calculate the fertilizer rates that would maximize net returns from fertilizer use (NR), the first partial derivatives of the profit function with respect to N and P, $\partial NR/\partial N$ and $\partial NR/\partial P$, are set equal to zero (first order or necessary conditions), as follows:

$$\partial NR/\partial N = (P_y * \partial Y/\partial N) - W_n = 0 \quad (3.3)$$
$$\partial NR/\partial P = (P_y * \partial Y/\partial P) - W_p = 0 \quad (3.4)$$

Defining the Value of the Marginal Product (VMP) as the value of the increase in output due to the addition of one unit of fertilizer, eq. 3.3 and 3.4 can be rewritten as follows:

$$VMP_n = W_n \quad (3.5)$$

and $$VMP_p = W_p \quad (3.6)$$

Equations 3.5 and 3.6 represent the necessary conditions for profit maximization, i.e., the cost of the last unit of fertilizer added should be equal to the returns from the yield increase due to the addition of that unit (Doll and Orazem, 1984, p. 183). The optimum fertilizer rates, N^* and P^*, are calculated by solving simultaneously a system of two equations (eq. 3.3 and 3.4) with two unknowns (N and P).

Total fertilizer requirements can then be computed by multiplying the total area to be fertilized by the calculated optimum rates. If the farmer is growing several crops, then the above procedure is repeated for all crops, assuming the farmer has perfect knowledge of the yield response function for each individual crop.

3.1.2 Assessing the Feasibility of Optimum Fertilizer Rates

As mentioned earlier, the above optimization model is based on the assumption that the only criterion guiding the farmer's decision is that of maximizing net returns from the use of fertilizers. In reality, however, farmers' decision criteria are much more complex. These criteria are usually affected by many factors, including (FAO, 1984, p. 132)

> ... the anticipated yield increase, expected crop prices, cost and availability of fertilizers, level of financial resources and credit availability, land tenure considerations, the degree of risk and uncertainty and the farmer's ability to bear them.

Given the above factors, farmers are expected to be cautious when deciding the fertilizer rates to apply, by building in a fair safety margin in their profitability calculations. Two measures, or indicators, of profitability are commonly used. The first one is the marginal rate of return (MRR), which is defined as (CIMMYT, 1988, p. 32)

> ... the marginal net benefit (i.e., the change in net benefits) divided by the marginal cost (i.e., the change in costs), expressed as a percentage.

CIMMYT (1988, p. 35) suggests, as a general rule, that farmers will not use fertilizer beyond the point at which the MRR is at least 50% in one crop season. A similar rule of thumb is suggested by FAO (1981, p. 41) whereby the minimum acceptable value for MRR is set at 40%. Such minimum MRR rules are frequently used in practice to set recommendations that are considered to reduce the risk of not obtaining a yield response to the last increments of fertilizer (see, for example, Josephson and Zbeetnoff, 1988). However, in assessing the profitability of fertilizer use in comparison to no fertilizer application, increases in yield, returns, and costs have to be viewed as non-marginal changes. Such economic evaluations of fertilizer use frequently rely on the Value-Cost-Ratio (VCR) as an indicator of profitability.

The VCR is defined as the value of the yield increase due to fertilizer use (i.e., over the unfertilized treatment), divided by total fertilizer costs (FAO, 1981, p. 42). The VCR value associated with the calculated optimum N-P combination can be calculated as follows:

$$VCR = \frac{P_y * (Y^* - Y^0)}{(W_n * N^*) + (W_p * P^*)}$$

Where Y^* is the yield obtained as a result of applying the optimum fertilizer rates (N^* and P^*).

The VCR is an indicator of <u>average</u> returns to the investment in fertilizers. Thus its use as a basis for assessing profitability seems to be a theoretically weak approach since it is based on average rather than marginal comparisons of costs and returns. If the magnitude of the VCR value is used as a basis for comparing the profitability of alternative fertilizer rates, this could result in very misleading conclusions. For instance, the VCR value associated with very low fertilizer rates would be much larger than the VCR associated with higher rates, since fertilizer costs would be close to zero if the very low rates are applied.

The most relevant conclusion that can be obtained from the VCR is whether its value is greater or smaller than one, with a value greater than one indicating that the investment in fertilizer use is profitable. However, in order to build in a safety margin, a VCR of 2.0 is typically used as the critical value for the profitability of fertilizer use in developing countries (FAO, 1984, p. 132; Lele, Christiansen, and Kadiresan, 1989, p. 41). There seems to be no valid justification for using this critical value except for its widespread use in many international organizations, particularly the United Nations Food and Agriculture Organization (FAO). This, in turn, has led to its adoption by national research centers in several developing countries.

In Syria, the Soils Directorate (SD) relies on the VCR as the predominant indicator of profitability in its economic analysis of fertilizer experiments. Therefore, in order to facilitate the communication of results to SD officials, the VCR will also be used in this study as the indicator of profitability of fertilizer use.

The above general requirement of a VCR of at least 2.0 will be relaxed to allow for a minimum VCR of 1.5. This is justified by the fact that most VCR calculations do not explicitly incorporate additional transport and labor costs associated with increased fertilizer use or with the resulting increased output (Lele, Christiansen, and Kadiresan, 1989, p. 41). If these additional costs are accounted for, then the value of the yield increase would decline and fertilizer costs would increase. This would give a lower value for the minimum VCR than the suggested value of 2.0. In this study most additional transport and labor costs will be explicitly included in the fertilizer and crop prices based on which VCR calculations are made[1]. Therefore, it would be reasonable to assume that the critical value for minimum VCR would be closer to 1.5 rather than 2.0.

3.1.3 Risk and Uncertainty

The wide variation in rainfall patterns prevailing in Syria introduces a large element of uncertainty into the farmer's decision making about fertilizer use. Although the sources of uncertainty include the variability in input and output prices, the most important

---

[1] Refer to chapter 4 for details about the methods used in estimating fertilizer and crop prices.

source of uncertainty in Syrian agriculture tends to be yield uncertainty due primarily to variability in rainfall.

The farm management literature includes a broad range of methods with varying degrees of complexity that attempt to incorporate risk and uncertainty considerations into agricultural production analysis (see, for example, Anderson, Dillon and Hardaker, 1977; Antle, 1983; and Taha, 1987, pp. 427-467). Boisvert and McCarl (1990) provided an extensive survey of the literature on the applications of risk modeling techniques in agriculture. Most of these techniques are direct or indirect applications of expected utility theory, as developed by von Neumann and Morgenstern (1947).

The two most-utilized approaches in applying the expected utility theory are the mean-variance (E-V) analysis and the stochastic dominance rules (da Cruz and da Fonseca Porto, 1988, p. 381). However, these approaches tend to be complex, require extensive data, and their results are difficult to interpret by non-economists. If the prime users of the model's results are policy makers or farmers, then the main criterion for choosing a particular model is its simplicity and the ease with which the results can be explained to decision or policy makers (Boisvert and McCarl, 1990, p. 44).

There are less complex methods that have been used to examine agricultural risk. A common approach involves manipulating the values of the most uncertain parameters to evaluate the consequences of optimistic and pessimistic scenarios (see, for example, Savoie and Kabay, 1980; and Adams, Hamilton, and McCarl, 1986). Such an approach will constitute the main basis for treating risk and uncertainty in this study. This is justified by two basic concerns related to the decision model proposed in this study: First, the proposed model should be simple enough to be used by Syrian planners with limited economics or mathematical backgrounds; and, second, the results from the model should be easy to interpret and to explain to policy makers.

As mentioned earlier, rainfall is the most uncertain parameter affecting the profitability of fertilizer use in Syria. The calculation of the VCR associated with optimum fertilizer rates is based on "average" yield response functions. However, farmers growing rainfed crops are usually more concerned with the profitability of their investments in fertilizers in the event of a dry year. Therefore, in assessing the profitability of the estimated optimum rates on rainfed crops, the 1.5 minimum-VCR criterion will be applied to VCR calculations based on estimates of yield increase due to fertilizer use in the event of a dry year.

The question of what constitutes a "dry" year is subjective. Recent surveys of farmers in northern Syria suggest that two to three years out of ten are considered as "bad" years by the responding farmers (Whitaker, 1990). Based on an analysis of rainfall data from several meteorological stations in northern Syria, it is possible to define four rainfall scenarios, "good", "normal", "dry", and "very dry", for the three zones of interest (see Table 3.1).

The inclusion of the "very dry" scenario seems also important although its probability of occurrence is only one in eight years. This is because farmers would probably decide not to use fertilizer rates that may result in financial losses in the event of a very dry year. In other words, an additional criterion for assessing the profitability of

Table 3.1: DEFINITIONS OF RAINFALL SCENARIOS
Syria, Agricultural Stability Zones 1b, 2, and 3.

Rainfall Scenario	Scenario Definition	Zone 1b	Zone 2	Zone 3
"Good"	Mean (mm/year):	500	350	300
	Probability (%):	29	32	35
"Normal"	Mean (mm/year):	400	300	250
	Probability (%):	47	42	41
"Dry"	Mean (mm/year):	350	250	200
	Probability (%):	12	13	12
"Very dry"	Mean (mm/year):	300	200	150
	Probability (%):	12	13	12

1/ Refer to chapter 2 for the definitions of the Agricultural Stability Zones.
Sources: Derived from Agricultural Statistical Abstracts, various years.

a given N-P combination is the requirement of a minimum VCR of 1.0 in the event of a very dry year.

It is possible to estimate the effect of the calculated optimum rates on yield and profitability under each of the above defined scenarios. This can be done by including the level of rainfall as an explanatory variable in the production function[1]. Assuming that rainfall is the only environmental factor affecting yield (i.e., the "Z" variables in Equation 3.1), four different production functions associated with the four rainfall scenarios can be estimated for each rainfed crop:

[1] Refer to the discussion on the specification of production functions later in this chapter.

Good year: $Y_G = G(N,P,X)$
Normal year: $Y_N = N(N,P,X)$
Dry year: $Y_D = D(N,P,X)$
Very Dry year: $Y_E = E(N,P,X)$

where, Y_G is yield in a good year;
Y_N is yield in a normal year;
Y_D is yield in a dry year;
Y_E is yield in a very dry year.

Optimum fertilizer rates (N^* and P^*) will be computed based on the "normal year" production function (Y_N). These optimum rates are then included in the other three production functions to solve for the yield levels, Y^*_G Y^*_D Y^*_E, that would be obtained under the corresponding scenarios. Thus, the above minimum VCR criteria can be written as follows:

$$VCR_G = \frac{P_{yG} * (Y^*_G - Y^0_G)}{(W_n * N^*) + (W_p * P^*)} \geq 1.5 \qquad (3.7)$$

$$VCR_N = \frac{P_{yN} * (Y^*_N - Y^0_N)}{(W_n * N^*) + (W_p * P^*)} \geq 1.5 \qquad (3.8)$$

$$VCR_D = \frac{P_{yD} * (Y^*_D - Y^0_D)}{(W_n * N^*) + (W_p * P^*)} \geq 1.5 \qquad (3.9)$$

$$VCR_E = \frac{P_{yE} * (Y^*_E - Y^0_E)}{(W_n * N^*) + (W_p * P^*)} \geq 1.0 \qquad (3.10)$$

where P_{yG}, P_{yN}, P_{yD} and P_{yE} refer to the output price under the various rain scenarios.

In addition to the above minimum-VCR criteria, the analysis will also consider the effect of the optimum fertilizer rates on yields in dry and very dry years. This is based on discussions with wheat and barley farmers in the drier zones of northern Syria. When these farmers were asked for the reasons for not increasing their current application rates, a frequent response was that higher rates may "burn" the crop (i.e., reduce yield) in the event of a dry year. These concerns can be included in the analysis by introducing a further criterion: the optimum N and P rates should not exceed the rates that would maximize yield (i.e., Stage III of the classical production function) in dry and very dry years. This can be written as

$$N^* \leq N_E^{max} \leq N_D^{max}$$

and $$P^* \leq P_E^{max} \leq P_D^{max}$$

where maximum N and P (N^{max} and P^{max}) are computed by setting the first partial derivatives of the production functions, Y_D and Y_E, equal to zero.

In looking at the issue of fertilizer use on rainfed crops, barley is a special case that deserves some further discussion. Fertilizer use on barley in Syria is still very limited, with recent surveys indicating that less than 15% of farmers apply any fertilizer on barley (ICARDA/FRMP, 1988, p. 148). In comparison, most farmers apply fertilizer on wheat and, as indicated by recent survey findings, they have been doing that for an average of 10 to 15 years (Whitaker, 1990). Therefore, farmers probably consider barley fertilization as a relatively new and untested technology whose profitability is not yet proven. Moreover, barley is mostly grown in the drier zones where rainfall is extremely variable. This further exacerbates the uncertainty characterizing farmers' decisions about fertilization. Thus, in evaluating the profitability of fertilizer use on barley, farmers would be primarily concerned with the fate of their investment in the event of a dry year.

Such concerns can be incorporated into the analysis by assuming a "worst-case scenario" approach, or what is often referred to in the literature as the "maximin" assumption (see, for example, McInerney, 1967). According to this approach, rather than assuming average rainfall, risk-averse barley farmers would assume that a dry year would occur. Therefore, they would choose optimum fertilizer rates that would maximize their net returns based on yield increases expected during a dry year. In other words, the calculation of N^* and P^* for barley will be based on the "dry year" production function, Y_D, rather than Y_N.

3.1.4 Constrained Optimization

The procedure outlined in the previous section for the calculation of optimum N and P rates is based on unconstrained optimization. In other words it is assumed that if farmers are willing to pay the price, they could buy as much fertilizer as they wish and, thus, they would choose to apply the rates that would maximize their profits according to equations 3.3 and 3.4. Similarly, it is assumed that if farmers decide to apply the rates that would maximize their profits, the government is capable of supplying all the quantities of fertilizer demanded by farmers, either from domestic production or from imports.

However, the above assumptions are unrealistic given the serious problems facing domestic fertilizer production, and given the limited availability of foreign exchange for the imports of fertilizers. Under such constraints the government can rarely supply all the fertilizer quantities that farmers would demand at the existing official prices. Instead, farmers are issued fertilizer rations based on the crops grown and the area planted to each crop. Therefore, the problem faced by farmers is how to allocate their fertilizer rations in such a way as to maximize their returns from the limited quantities of fertilizer available to them.

The simple model of profit maximization outlined earlier can be modified to solve the farmer's constrained optimization problem. Assuming that only two crops are grown, crop 1 and crop 2, and that the farmer has perfect knowledge about the production functions and about input and output prices, the constrained optimization problem can be formulated as follows:

$$\begin{aligned}\text{Maximize } NR = {} & P_{y1} * A_1 * (Y_1 - Y_1^0) + P_{y2} * A_2 * (Y_2 - Y_2^0) \\ & - W_n(N_1 * A_1 + N_2 * A_2) \\ & - W_p(P_1 * A_1 + P_2 * A_2)\end{aligned}$$

$$\begin{aligned}\text{Subject to: } & N_1 * A_1 + N_2 * A_2 = N_T \\ & P_1 * A_1 + P_2 * A_2 = P_T \\ & F(N_1, P_1, X_1, Z) = Y_1 \\ & G(N_2, P_2, X_2, Z) = Y_2\end{aligned}$$

where NR are net returns from fertilizer use for the whole farm;
Y_1 and Y_2 are the per ha yields of crop 1 and crop 2;
Y_1^0 and Y_2^0 are the yields of the unfertilized treatments;
$F(N_1, P_1)$ and $G(N_2, P_2)$ are the production functions for Y_1 and Y_2;
N_1 and P_1 are the per hectare fertilizer rates applied on crop 1;
N_2 and P_2 are the per hectare fertilizer rates applied on crop 2;
N_T and P_T are the total quantities of fertilizer available;
W_n and W_p are fertilizer prices;
P_{y1} and P_{y2} are output prices;
A_1 and A_2 are the fertilized areas planted to crop 1 and crop 2;
X_1 and X_2 are variable inputs other than fertilizers;
Z refers to environmental factors.

Such a problem is often set up in a form known as a *Lagrangean function* (*L*), as follows:[1]

$$\begin{aligned}L(N_1, N_2, P_1, P_2, \lambda_1, \lambda_2) = {} & P_{y1} * A_1 * (Y_1 - Y_1^0) + P_{y2} * A_2 * (Y_2 - Y_2^0) \\ & - W_n(N_1 * A_1 + N_2 * A_2) - W_p(P_1 * A_1 + P_2 * A_2) \\ & - \lambda_1 (N_1 * A_1 + N_2 * A_2 - N_T) \\ & - \lambda_2 (P_1 * A_1 + P_2 * A_2 - P_T) \qquad (3.11)\end{aligned}$$

[1] The following section is adapted from Appendix II in Doll and Orazem (1984).

where λ_1 and λ_2 are the *Lagrangean multipliers*, defined as

$$\lambda_1 = dL/dN_T$$

and $$\lambda_2 = dL/dP_T$$

In other words, λ_1 and λ_2 represent the amount by which net returns would increase if N_T or P_T are increased by one unit.

To maximize L, the first partial derivatives with respect to N_1, P_1, N_2, P_2, λ_1, and λ_2 are set equal to zero (first order conditions):

$$\partial L/\partial N_1 = A_1(P_{y1} * \partial Y_1/\partial N_1 - W_n - \lambda_1) = 0 \qquad (3.12)$$
$$\partial L/\partial P_1 = A_1(P_{y1} * \partial Y_1/\partial P_1 - W_p - \lambda_2) = 0 \qquad (3.13)$$
$$\partial L/\partial N_2 = A_2(P_{y2} * \partial Y_2/\partial N_2 - W_n - \lambda_1) = 0 \qquad (3.14)$$
$$\partial L/\partial P_2 = A_2(P_{y2} * \partial Y_2/\partial P_2 - W_p - \lambda_2) = 0 \qquad (3.15)$$
$$\partial L/\partial \lambda_1 = - N_1 * A_1 + N_2 * A_2 + N_T = 0 \qquad (3.16)$$
$$\partial L/\partial \lambda_2 = - P_1 * A_1 + P_2 * A_2 + P_T = 0 \qquad (3.17)$$

To calculate the optimum fertilizer rates on crop 1 and crop 2 (N_1^*, P_1^*, N_2^*, and P_2^*) the above six equations with six unknowns (N_1, P_1, N_2, P_2, λ_1, and λ_2) are solved simultaneously.

In the above system of six equations, the first four (eq. 3.12 to 3.15) can be written as

$$VMP_{n1} = W_n + \lambda_1$$
$$VMP_{p1} = W_p + \lambda_2$$
$$VMP_{n2} = W_n + \lambda_1$$
$$VMP_{p2} = W_p + \lambda_2$$

or $$VMP_{n1} = VMP_{n2} = W_n + \lambda_1 \qquad (3.18)$$
$$VMP_{p1} = VMP_{p2} = W_p + \lambda_2 \qquad (3.19)$$

The above two equations reflect what is often referred to as the equimarginal rule for profit maximization, i.e., the marginal revenues to the application of fertilizer should be equal across all crops. Also, according to this rule, these marginal revenues should be equal to the marginal cost of the applied fertilizer. However, under fertilizer rationing, the fertilizer purchase price does not represent its true marginal cost given that the farmer cannot buy any additional quantities beyond the ration purchased from the government. The true value to the farmer, or shadow prices, of the limited fertilizers are given by $(W_n + \lambda_1)$ and $(W_p + \lambda_2)$. These values would constitute the maximum prices that the farmer would be willing to pay if he could purchase additional quantities from the parallel market.

Combining eq. 3.18 and 3.19 we get:

$$\frac{VMP_{n1}}{W_n+\lambda_1} = \frac{VMP_{n2}}{W_n+\lambda_1} = \frac{VMP_{p1}}{W_p+\lambda_2} = \frac{VMP_{p2}}{W_p+\lambda_2} \qquad (3.20)$$

Equation 3.20 reflects a more general statement of the equimarginal rule specifying that "the ratio of the value of the marginal product to the price of an input be equal for all inputs in all uses" (Doll and Orazem, p. 191). Under constrained optimization, this rule would require the use of the shadow prices of fertilizers, as in eq. 3.20. In contrast, the purchase price would be the relevant price if there are no limits on the quantities of fertilizer that the farmer could buy (the Lagrangean multipliers would be equal to zero).

3.2 Fertilizer Allocation at the National Level

3.2.1 Conceptual Approach

The same conceptual approach for fertilizer allocation at the farm level can be used to model the fertilizer allocation problem at the national level. This can be done if all cropped areas in Syria are treated as a single farm with one decision maker responsible for deciding on the optimum fertilizer rates that would maximize net returns to the limited aggregate fertilizer supplies. In other words, the two-crop model of constrained optimization is extended to cover all crops grown in Syria.

Such an approach to the fertilizer allocation problem at the national level was proposed in an FAO fertilizer manual (FAO, 1966, pp. 39-40). Based on this approach, the national fertilizer allocation model is formulated as follows:

$$\text{Maximize } NR = \Sigma_i \, [P_{yi} * A_i * (Y_i - Y^0{}_i)] - \Sigma_f \, (W_f * F_{fT}) \tag{3.21}$$

$$\text{Subject to: } \Sigma_i \, (F_{fi} * A_i) = F_{fT} \tag{3.22}$$

$$N_i(F_{1i}, F_{2i}, \ldots, F_{fi}, X_i, Z) = Y_i \tag{3.23}$$

where NR is aggregate net return from fertilizer use in Syria
Y_i is the per ha yield of crop i;
$Y^0{}_i$ is the per ha yield of the unfertilized treatment;
$N_i(F_{1i}, F_{2i}, \ldots, F_{fi}, X_i, Z)$ is the production function for Y_i;
F_{fi} is the per hectare application rate of fertilizer f on crop i;
X_i refers to inputs on crop i other than fertilizers;
Z refers to environmental factors;
F_{fT} are aggregate available supplies of fertilizer f;
W_f is the price of fertilizer f;
P_{yi} is the price of crop i;
A_i is total fertilized area planted to crop i.

The Lagrangean function would be set up in a similar way as in the farm-level model, and optimum fertilizer rates on all crops would be calculated by simultaneously solving a system of (i*f + f) equations.

This national fertilizer allocation model is based on several simplistic assumptions, including:

1. There exist adequate reliable data to estimate production functions for all the crops grown in Syria.
2. For each crop, the estimated production function is representative of the crop's growing conditions in all regions.
3. Farmers will actually apply the fertilizer rates on each crop as recommended by the official fertilizer allocation plan.

4. All fertilizer supplies will be available for distribution at the time when farmers need them.

5. All farmers have access to the official fertilizer distribution network and they have the necessary financial resources to cover all their fertilizer purchases.

6. The optimum fertilizer rates are scale-neutral, i.e., they are equally applicable to small and large farms.

These assumptions clearly suggest that the results of the model may not be a very accurate representation of actual conditions in Syria. However, the above working assumptions had to be made given the limited data availability in Syria. Although the model may not be as accurate as one would desire under ideal circumstances, the results would represent rough approximations of actual and/or simulated conditions. These approximations would still constitute information that could assist policy-makers in formulating more efficient fertilizer allocation strategies.

3.2.2 Financial vs Economic Prices

In the earlier discussion on the procedure to estimate economically optimum fertilizer rates, the term "optimum" was often used. This term is somewhat vague since it does not specify from whose point of view these rates are optimal, the farmer's or the economy as a whole? This distinction becomes important if there are relatively large differences in the prices that farmers pay or receive, as compared to the true costs to the economy as a whole.

For instance, if the highly subsidized fertilizer producer prices are to be used in the analysis, then the optima calculated would be relevant only if the objective is to maximize farmers' income. If, on the other hand, the objective is to maximize national income (or any other measure of aggregate welfare), then these farmers' optima may be economically non-optimal. This would be the case if the input-to-output, or <u>relative</u>, price ratio faced by farmers is significantly different from the true relative price ratio. In other words, farmers' optima may lead to an economically inefficient allocation of the limited fertilizer resources. In this case, it would be more appropriate to use international market prices, which generally represent the true opportunity cost of resources used and of outputs produced.

The main objective of this study is to develop a national decision model for allocating the limited fertilizer resources in the most economically efficient way. This is based on the stated policy objective of maximizing net economic returns from the limited fertilizer supplies. This focus on "economic efficiency" necessitates that the analysis be based on the true value of resources used and of output produced, in order to achieve national welfare objectives.

Thus, whenever fertilizer or crop prices are significantly different from their true economic values, these prices should be adjusted to make them more closely represent the opportunity costs to the economy as a whole. These adjusted prices are referred to as <u>economic prices</u> (the term "shadow price" is also often used; see, for example, Gittinger, 1982, p. 243), whereas unadjusted prices (i.e., actual prices faced by farmers) are referred to as financial prices[1]. Therefore, the estimation of "optimum" fertilizer rates, whether based on constrained or unconstrained optimization, will be based on economic prices throughout this study.

In addition to the economic efficiency objective, an important objective of this study is to analyze the impact of alternative fertilizer allocations on farmers' net returns from fertilizer use. This is of particular importance since the ultimate decision on which policy alternative to adopt is essentially a political decision. Such a decision would be influenced by many factors, including the potential impact of the policy in question on farmers.

Therefore, the estimation of optimum fertilizer rates will be based on economic prices, while the impact of these rates will be evaluated using both financial and economic prices. In other words, for the economically optimum fertilizer rates to be considered acceptable, the VCR values calculated based on both economic and financial prices would have to satisfy the minimum VCR requirements mentioned earlier.

3.2.3 Incorporating Policy Concerns

In addition to their concern about the impact of alternative fertilizer allocation strategies on farmers' income, policy makers are also interested in the impact of these strategies on key macroeconomic policy objectives. These objectives include: (1) reducing foreign

---

[1] Refer to chapter 4 for a detailed discussion of the procedures used in estimating financial and economic prices, and their underlying assumptions.

exchange expenditures, (2) reducing the government's budget deficit, and (3) increasing food self-sufficiency.

1) Foreign Exchange Expenditures

The main reason for the current constraints on fertilizer supplies is the government's decision to limit fertilizer imports in an attempt to reduce its foreign exchange expenditures. Fertilizer policy affects the government's foreign exchange expenditures in three direct ways: (a) fertilizer imports, (b) crop imports, and (c) crop exports. For instance, if fertilizer imports are lowered to reduce expenditures in hard currencies, the resulting lower fertilizer use may reduce the output of crops that substitute for imports, and/or reduce the output of exportable crops. Therefore, the main focus should be on increasing net foreign exchange earnings, defined as

Net foreign exchange earnings = Earnings from increased crop exports
+ Savings from reduced crop imports
- Expenditures on fertilizer imports

As will be discussed later (see chapter 4), all crops covered in this study are treated as traded goods, i.e., they are either exported or they substitute for imports. Since the government has a complete monopoly on foreign trade in fertilizers and most crops, any increase or decrease in aggregate crop output, due to changes in fertilizer policies, will be reflected in an equal increase or decrease in net crop exports. This would apply only to crops, such as cotton and sugar beets, which are completely controlled by the official marketing system. In the case of cereals, however, significant proportions of total output are sold in the parallel market[1], while potato output is entirely sold in the recently legalized private market.

The net increase in foreign exchange earnings as a result of fertilizer use can be expressed as follows:

$$NFE = \Sigma_i \, [IP_{yi} * A_i * M_i \, (Y_i - Y^0{}_i)] - \Sigma_f \, (IP_f * F_{fT}) \tag{3.24}$$

where NFE is net increase in foreign exchange earnings relative to no fertilizer use;
IP_{yi} is the international price of crop i;
A_i is the total fertilized area planted to crop i;
M_i is the proportion of output of crop i sold to the government;
Y_i is the per ha yield of crop i;
$Y^0{}_i$ is the per ha yield of the unfertilized treatment of crop i;
IP_f is the international price of fertilizer f;
F_{fT} are aggregate available supplies of fertilizer f.

Given that crop yields would vary depending on rainfall levels, foreign exchange earnings from net crop exports are also expected to vary. It is, then, possible to compute four different equations for net foreign exchange earnings based on the four rainfall scenarios discussed earlier. These equations can be incorporated into the allocation model as additional constraints with lower limits specified to reflect policy objectives. For instance, minimum foreign exchange earnings during a normal year can be set to be equal to the current level of net foreign exchange earnings associated with fertilizer use.

Such explicit constraints, however, might impose too much rigidity on the model solution. Thus, the general approach followed in this study will be to calculate net foreign exchange earnings associated with each fertilizer allocation examined, without a priori restrictions on the lower limits. The results will be presented and their implications

---

[1] Refer to chapter 4 for more details on the estimated proportions of cereal output sold through official channels.

will be discussed, but the decision on whether these earnings are acceptable or not will be left to policy-makers.

3) The Government's Budget Deficit

In addition to concerns about the government's foreign exchange expenditures, the impact of alternative fertilizer strategies on the overall government budget is also an important policy issue. This is of particular importance given the heavy subsidies on fertilizers in Syria. Therefore, in comparing the feasibility of alternative fertilizer allocations, it is important to estimate the impact of these strategies on the government budget. To estimate this budgetary impact, we need first to calculate the net taxes or subsidies associated with the fertilizers and crops covered by this study.

If the official price of a crop is much lower than its true economic value, the government would be making additional revenues from each additional kilogram produced (i.e., the crop is implicitly taxed) as a result of fertilizer use. In contrast, the government would be incurring additional expenditures for each additional kilogram of fertilizer applied. If, on the other hand, the official crop price is higher than its true economic value (implicit subsidy), government expenditures would increase as a result of increased yields due to fertilizer use, besides the higher expenditures on fertilizer subsidies.

The net increase in government expenditures as a result of fertilizer use can be expressed as follows:

$$NGE = \Sigma_f (S_f * F_{fT}) - \Sigma_i [T_{yi} * A_i * M_i (Y_i - Y^0_i)] \qquad (3.25)$$

where NGE is net increase in government expenditures relative to no fertilizer use;
S_f is subsidy per unit of fertilizer f;
F_{fT} are aggregate available supplies of fertilizer f;
T_{yi} is implicit tax or subsidy per unit of crop i;
A_i is the total fertilized area planted to crop i;
M_i is the proportion of total output sold to the government;
Y_i is the per ha yield of crop i;
Y^0_i is the per ha yield of the unfertilized treatment.

As in the case of foreign exchange earnings, explicit constraints on maximum government expenditures might impose too much rigidity on the model solution. Thus, net government expenditures associated with each fertilizer allocation will be calculated and their implications discussed. But the decision on whether these expenditures are acceptable or not will be left to policy-makers.

3) <u>Food Self-Sufficiency</u>

The main concern about food self-sufficiency in Syria relates primarily to wheat production and, to a much lesser extent, the production of sugar beets. Wheat imports represent the single most important food import item, accounting for an average of 25% to 30% of total wheat consumption (Agricultural Statistical Abstracts, 1987). This percentage can be as high as 75% in a very dry year like 1984, when a record 1.5 million tons of wheat was imported. Therefore, increasing wheat self-sufficiency is a prime policy objective often influencing the design and implementation of other policies, including fertilizer policy. This is clearly implied by the high priority given to wheat in the current fertilizer allocation strategy adopted by the government.

Such concerns can be incorporated into the fertilizer allocation model by setting up constraints specifying lower limits on aggregate output for each crop. Also, these constraints can be formulated to reflect specific self-sufficiency requirements for each rainfall scenario. Although such constraints can be easily incorporated into the model, the minimum production limits would be difficult to determine given the vagueness of policy statements related to self-sufficiency. These statements are often expressed in very general terms, referring to the need to increase self-sufficiency in food, feed, and industrial crops, in addition to the objective of increasing agricultural exports.

Explicit self-sufficiency constraints may also reduce the model's flexibility in finding an optimum solution that would maximize economic net returns to fertilizer use. Thus, the general approach followed in this study will be to calculate the impact of alternative fertilizer allocations on aggregate crop output and to discuss their implications on food self-sufficiency.

3.3 The Fertilizer Allocation Model

3.3.1 Linear Programming

The general formulation of the fertilizer allocation model, given by equations 3.21, 3.22, and 3.23, may be too complex to solve based on standard calculus techniques. This would be particularly true if a large number of crops, or crop varieties, are to be included in the model. As mentioned earlier, such a model would require solving a constrained optimization problem consisting of (i*f + f) constraints, where i is the number of crop activities and f the number of fertilizer nutrients covered by the model. For instance, a model with 15 crop activities and two fertilizer nutrients would include at least 32 constraints, which can be computationally difficult to achieve particularly if additional constraints are to be incorporated into the model.

Fortunately, there exist other methods to solve constrained optimization problems. One of the most commonly used methods is linear programming (LP). In addition to finding an optimal solution to large constrained optimization problems, the LP solution can also generate other useful information such as the shadow prices of limited resources and information on non-optimal activities. A detailed review of literature on the theory and applications of linear programming is provided by Schrijver (1986). Hazell and Norton (1986) focus on the applications of programming techniques to agricultural problems. Bronson (1982), Mills (1984), and Taha (1987) provide practical introductions to LP including many agricultural examples.

Linear programming is an optimization technique to solve for "allocation problems in which limited resources are allocated to a number of economic activities" (Taha, p. 50). The LP problem consists of optimizing (maximizing or minimizing) a specific quantity, called the "objective", which depends on a finite number of input variables, subject to a set of constraints (Bronson, p. 1). The following section is adapted from Taha (p. 50), and provides a brief introduction to the formulation of a general LP model.

For a maximization problem, the LP model, in its general mathematical form, is expressed as follows:

$$\text{Maximize } Z = c_1.X_1 + c_2.X_2 + \ldots + c_n.X_n$$

subject to:

$$\begin{aligned}
a_{11}.X_1 + a_{12}.X_2 + \ldots + a_{1n}.X_n &\le b_1 \\
a_{21}.X_1 + a_{22}.X_2 + \ldots + a_{2n}.X_n &\le b_2 \\
\vdots \quad\quad \vdots \quad\quad \vdots \quad\quad \vdots \quad &\quad \vdots \\
a_{m1}.X_1 + a_{m2}.X_2 + \ldots + a_{mn}.X_n &\le b_m
\end{aligned}$$

$$X_1,\ X_2,\ \ldots,\ X_n \ge 0$$

The above model includes n activities X_1, X_2, ..., X_n and m resources with maximum amounts available given by b_1, b_2, ..., b_m. The first line of the model is the *objective function*, which can be expressed as

$$\text{Maximize } Z = \Sigma_j\ (c_j.X_j)$$

This function represents the combined contributions of each activity to total profit Z, where c_j represents the profit or net return per unit of activity j.

Under the objective function there are m constraints that can be expressed as follows:

$$\Sigma_j\ (a_{ij}.X_j) \le b_i \qquad\qquad i = 1, \ldots, m$$

This means that each unit of activity j uses an amount a_{ij} of resource i, and the summation of all $a_{ij}.X_j$ represents the total use of resource i by all n activities, which cannot exceed b_i. The resource limits or b_i's are often called Right Hand Side (RHS), referring to their positions with respect to the inequality signs. LP constraints can include "≤", "≥", or "=" signs. However, strict inequality signs (> or <) cannot be included in the formulation of an LP problem.

The last line, $X_1, X_2, \ldots, X_n \geq 0$, is what is often referred to as "non-negativity constraints", and it specifies that none of the activities in the solution can be negative, which is self-explanatory.

3.3.2 The Basic Model

An LP formulation of the fertilizer allocation problem was proposed by Nordblom and Al-Ashram (1989), who developed a conceptual model for the centrally planned allocation of limited fertilizer supplies to crops in contrasting production zones. The model's potential is illustrated through its application to a hypothetical three-crop country, using coefficients based on actual data from fertilizer experiments in Syria. In fact, Nordblom and Al-Ashram's study represents the first stage of a larger research project which is the basis of this dissertation. The LP model presented in this section is based on Nordblom and Al-Ashram's model, with some modifications that will be discussed later.

The fertilizer allocation model, given by equations 3.21, 3.22, and 3.23, can be re-formulated as an LP model, as follows:

$$\text{Maximize } NR = \Sigma_i \, [P_{yi} * A_i * (Y_i - Y^0_i)] - \Sigma_f \, (W_f * F_{fT}) \qquad (3.26)$$

$$\text{Subject to: } \Sigma_i \, (F_{fi} * A_i) \leq F_{fT} \qquad (3.27)$$

$$N_i(F_{1i}, F_{2i}, \ldots, F_{fi}, X_i, Z) = Y_i \qquad (3.28)$$

$$F_{1i}, F_{2i}, \ldots, F_{fi} \geq 0$$

$$Y_i \text{ and } Y^0_i \geq 0$$

where NR is aggregate net return from fertilizer use in Syria
Y_i is the per ha yield of crop i;
Y^0_i is the per ha yield of the unfertilized treatment;
$N_i(F_{1i}, F_{2i}, \ldots, F_{fi}, X_i, Z)$ is the production function for Y_i;
F_{fi} is the per hectare application rate of fertilizer f on crop i;
X_i refers to inputs on crop i other than fertilizers;
Z refers to environmental factors;

F_{fT} are aggregate available supplies of fertilizer f;
W_f is the price of fertilizer f;
P_{yi} is the price of crop i;
A_i is total fertilized area planted to crop i.

In this simple or "basic" version of the LP model, the objective is to maximize net returns from the use of fertilizers on all the major crops in Syria. This is subject to the constraints imposed by the quantities of fertilizer available, and the physical input/output relationship between the amounts of fertilizer applied and yields obtained. The model would solve for the optimum fertilizer rates on each crop, F^*_{fi}, that will maximize net returns from fertilizer use given the constraints on aggregate supplies. Crop and fertilizer prices, crop areas, and the upper limits on fertilizer supplies are all exogenous to the model, i.e., they are fixed by the analyst. The input/output coefficients are based on the estimated parameters of the production functions.

3.3.3 Specification of the Production Functions

A key determinant of the complexity of the above model is the specification of the production function constraints. These functions were expressed using a general formulation such as in eq. 3.1:

$$Y_i = N_i(F_{1i}, F_{2i}, \ldots, F_{fi}, X_i, Z)$$

The production functions need to be formulated in more specific terms. This refers to the functional forms to be used and the explanatory variables to be included in the production functions.

3.3.3.1 Functional Form

The true relationship between applied fertilizer nutrients and yield is never known. Thus, a key step in the specification of production functions is the choice of an appropriate functional form. This has typically been difficult in applied research conducted by soil scientists, agronomists, and agricultural economists. This task is further complicated by the growing number of available functional forms to choose from. Griffin, Montgomery, and Rister (1987) compiled twenty different categories of functional forms that have been used in the production economics literature. Therefore, the problem of choosing the "best" function cannot be solved from a simple set of rules.

The quadratic production function, and the polynomial function in general, has been successfully applied to a large number of fertilizer studies listed in the literature. The general approach is based on studying experimental data by statistical methods and an empirical polynomial equation of "best fit" is estimated, with no assumption or hypothesis as to the underlying causes (Mason, 1956, p. 77).

This approach emerged from the extensive efforts of agricultural economists during the 1950's. Heady and Dillon (1961) examined the estimation methods, and the mathematical and economic characteristics of three most commonly used production functions, power models (Cobb-Douglas function), exponential models (Mitscherlich and Spillman functions), and polynomial models (quadratic and square-root functions). Several studies during that period attempted to compare the appropriateness of these functions by comparing how well they fit fertilizer experiment data (see for example Johnson, 1953; Heady, 1954; Hutton, 1955; Hutton and Elderkin, 1954; and Heady, Pesek, and Brown, 1955). The conclusions reached in these studies were obviously specific to the unique fertilizer experiments. Nevertheless, for the majority of these studies the polynomial quadratic and square root models generally gave the best fit.

In this study, the quadratic polynomial functional form will be used in the estimation of production functions. This functional form has been the standard one used in fertilizer trials by agronomists from both the Soils Directorate (SD) and the International Center for Agricultural Research in the Dry Areas (ICARDA). Given that this dissertation is based on a collaborative project between the two institutions, a functional form that can be easily estimated and understood was desirable.

The quadratic function postulates a smooth, concave, and differentiable function, possessing a point maximum, with substitution among all nutrients (Baum, Heady and Blackmore, 1956; Baum, et al., 1957). The concavity assumption conforms with the empirically observed diminishing marginal response to fertilizer applications (Mason, 1956, p. 81). Empirical observations also confirm the assumption of substitution among nutrients (see, for example, Dumenil and Nelson, 1948). In Syria, these assumptions seem also to be confirmed by empirical observations, as noted by many SD agronomists working on fertilizer trials.

The assumption of point maximum generally applies to nitrogen since excess N application could result in excessive vegetative growth causing lodging and lower yields. However, in the case of phosphate and potassium applications the most commonly observed response is that of increasing yield until a plateau is reached (Lanzer, Paris, and

Williams, 1987, p. 2). Yield depression usually occurs at quantities far beyond the minimum needed to attain the yield plateau.

Such responses are more accurately represented using other functional forms, such as the Mitscherlich function or the linear response and plateau (LRP) function proposed by Cate and Nelson in 1971 (see also, Anderson and Nelson, 1975; Perrin, 1976; and Lanzer and Paris, 1981). These models are usually more complex than the quadratic function and they require more data, including accurate information on soil nutrient content. Therefore, the application of such models in Syria would be difficult given the data problems that relate to the inaccuracy of the soil testing procedures.

3.3.3.2 Explanatory Variables

Multiple regression is the standard approach in estimating the parameters of a quadratic production function. Yield per ha is the dependent variable, while the levels of applied nutrients per ha are the independent variables. The production function has the following general form:

$$Y = a_0 + a_1 N + a_2 P + a_3 N^2 + a_4 P^2 + a_5 NP \qquad (3.29)$$

where Y is estimated yield per ha;
N and P are the applied fertilizer rates per ha;
N^2 and P^2 are quadratic terms;
NP is an interaction term between N and P (i.e, N*P).

The parameters a_0, a_1, a_2, a_3, a_4, and a_5 are the estimated regression coefficients. The first term, a_0, is the estimated yield of the unfertilized or control treatment (i.e., when applied N=P=0); a_1 and a_2 are typically positive reflecting the increase in yield in response to fertilizer applications, and a_3 and a_4 are typically negative reflecting diminishing response to increasing applications of N and P. The term a_5 is usually positive reflecting the positive interaction between N and P, though it is not uncommon for a_5 to be negative.

The list of independent variables is not necessarily limited to N and P. Ideally, potassium (K) should have also been included in the production function. However, given that Syrian soils are usually rich in K, the use of potassium fertilizers is very limited, with the exception of root crops and fruit trees. Therefore, this study will be limited to nitrogen and phosphate fertilizers.

If the data are available, it is desirable to add several explanatory variables. These variables reflect the specific conditions under which each experiment was undertaken such as soil type, residual soil nutrients, rainfall level, temperature, and cultural practices (including the level of other inputs). It is also desirable to include interaction terms that reflect the empirically observed interaction between N or P and some of the explanatory variables. Most trials undertaken by the SD include data on residual soil nutrients before planting and growing season rainfall levels. However, SD officials have frequently questioned the accuracy of their soil analysis results which undermines the usefulness of these data. Therefore, the only variable for which reliable data is available is seasonal rainfall.

Rainfall level is expected to have little impact on irrigated crops (e.g., cotton, sugar beets, potatoes, corn, and irrigated wheat). However, in the case of rainfed wheat and barley, rainfall is by far the most important determinant of yield and the largest contributor to the variance in yield (SD/ICARDA, 1989 and 1990). Rainfall should be included in the analysis in order to estimate zone-specific production functions for wheat and barley. This can be done using two alternative approaches. One approach is to estimate a production function for each zone in the form given by eq. 3.29, based on trials from that zone. However, since the trial sites are unevenly distributed among the three zones, there are not enough data from each zone to estimate appropriate zone-specific functions.

An alternative approach is to pool all the data from the fertilizer trials and to estimate a single equation that would include rainfall as an independent variable. Then, by using the value for average rainfall in each zone, it is possible to compute three different zone-specific equations. Such an approach assumes that the only difference between zones is seasonal rainfall, while differences in other variables are ignored. Hence, for rainfed crops, the estimated production functions will have the following general form:

$$\begin{aligned} Y = {} & b_0 + b_1 N + b_2 P + b_3 EN + b_4 EP \\ & + b_5 N^2 + b_6 EN^2 + b_7 P^2 + b_8 EP^2 \\ & + b_9 NP + b_{10} ENP + b_{11} E + b_{12} E^2 \end{aligned} \tag{3.30}$$

where E is total seasonal rainfall, and EN, EP, EN^2, EP^2, and ENP are all interaction terms between E and N or P.

This equation is a generalized form and some terms may not be included in all estimated regression equations. In fact, as noted by Fuss, McFadden, and Mundlak (1978, p. 224), too many variables may exacerbate multicollinearity problems. Therefore, it is desirable to reduce the number of terms in the equation to a minimum, even if this means that the equation may lose some of its explanatory power. The choice of which terms to retain in the equation will largely depend on the crop in question and the data used.

The following two simpler forms will be used as a starting point for the analysis and will be subject to modification as the needs arise:

$$Y = b_0 + b_1 N + b_2 P + b_3 EN + b_4 EP + b_5 N^2 + b_6 P^2 + b_7 NP + b_8 E + b_9 E^2 \qquad (3.31)$$

and,

$$Y = b_0 + b_1 EN + b_2 EP + b_3 N^2 + b_4 P^2 + b_5 NP + b_6 E + b_7 E^2 \qquad (3.32)$$

Production functions based on the above two formulations will be estimated for each of the rainfed crops or varieties. The decision as to which formulation to use will depend on the statistical performance of the two formulations. This will include the value of the coefficient of determination (adjusted R^2), the standard error of the regression, the standard error of the coefficients, and whether the estimated coefficients have the expected signs.

Once the production function for a rainfed crop is estimated, based on either eq. 3.31 or eq. 3.32, zone-specific production functions can then be estimated by replacing "E" by its corresponding average value for the zone in question. These zone-specific functions will be then incorporated into the linear programming model to allow for the calculation of optimum fertilizer rates for each zone.

For instance, if a production function of the form expressed in eq. 3.31 was estimated for rainfed local (LYV) wheat varieties, then, in order to compute production functions specific to Zones 1, 2, and 3, the mean value of rainfall (E) for each zone[1] is entered into the equation. This would give a production function of the form given by eq. 3.29:

[1] Refer to rainfall data in Table 3.1.

$$Y = a_0 + a_1 N + a_2 P + a_3 N^2 + a_4 P^2 + a_5 NP$$

Where, $a_0 = (b_0 + b_8 E + b_9 E^2)$
$a_1 = (b_1 + b_3 E)$
$a_2 = (b_2 + b_4 E)$
$a_3 = b_5$
$a_4 = b_6$
$a_5 = b_7$
$b_0, \ldots, b_9$ are the estimated coefficients in eq. 3.31.

3.3.3.3 Linear Approximation

A basic assumption of linear programming is that the objective function and the constraints are linear. Since the production function constraints, given by eq. 3.28, are based on quadratic functions, linear approximations of these functions are needed before the model can be solved using standard LP methods. Hazell and Norton (1986) describe two general procedures for approximating nonlinear functions in linear programming, or what is often referred to as *separable linear programming* methods[1]:

The first procedure consists in dividing a nonlinear, concave and separable function $Y = f(X)$ into linear segments which are defined over intervals $(X_i - X_{i-1})$ on the X axis and corresponding intervals $(Y_i - Y_{i-1})$ on the Y axis. The slope of the linear segment, s_i, in the *i*th interval is defined as

$$s_i = \frac{Y_i - Y_{i-1}}{X_i - X_{i-1}}$$

Let V_i denote variables that measure the value of ΔX over the corresponding *i*th interval, such that $0 \leq V_i \leq X_i - X_{i-1}$. Since the s_i are

[1] This section is adapted from Hazell and Norton (1986), pp. 73-75. See also Kilmer (1978).

predetermined, then a linear approximation to Y is obtained based on the following equation system:

$$\text{Max } Y^* = \Sigma_i V_i s_i$$

subject to $X = \Sigma_i V_i$

and $0 \le V_i \le X_i - X_{i-1}$, all i.

A similar approach is used by Nordblom and Al-Ashram (1989) to obtain linear approximations for the quadratic production functions included in their fertilizer allocation LP model. Such an approach, however, may create computational problems if the LP model includes a large number of crop activities, as discussed by Hazell and Norton (p. 74):

> ... the degree of accuracy of the approximation depends on the number of segments introduced, but the associated costs is an extra column (V_i) and upper bound row for each segment. While extra columns add little to computational costs with modern linear programming computer codes, extra rows are expensive. Consequently, the cost of introducing many nonlinear approximations would soon become prohibitive.

Hazell and Norton suggest using another more efficient procedure for linearizing a nonlinear function. By defining new variables W_i, or weights, for each interval i, a linear approximation to $Y = f(X)$ is then given by:

$$\text{Max } Y^* = \Sigma_i Y_i W_i \tag{3.33}$$

subject to

$$\Sigma_i W_i \le 1 \tag{3.34}$$

$$X = \Sigma_i W_i X_i \tag{3.35}$$

and $W_i \ge 0$

This procedure is computationally superior to the first one since it requires adding only two constraints, and it is not affected by the number of segments.

3.3.4 <u>The Expanded Model</u>

3.3.4.1 <u>Data Sources and Crops Covered</u>

Crop responses to varying levels of fertilizer applications can be estimated based on results from experimental fertilizer trials. In Syria, the Soils Directorate (SD) has been conducting fertilizer trials since the 1950's with an initial focus on cotton (for a summary of these early studies, see Kanbar and El-Hajj, 1974, pp. 6-9; see also Loizides, 1968). The most important research effort took place in the late 1960's and early 1970's. This involved a large number of on-farm and on-station fertilizer experiments primarily on wheat and cotton (FAO, 1970; Kanbar and El-Hajj, 1973, 1974, 1975a, and 1975b; and El-Hajj, 1985a and 1986).

Between 1975 and 1980, most of the SD staff were involved full-time in the Syrian soil survey and classification project and thus very few fertilizer experiments were conducted. Fertilizer research efforts resumed in the early 1980's, with the main focus of comparing alternative forms of nitrogen fertilizers (urea and ammonium nitrate) on yield. This research interest was influenced by the plans to construct a urea plant which would result in urea replacing ammonium nitrate as the primary source of nitrogen.

Fertilizer trials on wheat and cotton also resumed but on a much smaller scale than those conducted during the previous decade. The SD decided to shift its fertilizer trials to other economically important crops such as sugar beets, potatoes, and chickpeas, and to newly introduced crops such as corn, soybeans, and sunflower. Also, a limited number of trials were started on vegetables (tomatoes and cucumbers) and on fruit trees (olives, apples, and peaches) (MAAR, 1980, 1981, 1982, 1983, and 1987). The results from most these experiments are not yet available for general use, with the exception of initial results of sugar beets (Kanbar and El-Hajj, 1986).

In addition, two major fertilizer research projects were undertaken by ICARDA in collaboration with the SD in the 1980's. The first project was on fertilizer use on barley in northern Syria conducted from 1984/85 to 1987/88 (SD/ICARDA, 1990). A similar study was also conducted in northern Syria on durum wheat (HYV variety Sham 1) from 1986/87 to 1988/89 (SD/ICARDA, 1989).

The above data sources do not cover all the crops grown in Syria. But there exist enough data to estimate production functions for the following crops: wheat, cotton, barley, sugar beets, potatoes, and corn. These are the main crops grown in Syria and they currently account for about 86% of nitrogen and 78% of phosphorus consumption by field crops, or about 66% of total fertilizer consumption in Syria.

In the case of wheat, there are adequate data from irrigated and rainfed experiments to allow for the estimation of distinct production functions for irrigated and rainfed wheat. Similarly, the data allow for the estimation of different functions for high-yielding (HYV) and local (LYV) wheat varieties. Since virtually all irrigated wheat varieties are HYV, only three distinct functions are needed for wheat: irrigated, rainfed HYV, and rainfed LYV. Similarly, sugar beets and potatoes can be planted either in fall or in spring, with distinct growing patterns, yields, and fertilizer requirements. Since fertilizer trials exist for both seasons, separate production functions can be estimated for fall- and spring-planted sugar beets and potatoes.

Given the available data, production functions for ten different crops will be estimated. These are: irrigated wheat; rainfed HYV wheat; rainfed LYV wheat; rainfed barley; irrigated cotton; irrigated corn; irrigated fall sugar beets; irrigated summer sugar beets; irrigated fall potatoes; and irrigated spring and summer potatoes. Moreover, in the case of the rainfed crops (wheat and barley), the SD provides fertilizer recommendations that are specific to each of the agroclimatic zones. These include zone-specific rates for rainfed LYV wheat and for barley in Zones 1b, 2, and 3. Since very little HYV wheat is grown in Zone 3, specific rates for HYV wheat are provided for only Zones 1b and 2. Zone 1a is excluded from the analysis since it is used mostly for fruit and vegetable production, with insignificant amounts of wheat and barley (see Appendix A, Table A.2). Zones 4 and 5 are also excluded since they are not covered by the fertilizer allocation system.

Most of the above experiments focused on yield response to N and P_2O_5. Potassium (K) was included in the 1970's cotton trials but the findings strongly suggest that cotton does not respond to K application (Kanbar and El-Hajj, 1974 and 1975b). The results are reasonable since most Syrian soils are naturally rich in potassium. This makes it unnecessary to apply any K fertilizer on most crops, with the exception of root crops (sugar beets and potatoes) which are fairly responsive to K (Kanbar and El-Hajj, 1986). Thus, given the current limited use of K fertilizers in Syrian agriculture, only N and P will be included in this study.

3.3.4.2 Model Specification

The mathematical formulation of the actual or "expanded" linear programming model for fertilizer allocation used in this study is described below. It is based on the "basic" model given by Equations 3.26, 3.27 and 3.28, with several modifications that are discussed in details in this section. These modifications include a change in notations to coincide with those used in the computer input file presented in Appendix C. The full model specification appears at the end of this chapter.

Objective Function:

In this model the objective is to maximize the economic net returns from fertilizer use on the main crops grown in Syria (wheat, barley, cotton, corn, sugar beets, and potatoes). These crops are grouped into 15 crop activities based on whether they are irrigated or rainfed, on Agricultural Stability Zones, and whether they are planted in the fall or spring. The objective function (eq. 3.36) is specified in terms of the economic value of the aggregate increase in crop output due to fertilizer use, minus the economic value of total nitrogen (N) and phosphorus (P_2O_5) fertilizers applied on these crops. The increase in crop output is based on the assumption of "normal" rainfall, except for barley, where a "dry" rainfall scenario is assumed. This is in accordance with the "maximin" assumption about the behavior of risk-averse barley farmers, which was discussed earlier in this chapter.

Constraints:

The model's constraints include eleven groups of equations:

1) Production Function Constraints:

These equations (eq. 3.37 to eq. 3.42) specify the input/output relationships between the fertilizer rates applied and the resulting yield increase relative to no fertilizer use. Since the production relationships are based on quadratic functions, linear approximations of these functions are included in the LP model based on the procedure suggested by Hazell and Norton (1986), as discussed earlier (see Equations 3.33, 3.34 and 3.35). To obtain linear approximations for the 15 production functions included in the model, the crop activities were grouped into three categories:

(1) crop activities with relatively low expected optimum fertilizer rates, i.e., rainfed wheat and barley;

(2) crop activities with relatively high expected optimum fertilizer rates, i.e., irrigated wheat and cotton;

(3) crops whose production functions were estimated in terms of N only because of data limitation problems, i.e., corn, sugar beets, and potatoes.

In the first category, each production function was divided into 100 linear segments corresponding to 100 different N-P_2O_5 combinations (10 rates of N by 10 rates of P_2O_5) ranging from 0 kg/ha for both N and P_2O_5 to 90 kg/ha N and 65 kg/ha P_2O_5. The production functions in the second category were divided into 143 linear segments corresponding to 143 N-P_2O_5 combinations (11 rates of N by 13 rates of P_2O_5) ranging from

0 kg/ha for both N and P_2O_5 to 230 kg/ha N and 130 kg/ha P_2O_5. In the third category, the yield response functions to nitrogen were divided into 34 linear segments corresponding to 34 N rates (0 to 220 kg/ha) by one rate of P_2O_5 (0 kg/ha).

The number of segments in the above categories was selected in such a way as to cover the range of N-P_2O_5 combinations from zero to the rates that would maximize yield (i.e., Phase II of the production function). The accuracy of separable programming depends to a large extent on the number of segments per production function. Thus, the above segmentation approach attempted to include the largest number of segments allowable by the memory available on standard personal computers, which is the technology currently available at the Soils Directorate.

It should be noted that the linearization of production functions in the third category does not allow for the estimation of optimum P_2O_5 rates on corn, sugar beets and potatoes. Therefore, arbitrary assumptions are needed as to how optimum P_2O_5 rates would change when the amounts of fertilizer available are varied. The assumption adopted in this study is that optimum P_2O_5 rates would change at the same rate as the change in optimum N rate. In other words, it is assumed that the ratio of optimum P_2O_5 to optimum N ($PNRATIO_r$) is constant. Assuming that the current P_2O_5 recommendations on these crops represent the unconstrained economic optimum rates ($ECONOPT_{r,f}$), this constant ratio is defined as:

$$PNRATIO_r = \frac{ECONOPT_{r,\text{"P"}}}{ECONOPT_{r,\text{"N"}}}$$

Optimum P_2O_5 rates are then estimated by multiplying the optimum N rate ($OPTF_{r,"N"}$) by $PNRATIO_r$, rather than $OPTF_{r,"P"}$ which will always be equal to zero according to the segmentation of the third crop category mentioned above.

2) <u>Upper Limits on Optimum Fertilizer Rates</u>:

Two sets of constraints are imposed on the maximum values of the estimated optimum fertilizer rates. The first constraint (eq. 3.43) specifies that the economically optimum fertilizer rates should not exceed the optimum rates calculated based on financial prices. This constraint is needed since farmers will not apply rates beyond those maximizing their net returns. The second constraint (eq. 3.44) specifies that the optimum rates should not result in a yield decline in the event of a very dry year. This is in accordance with farmers' concerns about the possibility that fertilizers may "burn" the crop in very dry years.

3) <u>Calculation of Aggregate Production per Crop Activity</u>:

This group consists of three definitional equations (equations 3.45, 3.46 and 3.47), related to the above three categories of crop activities, which enables the calculation of the aggregate increase in output for each crop activity. This is done by multiplying the total area fertilized by the yield increase due to the application of the estimated optimum fertilizer rates.

4) Calculation of Aggregate Crop Output:

This group of equations (eq. 3.48 to eq. 3.51) adds the total output of crop activities by crop. For instance, the outputs of all wheat activities are aggregated together to give the total wheat output ($TOTWHEAT_e$). Similar aggregations are done for barley, sugar beets and potato activities.

5) Minimum VCR Constraints:

As discussed earlier, one criterion for assessing the economic feasibility of the estimated optimum fertilizer rates is that the Value-Cost-Ratio, calculated based on these rates, should be equal to at least 1.5. This applies to VCR's calculated based on "good", "normal", and "dry" rainfall scenarios, while in very dry years the minimum VCR limit is reduced to 1.0. These minimum VCR conditions apply to VCR calculations based on either economic prices (eq. 3.52) or financial prices (eq. 3.53). In these two equations, $MINVCR_e$ is a vector of minimum VCR values corresponding to each of the rain scenarios.

6) Calculation of Aggregate Fertilizer Use:

Total fertilizer use for each crop activity is calculated by multiplying the estimated optimum fertilizer rates by the total fertilized area planted to each crop. Aggregate fertilizer use by all crop activities is then calculated by adding up total fertilizer use by each crop. Since fertilizer allocation decisions for winter and summer crops are frequently made independently of each other, aggregate fertilizer use for each season needs to be computed. These calculations of aggregate fertilizer use by season are given by eq. 3.54 to eq. 3.57, while eq. 3.58 adds up total fertilizer use over the two seasons.

The calculation of aggregate N use is straightforward, as shown in eq. 3.54 and eq. 3.56. On the other hand, the calculation of aggregate P_2O_5 use is slightly more complicated. This is related to the procedure for estimating optimum P_2O_5 rates on corn, sugar beets and potatoes, as described earlier. Since the optimum value of $OPTF_{"P",r}$ will always be zero for these crops, the estimated P_2O_5 rates on these crops need to be added to the equation to avoid underestimating aggregate P_2O_5 use, as shown in eq. 3.55 and eq. 3.57.

7) Fertilizer Availability Constraints:

The upper limits on total fertilizer supplies available are given by equations 3.59, 3.60 and 3.61. These limits are expressed as a percentage ($FPER_f$) of "ideal" total fertilizer requirements ($FLIM_f$), i.e., total requirements if there were no constraints on supplies. These constraints allow for examining different fertilizer availability scenarios for the winter and summer seasons. For instance, if the policy issue of interest is fertilizer availability for the winter season only, the percentage of total fertilizer requirements for the summer season ($SPER_f$) would be set at 100. That for the winter season ($WFPER_f$) would be varied according to the assumed levels of fertilizer availability.

8) Calculations of Economic Net Returns:

The optimum fertilizer rates are estimated based on the objective of maximizing net economic returns from fertilizer use, assuming a dry year for barley and a normal year for all other crops. As discussed earlier, the dry year assumption for barley was made to account for the relatively higher risk aversion among barley farmers. However, the value of the objective (i.e., maximum Z) does not represent net economic returns in a normal year, because of the dry year assumption for barley. Therefore, to calculate the impact of the estimated optimum rates on net economic returns in a normal year, a normal year rainfall should be assumed for all crops, including barley. Similarly, net economic returns to the application of the estimated optimum rates are calculated under the good, dry, and very dry rainfall scenarios. These calculations are given by equations 3.62, 3.63 and 3.64, which also provide a breakdown of net economic returns by season (winter vs summer).

9) Calculations of Financial Net Returns:

The calculation of financial net returns (or net increase in farm income) for the four rain scenarios is identical to that of economic net returns except for the use of financial instead of economic prices. These calculations are given by equations 3.65, 3.66 and 3.67.

10) Calculation of Net Foreign Exchange Earnings:

The net foreign exchange earnings ($DOLLARS_{\bullet}$) associated with fertilizer use are calculated by adding the value of additional crop exports and lower crop imports due to fertilizer use, minus the import value of fertilizers. Since not all crop output is sold to the government, foreign exchange earnings per unit of crop output produced ($FECROP_{i,\bullet}$) are weighted by the proportion of total output sold to the government. For instance, if the import value of wheat is 224 $US/ton, and assuming only 40% of total wheat output is sold to the government, then the foreign exchange earnings per ton of wheat produced would be equal to 89.6 $US/ton (i.e., $224 * 40%). The calculation of net foreign exchange earnings under the four rain scenarios is given by eq. 3.68.

11) Calculation of Government Net Expenditures:

As discussed earlier net government expenditures related to fertilizer use need to be calculated to assess the impact of the optimum rates on the government budget. These net expenditures ($GOVEXP_{\bullet}$) are calculated by subtracting the increase in government revenues, due to indirect taxes on crops, from total expenditures on fertilizer subsidies, as shown in eq. 3.69. Since taxes on crops are proportional to yields, government revenues from crop taxation would vary depending on the level of rainfall. Therefore, for each rain scenario there would be a specific level of net government expenditures.

12) Non-Negativity Constraints:

These are the standard constraints specifying which decision variables cannot be negative.

3.3.4.3 Algebraic Formulation of the Fertilizer Allocation Model:

A. Indices (Sets):

i - crop activities
- (WIRR, WHYV1, WHYV2, WLYV1, WLYV2, WLYV3, BARLEY1, BARLEY2, BARLEY3, COTTON, MAIZE, FALLBEET, SUMBEET, FALLPOT, SUMPOT)

where WIRR - Irrigated wheat
WHYV1 - rainfed HYV wheat Zone 1b
WHYV2 - rainfed HYV wheat Zone 2
WLYV1 - rainfed LYV wheat Zone 1b
WLYV2 - rainfed LYV wheat Zone 2
WLYV3 - rainfed LYV wheat Zone 3
BARLEY1 - rainfed barley Zone 1b
BARLEY2 - rainfed barley Zone 2
BARLEY3 - rainfed barley Zone 3
COTTON - irrigated cotton
MAIZE - irrigated yellow maize (corn)
FALLBEET - irrigated fall sugar beets
SUMBEET - irrigated summer sugar beets
FALLPOT - irrigated fall potatoes
SUMPOT - irrigated spring and summer potatoes

w - winter crops
- (WIRR, WHYV1, WHYV2, WLYV1, WLYV2, WLYV3, BARLEY1, BARLEY2, BARLEY3, FALLBEET, FALLPOT)

g - rainfed crops
- (WHYV1, WHYV2, WLYV1, WLYV2, WLYV3, BARLEY1, BARLEY2, BARLEY3)

ir - irrigated crops
- (WIRR, COTTON, MAIZE, FALLBEET, SUMBEET, FALLPOT, SUMPOT)

c - irrigated wheat and cotton
- (WIRR, COTTON)

wh - wheat
- (WIRR, WHYV1, WHYV2, WLYV1, WLYV2, WLYV3)

rw - rainfed wheat
- (WHYV1, WHYV2, WLYV1, WLYV2, WLYV3)

b - barley
- (BARLEY1, BARLEY2, BARLEY3)

s - summer crops
- (COTTON, MAIZE, SUMBEET, SUMPOT)

r - maize, sugar beets, and potatoes
 - {MAIZE, FALLBEET, SUMBEET, FALLPOT, SUMPOT}

sg - production function segments for rainfed crops
 - {G001, ..., G100}

sc - production function segments for irrigated wheat and cotton
 - {C001, ..., C143}

sr - production function segments for maize, sugar beets, and potatoes
 - {R01, ..., R34}

f - fertilizer nutrients - {N, P}

e - rain scenarios - {GOOD, NORMAL, DRY, V-DRY}

B. Given Data (Exogenous Variables):

$CPRICE_{i,e}$ - economic field price of crop i under rain scenario e (SL/kg)

$FPRICE_f$ - economic field price of fertilizer f (SL/kg)

$CPRICEF_{i,e}$ - financial field price of crop i under rain scenario e (SL/kg)

$FPRICEF_f$ - financial field price of fertilizer f (SL/kg)

$FECROP_{i,e}$ - foreign exchange earning per unit of crop i under rain scenario e ($US/kg)

$FEFERT_f$ - foreign exchange expenditures per unit of fertilizer f ($US/kg)

$TAX_{i,e}$ - indirect tax on crop i under rain scenario e (SL/kg)

$SUBSIDY_f$ - subsidy on fertilizer f (SL/kg)

$AREA_i$ - total fertilized area planted to crop i (million ha)

$FLIM_f$ - total requirements of fertilizer f (thousand tons)

$WFLIM_f$ - total winter requirements of fertilizer f (thousand tons)

$SFLIM_f$ - total summer requirements of fertilizer f (thousand tons)

$FPER_f$ - percentage of total requirements of fertilizer f assumed to be actually available (%)

$WPER_f$ - percentage of total winter requirements of fertilizer f assumed to be actually available (%)

$SPER_f$ - percentage of total summer requirements of fertilizer f assumed to be actually available (%)

$FINOPT_{f,i}$ - optimum rate of fertilizer f on crop i, based on financial prices (kg/ha)

$ECONOPT_{f,i}$ - optimum rate of fertilizer f on crop i, based on economic prices (kg/ha)

$VDRYMAX_{f,g}$ - the rate of fertilizer f on rainfed crop g that maximizes yield in a very dry year (kg/ha)

$PNRATIO_r$ - ratio of optimum P_2O_5 rate to optimum N rate, on crop r, based on economic prices

$FERTG_{f,sg}$ - rate of fertilizer f associated with production function segment sg (kg/ha)

$FERTC_{f,sc}$ - rate of fertilizer f associated with production function segment sc (kg/ha)

$FERTR_{f,sr}$ - rate of fertilizer f associated with production function segment sr (kg/ha)

$YG_{g,e,sg}$ - yield increase of rainfed grain crop g, under rain scenario e, associated with production function segment sg (kg/ha)

$YC_{c,e,sc}$ - yield increase of crop c (irrigated wheat or cotton) associated with production function segment sc (kg/ha)

$YR_{r,e,sr}$ - yield increase of maize, sugar beet, or potato associated with production function segment sr (kg/ha)

$MINVCR_e$ - minimum Value-Cost-Ratio under rain scenario e (no units)

C. <u>Decision (Endogenous) Variables</u>:

$GWGHT_{g,sg}$ - optimum weight associated with production function segment sg for crop g (no units)

$CWGHT_{c,sc}$ - optimum weight associated with production function segment sc for crop c (no units)

$RWGHT_{r,sr}$ - optimum weight associated with production function segment sr for crop r (no units)

$OPTF_{f,i}$ - optimum rate of fertilizer f on crop i (kg/ha)

$TY_{i,e}$ - total production increase in crop i, under scenario e, due to the application of the calculated optimum N and P_2O_5 rates (thousand tons)

$TOTWHEAT_e$ - aggregate increase in wheat output under rain scenario e (thousand tons)

$TOTBAR_e$ - aggregate increase in barley output under rain scenario e (thousand tons)

TOTCOT - aggregate increase in cotton output (thousand tons)

TOTMAIZE - aggregate increase in maize output (thousand tons)

TOTSUG - aggregate increase in sugar beet output (thousand tons)

TOTPOT - aggregate increase in potato output (thousand tons)

TFU_f - total utilization of fertilizer f (thousand tons)

$WTFU_f$ - total utilization of fertilizer f for the winter season (thousand tons)

$STFU_f$ - total utilization of fertilizer f for the summer season (thousand tons)

$RETURNS_e$ - net aggregate economic returns from total fertilizer use under rain scenario e (million SL)

$WRETURNS_e$ - net aggregate economic returns from total fertilizer use in winter, under rain scenario e (million SL)

SRETURNS - net aggregate economic returns from total fertilizer use in summer (million SL)

$FINCOME_e$ - net aggregate financial returns from total fertilizer use under rain scenario e (million SL)

$WFINCOME_e$ - net aggregate financial returns from total fertilizer use in winter, under rain scenario e (million SL)

SFINCOME - net aggregate financial returns from total fertilizer use in summer (million SL)

$DOLLARS_e$ - net foreign exchange earnings associated with fertilizer use under rain scenario e (million \$US)

$GOVEXP_e$ - net government expenditures associated with fertilizer use under rain scenario e (million SL)

Z - The objective to be maximized; aggregate net economic returns to fertilizer use assuming a normal year for all crops, except for barley, where a dry year is assumed (million SL)

C. Objective Function:

$$\text{Maximize} \quad Z = \Sigma_{rw} (CPRICE_{rw,\text{"NORMAL"}} * TY_{rw,\text{"NORMAL"}}) + \Sigma_{b} (CPRICE_{b,\text{"NORMAL"}} * TY_{b,\text{"dry"}}) + \Sigma_{ir} (CPRICE_{ir,\text{"NORMAL"}} * TY_{ir,\text{"NORMAL"}}) - \Sigma_{f} (FPRICE_{f} * TFU_{f}) \quad (3.36)$$

D. Constraints:

D.1 Production Function Constraints:

$$\Sigma_{sg} (GWGHT_{g,sg}) = 1 \quad (3.37)$$

$$\Sigma_{sc} (CWGHT_{c,sc}) = 1 \quad (3.38)$$

$$\Sigma_{sr} (RWGHT_{r,sr}) = 1 \quad (3.39)$$

$$\Sigma_{sg} (GWGHT_{g,sg} * FERTG_{f,sg}) = OPTF_{f,g} \quad (3.40)$$

$$\Sigma_{sc} (CWGHT_{c,sc} * FERTC_{f,sc}) = OPTF_{f,c} \quad (3.41)$$

$$\Sigma_{sr} (RWGHT_{r,sr} * FERTR_{f,sr}) = OPTF_{f,r} \quad (3.42)$$

D.2 Upper Limits on Optimum Fertilizer Rates:

$$OPTF_{f,i} \le FINOPT_{f,i} \quad (3.43)$$

$$OPTF_{f,g} \le VDRYMAX_{f,g} \quad (3.44)$$

D.3 Calculation of Aggregate Production per Crop Activity:

$$\Sigma_{sg} (GWGHT_{g,sg} * YG_{g,e,sg} * AREA_{g}) = TY_{g,e} \quad (3.45)$$

$$\Sigma_{sc} (CWGHT_{c,sc} * YC_{c,e,sc} * AREA_{c}) = TY_{c,e} \quad (3.46)$$

$$\Sigma_{sr} (RWGHT_{r,sr} * YR_{r,e,sr} * AREA_{r}) = TY_{r,e} \quad (3.47)$$

D.4 Calculation of Aggregate Crop Output:

$$\Sigma_{wh} (TY_{wh,\bullet}) + TY_{"WIRR",\bullet} = TOTWHEAT_{\bullet} \quad (3.48)$$

$$\Sigma_{b} (TY_{b,\bullet}) = TOTBAR_{\bullet} \quad (3.49)$$

$$TY_{"FALLBEET","NORMAL"} + TY_{"SUMBEET","NORMAL"} = TOTSUG \quad (3.50)$$

$$TY_{"FALLPOT","NORMAL"} + TY_{"SUMPOT","NORMAL"} = TOTPOT \quad (3.51)$$

D.5 Minimum VCR Constraints:

$$(AREA_{i} * \Sigma_{f} (FPRICE_{f} * OPTF_{f,i})) * MINVCR_{\bullet} - CPRICE_{i,\bullet} * TY_{i,\bullet} \le 0 \quad (3.52)$$

$$(AREA_{i} * \Sigma_{f} (FPRICEF_{f} * OPTF_{f,i})) * MINVCR_{\bullet} - CPRICEF_{i,\bullet} * TY_{i,\bullet} \le 0 \quad (3.53)$$

D.6 Calculation of Aggregate Fertilizer Use:

$$\Sigma_{w} (OPTF_{"N",w} * AREA_{w}) = WTFU_{"N"} \quad (3.54)$$

$$\Sigma_{w} (OPTF_{"P",w} * AREA_{w}) + (PNRATIO_{"FALLBEET"} * OPTF_{"N","FALLBEET"} * AREA_{"FALLBEET"}) + (PNRATIO_{"FALLPOT"} * OPTF_{"N","FALLPOT"} * AREA_{"FALLPOT"}) = WTFU_{"P"} \quad (3.55)$$

$$\Sigma_{s} (OPTF_{"N",s} * AREA_{s}) = STFU_{"N"} \quad (3.56)$$

$$\Sigma_{s} (OPTF_{"P",s} * AREA_{s}) + (PNRATIO_{"SUMBEET"} * OPTF_{"N","SUMBEET"} * AREA_{"SUMBEET"}) + (PNRATIO_{"SUMPOT"} * OPTF_{"N","SUMPOT"} * AREA_{"SUMPOT"}) + (PNRATIO_{"MAIZE"} * OPTF_{"N","MAIZE"} * AREA_{"MAIZE"}) = STFU_{"P"} \quad (3.57)$$

$$WTFU_{f} + STFU_{f} = TFU_{f} \quad (3.58)$$

D.7 Fertilizer Availability Constraints:

$$TFU_{f} \le 0.01 * FPER_{f} * FLIM_{f} \quad (3.59)$$

$$WTFU_{f} \le 0.01 * WPER_{f} * WFLIM_{f} \quad (3.60)$$

$$STFU_{f} \le 0.01 * SPER_{f} * SFLIM_{f} \quad (3.61)$$

D.8 Calculation of Economic Net Returns:

$$\Sigma_{i} (CPRICE_{i,\bullet} * TY_{i,\bullet}) - \Sigma_{f} (FPRICE_{f} * TFU_{f}) = RETURNS_{\bullet} \quad (3.62)$$

$$
\begin{aligned}
&\Sigma_{s}\ (CPRICE_{s,\bullet} * TY_{s,\bullet}) \\
&+ (CPRICE_{\text{"WIRR"},\bullet} * TY_{\text{"WIRR"},\bullet}) \\
&+ (CPRICE_{\text{"FALLBEET"},\bullet} * TY_{\text{"FALLBEET"},\bullet}) \\
&+ (CPRICE_{\text{"FALLPOT"},\bullet} * TY_{\text{"FALLPOT"},\bullet}) \\
&- \Sigma_{f}\ (FPRICE_{f} * WTFU_{f}) = WRETURNS_{\bullet}
\end{aligned}
\tag{3.63}
$$

$$
\begin{aligned}
&\Sigma_{ir}\ (CPRICE_{ir,\text{"NORMAL"}} * TY_{ir,\text{"NORMAL"}}) \\
&- (CPRICE_{\text{"WIRR"},\text{"NORMAL"}} * TY_{\text{"WIRR"},\text{"NORMAL"}}) \\
&- (CPRICE_{\text{"FALLBEET"},\text{"NORMAL"}} * TY_{\text{"FALLBEET"},\text{"NORMAL"}}) \\
&- (CPRICE_{\text{"FALLPOT"},\text{"NORMAL"}} * TY_{\text{"FALLPOT"},\text{"NORMAL"}}) \\
&- \Sigma_{f}\ (FPRICE_{f} * STFU_{f}) = SRETURNS
\end{aligned}
\tag{3.64}
$$

D.9 <u>Calculation of Financial Net Returns</u>:

$$\Sigma_{i}\ (CPRICEF_{i,\bullet} * TY_{i,\bullet}) - \Sigma_{f}\ (FPRICEF_{f} * TFU_{f}) = FINCOME_{\bullet} \tag{3.65}$$

$$
\begin{aligned}
&\Sigma_{s}\ (CPRICEF_{s,\bullet} * TY_{s,\bullet}) \\
&+ (CPRICEF_{\text{"WIRR"},\bullet} * TY_{\text{"WIRR"},\bullet}) \\
&+ (CPRICEF_{\text{"FALLBEET"},\bullet} * TY_{\text{"FALLBEET"},\bullet}) \\
&+ (CPRICEF_{\text{"FALLPOT"},\bullet} * TY_{\text{"FALLPOT"},\bullet}) \\
&- \Sigma_{f}\ (FPRICEF_{f} * WTFU_{f}) = WFINCOME_{\bullet}
\end{aligned}
\tag{3.66}
$$

$$
\begin{aligned}
&\Sigma_{ir}\ (CPRICEF_{ir,\text{"NORMAL"}} * TY_{ir,\text{"NORMAL"}}) \\
&- (CPRICEF_{\text{"WIRR"},\text{"NORMAL"}} * TY_{\text{"WIRR"},\text{"NORMAL"}}) \\
&- (CPRICEF_{\text{"FALLBEET"},\text{"NORMAL"}} * TY_{\text{"FALLBEET"},\text{"NORMAL"}}) \\
&- (CPRICEF_{\text{"FALLPOT"},\text{"NORMAL"}} * TY_{\text{"FALLPOT"},\text{"NORMAL"}}) \\
&- \Sigma_{f}\ (FPRICEF_{f} * STFU_{f}) = SFINCOME
\end{aligned}
\tag{3.67}
$$

D.10 <u>Calculation of Net Foreign Exchange Earnings:</u>

$$\Sigma_{i}\ (FECROP_{i,\bullet} * TY_{i,\bullet}) - \Sigma_{f}\ (FEFERT_{f} * TFU_{f}) = DOLLARS_{\bullet} \tag{3.68}$$

D.11 <u>Calculation of Government Net Expenditures</u>:

$$\Sigma_{f}\ (SUBSIDY_{f} * TFU_{f}) - \Sigma_{i}\ (TAX_{i,\bullet} * TY_{i,\bullet}) = GOVEXP_{\bullet} \tag{3.69}$$

D.12 <u>Non-negativity Constraints</u>:

$GWGHT_{s,ss} \geq 0$, $CWGHT_{c,sc} \geq 0$, $RWGHT_{r,sr} \geq 0$, $TY_{i,\bullet} \geq 0$, and $OPTF_{f,i} \geq 0$.

CHAPTER 4

ESTIMATION OF FERTILIZER AND CROP PRICES

The conceptual differences between financial and economic prices were discussed in chapter 3. Financial prices are used to estimate costs and benefits associated with fertilizer use as seen from the farmers' viewpoint. Economic prices, on the other hand, refer to the true economic costs and benefits of fertilizer use from the point of view of the economy as a whole. The main purpose of this chapter is to present the procedures involved in estimating financial and economic prices and to discuss the procedures' underlying assumptions. These procedures are used to estimate financial and economic prices for nitrogen and phosphorus fertilizers and the crops included in this study.

Foreign exchange earnings or expenditures associated with each crop and fertilizer included in this study are also estimated in this chapter. This is needed to assess the impact of alternative fertilizer allocations on the government's foreign exchange budget. Similarly, taxes or subsidies on crops and fertilizers are also estimated to assess the impact of alternative allocations on the government's general budget.

4.1 Financial Prices

Financial prices of crops and fertilizers are the actual prices that farmers receive from the sale of their crops or pay for their fertilizer purchases. However, for the same commodity there exist several prices: official producer price, market price, farm price, field price, and so forth. In this study, the main interest is to estimate the farmer's net benefits from the application of fertilizers. Therefore, the most appropriate price to use would be the field price, which is defined as follows (CIMMYT, 1988, p. 25):

> The field price of the crop is defined as the value to the farmer of an additional unit of production in the field, prior to harvest. It is calculated by taking the price that farmers receive (or can receive) for the crop when they sell it, and subtracting all costs associated with harvest and sale that are proportional to yield, that is, costs that can be expressed per kilogram of crop.

Ideally, the crop wholesale market price should be used as the basis for calculating financial field prices. However, in Syria the prices of most field crops are officially set by the government. This system of official pricing often involves compulsory delivery of all or a large proportion of the crop to the government. Official crop prices are generally lower than their international market equivalents. However, recent trends in official prices suggest that the government intends to increase these prices gradually to align them with prevailing international prices.

In spite of these trends, parallel markets in most controlled agricultural commodities continue to operate. These markets tend to play a much greater role for cereals than for industrial crops such as cotton and sugar beets. Given that the public sector has complete monopoly on cotton ginning and sugar refining activities, parallel markets in cotton and sugar beets are almost non-existent. On the other hand, although the government has a legal monopoly over cereals marketing, an average of only 35% of total production is procured through official marketing channels (FAO, 1989, p. 50). The remaining is either sold in the parallel market, retained for seeds, or consumed on the farm. Discussions with farmers suggest that parallel market prices of cereals are, on the average, about 20% higher than official prices. During dry years these prices may be 40 to 60% higher than official prices, while in good years the margin declines to less than 10%. Therefore, the basis for estimating crop field prices should be a weighted average between official and market prices, accounting for the relative shares of official deliveries and market sales.

A similar approach also will be used in estimating fertilizer field prices. Given that fertilizers are sold to farmers at subsidized prices, parallel markets in fertilizers appear only if quantities demanded by farmers exceed the actual amounts distributed by the government. Situations of excess fertilizer demand have been most visible during very wet years such as 1987/88. However, fertilizer production problems and limited foreign exchange available for fertilizer imports have often contributed in the appearance of shortages even in normal years. During dry years, such as in 1988/89 and 1989/90, there was no visible sign of any fertilizer shortages. This may also be related to the recent substantial reduction in fertilizer subsidies, further lowering the quantity of fertilizer demanded.

Thus, except for dry years, farmers are expected to continue to rely on the parallel market for part of their fertilizer needs. Discussions with farmers indicate that they purchase an average of 20% of their fertilizer needs from the parallel market at average market prices 20% higher than official prices. It should be noted that whenever farmers purchase fertilizer from the Agricultural Cooperative Bank (ACB) they usually incur some additional transaction costs. These include the costs of the several trips that farmers usually have to make to the nearest ACB branch before they receive their fertilizer allotments, in addition to any illegal payoffs to ACB employees.

Therefore, based on the above discussion, field prices of crops and fertilizers are estimated according to the following general approach:

Crop field price = average producer price - transport costs
- harvest costs - handling costs

Fertilizer field price = average producer price + transaction costs
+ transport costs + handling costs
+ application costs

4.2 Economic Prices

As mentioned earlier, financial field prices will be used in this study to estimate the impact of alternative fertilizer rates on farmers' net income. However, the calculation of these rates will be based on economic field prices. This is to ensure that the true economic value, or opportunity cost, of crops produced and of fertilizers used is taken into consideration. Therefore, whenever financial prices are suspected to be significantly different from their true economic values, then they need to be adjusted to make them more closely represent the opportunity cost to the economy as a whole.

Gittinger (1982) provided a detailed step-by-step procedure to use in adjusting financial prices to economic values (see pp. 250-271). This procedure involves three main steps: (1) adjustment for direct transfer payments; (2) adjustment for price distortions in traded items; and (3) adjustment for price distortions in nontraded items.

A first step in estimating economic prices is to decide whether the crops and fertilizers in this study are to be treated as "traded" or "nontraded" goods. Traded goods include imports, exports, import substitutes, and diverted exports. Nontraded goods are those for which the domestic cost of production is higher than the export price but lower than the import price (ibid., p. 253). They also include goods that are not traded due to government policy. Nontraded goods are often bulky goods such as straw, or highly perishable goods such as fresh vegetables or fluid milk.

The commodities covered by this study include exports, such as cotton and potatoes; imports, such as urea and TSP fertilizers; and import substitutes, such as wheat, sugar beets, and corn. Substantial barley exports occur only in good years, while Syria is usually self-sufficient in normal years. During dry years such as 1989 and 1990, there were clear indications of domestic barley shortages. In spite of these shortages the government maintained a ban on barley imports given the severe limitations on foreign exchange. Despite this ban on imports, it still seems appropriate to treat barley as a traded good.

The estimation of economic field prices of traded goods is based on the calculation of Import or Export Parity Prices (IPP or EPP) (ibid., p. 269). These prices refer to commodity prices at the point of entry or exit of the country, or border prices, adjusted for any domestic costs incurred in transferring these commodities from or to the main point where they are to be used. Therefore, for an imported commodity such as fertilizer, the import or CIF price (Costs, Insurance, and Freight) is adjusted by adding domestic costs incurred by the government. These costs include unloading, storage, transport, distribution, administration, and so forth, i.e., from the harbor to the main warehouses of the Agricultural Cooperative Bank (ACB). This would add up to the economic value of fertilizers at the warehouse. To compute the economic field price, transport, handling, and application costs incurred by farmers need also to be added.

The same rationale is also applied to exports, such as cotton. The economic value of exported cotton is equal to the export or FOB price (Free on Board) minus (1) domestic transfer costs from the warehouses and cotton gins of the Cotton Marketing Organization (CMO) to the harbor, and (2) ginning costs. This would give the economic value of cotton at the gin. When farmers' harvesting and handling costs are subtracted, this would give the economic field price.

In estimating the true economic values of costs or benefits faced by the economy, it is important to adjust these values by considering direct or indirect taxes or subsidies and all other distortions included in actual costs of fertilizers and crops. The Syrian government provides farmers with a wide range of subsidies, including subsidies on crop transport, credit and other inputs. Thus the main adjustments to be included in this study are those for (1) transport subsidies, (2) credit subsidies, (3) subsidies on other inputs, and (4) exchange rate adjustment.

1) Transport Subsidies:

Transport subsidies are most commonly used on wheat, barley, and cotton. In the case of wheat and barley, government trucks usually collect the harvested grain at the farm gate at no cost to the farmer. A similar arrangement is made with cotton growers. Cotton farmers have to pay the cost of transport for the first 100 kilometers, with the government covering any additional transport costs.

2) Credit Subsidies:

Credit subsidies are essentially in the form of interest-free loans for fertilizer purchases, which are to be repaid at harvest time. In other words, the average eight-month delay in loan repayments constitutes a real cost to the government and, by implication, to the economy as a whole. In Syria, all the formal financial institutions are entirely controlled by the government. There exist several official interest rates applying to different sectors of the economy. The annual interest rate on short-term agricultural loans is set at 4%, while the interest rate on savings accounts is fixed at 7.5%. The highest rate that can be obtained in the formal sector is the rate on government bonds, set at 9% annually.

This is in contrast to annual interest rates ranging from 25% to 40% charged by local money lenders in the informal financial sector. Since the opportunity cost of fertilizer loans are incurred by the government, the use of the market rate would be inappropriate. Since the government relies heavily on issuing bonds to finance its budget deficit, the appropriate interest rate to use would be the highest rate that the government would have to pay, i.e., 9% per year.

3) Subsidies on Other Inputs:

Direct input subsidies cover several farm inputs such as pesticides, diesel fuel, seeds, farm equipment, bags, and so forth, besides fertilizer subsidies. Ideally, all these subsidies ought to be accounted for in estimating the true value of crops. However, the main focus of this study is to assess the value of the increase in yield due to fertilizer use. In other words, the inputs of interest are only those that increase incrementally with any increase in yield. These are essentially limited to harvesting labor, transport, and bags. The government provides farmers with bags at a subsidized price equivalent to 160 SL per ton of grain, but with the condition that an equal number of filled bags be delivered after harvest. Therefore, farmers would need to buy bags from the market at prices twice as high as official prices for all their parallel market sales.

4) Exchange Rate Adjustment:

A final issue related to the estimation of economic prices is the question of which exchange rate to use in converting border prices (in US dollars) into Syrian Liras. As in many developing countries, the foreign exchange policy adopted in Syria is based on a fixed official exchange rate. This policy also imposes strict restrictions on private transactions and transfers of foreign currencies abroad. Several exchange rates are currently officially in use in Syria. Cowitt (1991, p. 770) lists the following official exchange rates in operation as of December 30, 1988 (all rates in Syrian Liras per U.S. Dollar):

A.	Basic rate (theoretically defined at 336.375 milligrams of fine gold); inoperative	2.19
B.	Effective (Official) rate; applicable to official loans, grants and budgetary receipts, most exports, some travel earnings, public sector imports and invisibles payments (except travel) and capital transactions, with buying and selling rates of SL11.20/11.25	11.225
C.	Promotion rate; applicable to private remittances, most travel and tourism transactions, transfers of Syrian workers abroad, some export proceeds and medical expenses abroad	21.00
D.	Special export rates; based on	
	1. Tax of 8% on shipments of fruit, vegetables and vegetable oil	10.35
	2. Tax of 7% on shipments of all other agricultural products	10.46
E.	Airline rates[1]; applicable to	
	1. Purchases of airline tickets by residents and nonresidents	16.25
	2. Airline company transfers abroad	18.00

Parallel market trading in the Syrian Lira has been in existence since the introduction of exchange controls in 1961. The parallel market rate is essentially determined in the Beirut foreign exchange market, where the value of the Syrian Lira is freely determined by supply and demand forces. The Beirut market rate (and by implication the parallel market rate inside Syria) witnessed a period of extreme fluctuations since the mid-1980's. The market rate increased from 13.85 SL/$US in December 1985 to 27.25 in December 1986, 45.00 in December 1987, and reached a maximum of 60.00 SL/$US in May 1988 (ibid., p. 771). The Syrian Lira then went into a period of steady improvement, stabilizing at a range of 42 to 46 SL/$US, with an average of 44 SL/$US at mid-1989.

[1] Abolished on October 1st, 1990.

As a result of this renewed stability in the market exchange rate, the government recently introduced a "neighboring countries" (NC) rate. The NC rate is officially set at 40 SL/$US, i.e., about 10% below the actual rate prevailing in the Beirut market. Although the official rate of 11.225 SL/$US is still widely used in public transactions, the shift to the NC rate is becoming more common, especially in valuing public sector imports. Moreover, all signs suggest that this shift will prevail in the coming years, provided that the market rate maintains its current stability. Therefore, although the NC rate is slightly below the free market rate, its use by many public agencies justifies its use as a basis for estimating economic prices of fertilizers and crops in this study.

To sum up the above discussion on the estimation of economic field prices, Import and Export Parity Prices (IPP and EPP) will be estimated based on the following approach:

IPP (SL) = CIF Price ($US x 40 SL/$US)
+ Government Costs (SL)
- Farmer's Costs (SL)

EPP (SL) = FOB Price ($US x 40 SL/$US)
- Government Costs (SL)
- Farmer's Costs (SL)

Where, IPP = Field-level Import Parity Price (SL/kg)
EPP = Field-level Export Parity Price (SL/kg)
CIF Price = Costs Insurance and Freight ($US/kg)
FOB Price = Free on Board ($US/kg)
Government Costs = Administrative, transport, and other local costs (SL/kg)
Farmer's Costs = Transport, handling, bags, and harvesting costs

4.3 Impact on the Government's Foreign Exchange and General Budgets

As discussed earlier, an important criterion in assessing the economic feasibility of alternative fertilizer allocations is their impact on two key policy concerns: (1) foreign exchange earnings, and (2) the government's budget deficit.

4.3.1 Foreign Exchange Earnings and Expenditures

To estimate the impact of alternative fertilizer allocations on the government's foreign exchange budget, we need first to estimate how much each additional unit of fertilizer used and crop produced would increase or decrease foreign exchange earnings. The underlying assumption is that, for any increase in fertilizer requirements, the government would need to import an equal amount to satisfy that increase. Thus, for each additional kilogram of fertilizer used the government's foreign exchange expenditures would increase by the import price of fertilizer plus any additional expenses paid in hard currencies (e.g., commissions to foreign banks or importing agents).

Similarly, it is assumed that every additional kilogram of export crop produced would be exported and thus constitute additional foreign exchange earnings. These earnings are equal to the crop's export price minus any additional costs incurred in hard currencies. Conversely, any increase in the output of imported crops implies an equal decline in imports and savings in foreign exchange. These savings are equal to the import price plus any additional import-related hard currency expenses.

As noted earlier, the above assumptions would apply only to crops that are completely controlled by the government (e.g., cotton and sugar beets). However, farmers usually sell only part of their cereals (e.g., wheat, barley, and corn) to the government. Therefore, it is assumed that for any increase in cereal output, only part of that increase (i.e., whatever is sold to the government) would substitute for cereal imports. Thus, the contribution of each additional kilogram of cereal output to foreign exchange earnings would be equal to the import price multiplied by the fraction of total output sold to the government.

Therefore, the general approach used in estimating the impact of fertilizers and crops on the government's foreign exchange budget is as follows:

1) For fertilizers:

Foreign Exchange Expenditures ($US/kg) =
CIF Price ($US/kg) + Other Import Costs ($US/kg)

2) For crops substituting for imports:

Savings on Foreign Exchange ($US/kg) =
(Fraction of total output sold to government)
* {CIF Price ($US/kg) + Other Import Costs ($US/kg)}

3) For export crops:

Foreign Exchange Earnings ($US/kg) =
(Fraction of total output sold to government)
* {FOB Price ($US/kg) - Other Export Costs ($US/kg)}

4.3.2 Taxes and Subsidies

To assess the impact of alternative fertilizer allocations on the government's general budget, we need to estimate the implicit taxes or subsidies on the fertilizers and crops covered by this study. Implicit taxes or subsidies are defined as the difference between the commodity's true costs or revenues faced by the government and the official producer price. Therefore, the general approach used in estimating net taxes or subsidies on a given commodity is to subtract the official price and the indirect subsidies (mainly transport subsidies and subsidies on bags) from the true economic value incurred by the government in purchasing or selling the commodity in question, as follows:

1) For fertilizers:

Net Subsidies (SL/kg) = CIF Price ($US/kg x 40 SL/$US)
+ Government Costs (SL/kg)
+ Indirect Subsidies (SL/kg)
- Official Sales Price (SL/kg)

2) For crops substituting for imports:

Net Taxes[1] (SL/kg) = CIF Price ($US/kg x 40 SL/$US)
+ Government Costs (SL/kg)
- Indirect Subsidies (SL/kg)
- Official Purchase Price (SL/kg)

3) For export crops:

Net Taxes (SL/kg) = FOB Price ($US/kg x 40 SL/$US)
- Government Costs (SL/kg)
- Indirect Subsidies (SL/kg)
- Official Purchase Price (SL/kg)

4.4 Fertilizer Prices

4.4.1 Fertilizer Financial Prices

A list of 1989/90 official prices for all the nitrogen and phosphorus fertilizers sold in Syria is provided in Table 4.1. Of the five types of fertilizers sold, urea and TSP are the predominant fertilizers used, with the remaining types constituting only a minor proportion of total use. Therefore, all the calculations included in this study will be based on urea and TSP. Based on the above official prices, fertilizer financial field prices are calculated by adding

[1] A negative tax would indicate a subsidized commodity.

Table 4.1: OFFICIAL FERTILIZER SALES PRICES
Syria, 1989/1990

Fertilizer Name	Nutrient Content (%) N	Nutrient Content (%) P_2O_5	Price (SL/ton)
Ammonium Nitrate (local):	30	--	3400
Ammonium Nitrate (imported):	33.5	--	3800
Urea:	46	--	4900
Di-Ammonium Phosphate (DAP):	18	46	7100
Triple Superphosphate (TSP):	--	46	5200

Source: Decisions of the Higher Agriculture Council's meeting of 26 August 1989.

fertilizer application costs and the costs of loading, unloading, and transport, to the weighted average of official and market prices (see Table 4.2).

4.4.2 Fertilizer Economic Prices

Calculations of economic field prices for N and P_2O_5 fertilizers are summarized in Table 4.3.

4.4.3 Foreign Exchange Expenditures on Fertilizer Imports

Foreign exchange expenditures per ton of imported fertilizer are equal to the border price plus all other import-related expenses incurred in hard currencies. This is given by the "Port Prices" of 156 \$US/ton and 228 \$US/ton for urea and TSP, respectively (see Table 4.3). These prices are equivalent to 339 \$US per ton of N and 496 \$US per ton of P_2O_5.

Table 4.2: FINANCIAL PRICES OF N AND P_2O_5 FERTILIZERS
Syria, October 1989.

	UREA		TSP
		(SL/Ton)	
Official Price:	4900		5200
Margin between Market and Official Price (%):	+20		+20
Market Price:	5880		6240
Market Purchases as a % of Total Purchases:	20		20
PRODUCER PRICE (Weighted Avg.):	5096		5408
Transport, Loading, and Unloading Costs:	+240		+240
Transaction Costs:	+28		+28
FARM PRICE:	5364		5676
Application Costs:	+200		+200
FIELD PRICE:	5564		5876
FIELD PRICE OF PURE NUTRIENT [1]:	12096		12800

1/ Urea contains 46% N; TSP contains 46% P_2O_5

Sources: Based on informal interviews with farmers in northern Syria.

Table 4.3: ECONOMIC PRICES OF N AND P_2O_5 FERTILIZERS
Syria, October 1989

	UREA	TSP
BORDER PRICE (C&F $US/ton):	130	190
Insurance (1.25%):	+2	+2
Commissions for Foreign Banks (7.5% for 3 months):	+2	+4
Commissions of Importing Agency and Local Expenses (16.875%):	+22	+32
PORT PRICE ($US/ton):	156	228
PORT PRICE[1] (SL/ton):	6240	9120
Transport Costs (Port to Warehouse):	+120	+120
Bags, Storage costs, and Insurance on Storage:	+24	+24
WAREHOUSE PRICE:	6384	9264
Interest (9% for 4 months):	+192	+278
Administrative Costs (4%):	+255	+371
PRODUCER PRICE:	6831	9913
Transport, loading, and unloading:	+240	+240
Interest on fertilizer loan (9% for 9 months):	+461	+669
FARM PRICE:	7532	10822
Application costs:	+200	+200
FIELD PRICE (SL/ton):	7732	11022
FIELD PRICE OF PURE NUTRIENT[2] (SL/ton):	16809	23961

1/ Converted at the "Neighboring Countries" exchange rate of 40 SL/$US.
2/ Urea contains 46% N; TSP contains 46% P_2O_5
Sources: Soils Directorate internal documents.

4.4.4 Net Subsidies on Fertilizers

To calculate net subsidies on fertilizers, we need first to determine how much of the true economic value of fertilizer is incurred by the government. The true cost to the government of one ton of fertilizer is equal to the economic Producer Price (see Table 4.3) plus the interest on fertilizer loans, which are incurred by the government. In contrast, government revenues from the sale of one ton of fertilizer are equal to the official producer price. Thus, net subsidies on fertilizers are then computed by subtracting the official sales price from the true economic value incurred by the government, as follows (refer to Table 4.2 and Table 4.3):

1) Net subsidies on urea = 6831 + 461 - 4900 = 2392 SL/ton.

   or

   Net subsidies on pure N = 2392/0.46 = 5200 SL/ton.

2) Net subsidies on TSP = 9913 + 669 - 5200 = 5382 SL/ton.

   or

   Net subsidies on P_2O_5 = 5382/0.46 = 11,700 SL/ton.

4.5 Wheat Prices

4.5.1 Financial Prices of Wheat Grain

Official prices of wheat grain for the 1989/1990 season were set at 8.5 SL/kg for durum (or hard) wheat and 7.5 SL/kg for soft (or bread) wheat. Shortly prior to harvest, and given projections of a poor harvest due to low rains, the government decided to add 1 SL/kg to the above prices. This was done to provide additional incentives to farmers to increase their wheat deliveries to the government[1]. However, these bonuses will not be included in the estimation of field prices. This is because fertilizer application decisions were made by the farmer based on the original official prices.

In the fertilizer requirement schedule no distinction is made between durum and soft wheat. Instead, fertilizer recommendations are based on whether the planted wheat is irrigated or rainfed; on the Agricultural Stability Zone for rainfed wheat; and on whether the planted wheat varieties are local (LYV) or high-yielding (HYV). The 1989/1990 fertilizer allocation plan included the following six categories for wheat grain:

1. Irrigated HYV
2. Rainfed HYV Zone 1
3. Rainfed HYV Zone 2
4. Rainfed LYV Zone 1
5. Rainfed LYV Zone 2
6. Rainfed LYV Zone 3

However, no data are available on the relative shares of durum and soft wheat varieties according to the above categories. Based on discussions with officials from the Seed Multiplication Establishment[2], it is estimated that about two-thirds of the HYV varieties grown in Syria are soft wheat and one-third are durum. In contrast, the vast majority of local varieties are durum wheat. Therefore, the official price of LYV wheat grain is assumed to be equal to that of durum wheat

---

[1] Based on the decision of the Higher Agriculture Council's meeting of 22 May, 1990.

[2] The Seed Multiplication Establishment is a semi-autonomous agency of the Ministry of Agriculture and Agrarian Reform responsible for the production and distribution of certified seeds, including HYV wheat seeds.

(8.5 SL/kg), while the official price of HYV wheat grain is 7.83 SL/kg (based on a weighted average of 2/3 soft and 1/3 durum).

To calculate wheat grain producer prices, a weighted average between official and parallel market prices needs to be computed. Discussions with farmers indicated that market prices are usually about 20% higher than official prices in a normal year. This margin would increase to about 30% and 40% during dry and very dry years, respectively. During good years, the margin between market and official prices would decline to about 10% (see Table 4.4).

The level of rainfall is also expected to affect the proportion of total output delivered to the government. Discussions with government officials suggested that, for HYV wheat, this proportion is around 40% in good and normal years, and 30% in drier years. Given that consumers in the rural areas prefer durum to soft wheat, a relatively smaller proportion of durum wheat is sold to the government. This proportion is around 30% in good and normal years and 20% in drier years (see Table 4.5).

Weighted averages are computed for wheat grain producer prices under different rainfall scenarios, based on the above estimates of the margins between official and market prices and the shares of total output sold to the government (see Table 4.4 and Table 4.5). To estimate field prices, harvesting, handling, and transport costs need to be subtracted from producer prices. However, farmers do not pay any transport costs on official procurements since the crop is delivered at the farm gate to government collectors. Also, the number of the subsidized government-supplied bags is proportional to the volume of official deliveries. Therefore, as can be noted from Table 4.4 and

Table 4.4: FINANCIAL PRICES OF HYV WHEAT GRAIN
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
		(SL/Ton)		
Official Price[2]:	7830	7830	7830	7830
Margin between Market and Official Price (%):	+10	+20	+30	+40
Market Price:	8613	9396	10179	10962
Official Sales as a % of Total Output:	40	40	30	30
PRODUCER PRICE[3]:	8300	8770	9474	10022
Transport Costs[4]:	-96	-96	-112	-112
FARM PRICE:	8204	8674	9362	9910
Harvesting costs as % of Gross Revenues:	10	10	12	12
Harvesting Costs:	-820	-867	-1123	-1189
Loading and Unloading Costs:	-60	-60	-60	-60
Government-Supplied Bags[4]:	-64	-64	-48	-48
Market Bags[4]:	-192	-192	-224	-224
FIELD PRICE:	7068	7491	7907	8389

1/ See Table 3.1 for the definitions of rain scenarios.
2/ Weighted average between hard and soft wheat prices.
3/ Weighted average between official and market prices.
4/ These costs are already adjusted to account for the relative shares of official vs market sales.
Sources: Based on informal interviews with farmers in northern Syria.

Table 4.5: FINANCIAL PRICES OF LYV WHEAT GRAIN
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
	(SL/Ton)			
Official Price:	8500	8500	8500	8500
Margin between Market and Official Price (%):	+10	+20	+30	+40
Market Price:	9350	10200	11050	11900
Official Sales as a % of Total Output:	30	30	20	20
PRODUCER PRICE[2]:	9095	9690	10540	11220
Transport Costs[3]:	-112	-112	-128	-128
FARM PRICE:	8983	9578	10412	11092
Harvesting costs as % of Gross Revenues:	10	10	12	12
Harvesting Costs:	-898	-958	-1249	-1331
Loading and Unloading Costs:	-60	-60	-60	-60
Government-Supplied Bags[3]:	-48	-48	-32	-32
Market Bags[3]:	-224	-224	-256	-256
FIELD PRICE:	7753	8288	8815	9413

1/ See Table 3.1 for the definitions of rain scenarios.
2/ Weighted average between official and market prices.
3/ These costs are already adjusted to account for the relative shares of official vs market sales.
Sources: Based on informal interviews with farmers in northern Syria.

Table 4.5, a weighted average was used in computing the cost of transport and bags. Also, it should be noted that harvesting costs are expressed as a percentage of gross revenues. This is because most grain harvesting in Syria is usually done by independent harvesting contractors. These contractors retain an average of 10% of the harvested grain in return for their services. During drier years these contractors charge a higher rate, averaging 12%.

4.5.2 Economic Prices of Wheat Grain

Given that Syria imports substantial amounts of wheat every year, wheat import (CIF) prices are used as the basis for calculating economic prices for wheat grain. The CIF price of soft wheat is estimated at 200 $US/ton and that of durum wheat at 212 $US/ton. As mentioned earlier, about two-thirds of all HYV varieties are soft wheat varieties and one-third durum varieties, while all local varieties are durum wheat. Thus, by taking the weighted average the CIF price for HYV wheat grain would be equal to 204 $US/ton, while the price of LYV wheat grain would be equal to 212 $US/ton. The calculations of economic field prices of wheat grain are presented in Table 4.6 and Table 4.7.

4.5.3 Financial Prices of Wheat Straw

The above estimations of financial and economic prices of wheat referred to wheat grain only. However, fertilizer use is expected to increase both grain and straw yields. Therefore, the value of straw ought to be included in the economic analysis of fertilizer use. Straw is usually stored on the farm and fed to livestock during the winter season. There are few economic incentives for farmers to sell straw in

Table 4.6: ECONOMIC PRICES OF HYV WHEAT GRAIN
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
BORDER PRICE CIF ($US/ton)[2]:	204	204	204	204
Local Expenses (10%):	+20	+20	+20	+20
PORT PRICE				
$US/ton:	224	224	224	224
SL/ton:	8960	8960	8960	8960
Transport Costs (Port to Warehouse):	+120	+120	+120	+120
PRODUCER PRICE:	9080	9080	9080	9080
Transport Costs (Farm to Warehouse):	-160	-160	-160	-160
FARM PRICE:	8920	8920	8920	8920
Harvesting costs as % of Gross Revenues:	10	10	12	12
Harvesting Costs:	-892	-892	-1070	-1070
Loading and Unloading Costs:	-60	-60	-60	-60
Bags:	-320	-320	-320	-320
FIELD PRICE:	7648	7648	7470	7470

1/ See Table 3.1 for the definitions of rain scenarios.
2/ Weighted average between the import prices of soft and durum wheat
Sources: Based on discussions with officials from the Soils Directorate.

Table 4.7: ECONOMIC PRICES OF LYV WHEAT GRAIN
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
BORDER PRICE				
CIF ($US/ton):	212	212	212	212
Local Expenses (10%):	+21	+21	+21	+21
PORT PRICE				
$US/ton:	233	233	233	233
SL/ton:	9320	9320	9320	9320
Transport Costs (Port to Warehouse):	+120	+120	+120	+120
PRODUCER PRICE:	9440	9440	9440	9440
Transport Costs (Farm to Warehouse):	-160	-160	-160	-160
FARM PRICE:	9280	9280	9280	9280
Harvesting costs as % of Gross Revenues:	10	10	12	12
Harvesting Costs:	-928	-928	-1114	-1114
Loading and Unloading Costs:	-60	-60	-60	-60
Bags:	-320	-320	-320	-320
FIELD PRICE:	7972	7972	7786	7786

1/ See Table 3.1 for the definitions of rain scenarios.
Sources: Based on discussions with officials from the Soils Directorate.

the local market unless market prices are high enough to justify the very high costs of transport and bags.

As shown in Table 4.8, the average market price of straw in normal years is 3200 SL/ton. This is slightly higher than the total costs that farmers would have to incur for harvesting, bagging, and transporting straw to the market. In good years, the supply of grain and straw is usually abundant enough to drive straw prices down to around 1750 SL/ton, which is less than total farmer's costs.

Table 4.8: FINANCIAL PRICES OF WHEAT STRAW
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
	(SL/Ton)			
MARKET PRICE:	1750	3200	5600	8000
Transport Costs:	-480	-480	-480	-480
FARM PRICE:	1270	2720	5120	7520
Harvesting costs as % of Gross Revenues:	50	50	50	60
Harvesting Costs:	-635	-1360	-2560	-4512
Loading and Unloading Costs:	-60	-60	-60	-60
Bags:	-960	-960	-960	-960
FIELD PRICE:	0	340	1540	1988

1/ See Table 3.1 for the definitions of rain scenarios.
Sources: Based on informal interviews with farmers in northern Syria.

In other words, for most farmers it would be uneconomical to market their straw under such conditions. This is confirmed by the phenomenon of straw burning in farmers' fields often observed during good years such as in 1988. In drier years, on the other hand, feed shortages would drive market straw prices up to 8000 SL/ton. These prices would constitute a greater economic incentive for farmers to harvest and sell their straw in the market.

4.5.4 Financial and Economic Prices of Total Wheat Output

The above discussion illustrates the importance of including straw prices in valuing the increase in wheat yield as a result of fertilizer use. This is particularly important in dry and very dry years. Given that there is no indication that straw prices are affected by price distortions, economic and financial prices of straw are assumed to be equal. Research results at ICARDA suggest that for each ton of wheat grain harvested, an average of 470 kg of straw is also produced (Nordblom and Thomson, 1987, p. 9). This ratio is taken into consideration in the estimation of financial and economic field prices of total wheat output, as shown in Table 4.9.

4.5.5 Net Savings in Foreign Exchange on Wheat Grain

For every ton of additional HYV wheat output, 300 to 400 kg are sold to the government, depending on seasonal rainfall (see Table 4.4). As mentioned earlier, wheat imports are assumed to decline by an amount equal to the quantities of wheat marketed through official channels. Given a port price of 224 $US/ton (see Table 4.6), an increase of one ton in HYV wheat output would result in 89.6 $US (i.e., 224 $US * 40%) of savings in import costs in normal and good years, and 67.2 $US (i.e., 224 $US * 30%) in dry and very dry years.

Table 4.9: PRICES OF TOTAL WHEAT OUTPUT
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
	(SL/Ton)			
(1) Financial Price of HYV Wheat Grain[2]:	7068	7491	7907	8389
(2) Financial Price of LYV Wheat Grain[3]:	7753	8288	8815	9413
(3) Economic Price of HYV Wheat Grain[4]:	7648	7648	7470	7470
(4) Economic Price of LYV Wheat Grain[5]:	7972	7972	7786	7786
(5) Straw Price[6]:	0	340	1540	1988
(6) Quantity of Straw Harvested per Ton of grain (tons):	0.47	0.47	0.47	0.47
(7) Straw Value per Ton of Grain (5)x(6):	0	160	724	934
FINANCIAL PRICE OF TOTAL HYV WHEAT OUTPUT (1)+(7):	7068	7651	8631	9323
FINANCIAL PRICE OF TOTAL LYV WHEAT OUTPUT (2)+(7):	7753	8448	9539	10347
ECONOMIC PRICE OF TOTAL HYV WHEAT OUTPUT (3)+(7):	7648	7808	8194	8404
ECONOMIC PRICE OF TOTAL LYV WHEAT OUTPUT (4)+(7):	7972	8132	8510	8720

1/ See Table 3.1 for the definitions of rain scenarios.
2/ From Table 4.4; 3/ From Table 4.5; 4/ From Table 4.6;
5/ From Table 4.7; 6/ From Table 4.8.

The same approach is used to estimate foreign exchange savings from increased LYV wheat production. Given a port price of 233 $US/ton (see Table 4.7), an increase of one ton in total output would result in 69.9 $US (233 $US * 30%) in foreign exchange savings in normal and good years. In dry and very dry years only 20% of total LYV wheat output is delivered to the government (see Table 4.5). Thus, net foreign exchange savings per ton of additional output would be equal to 46.6 $US (233 $US * 20%).

4.5.6 Net Taxes on Wheat Grain

To calculate net taxes (or subsidies) on wheat grain, we need first to determine how much of the true economic value of wheat is incurred by the government. In other words, the wheat purchased from farmers has an opportunity cost to the government equal to the import price plus all additional government costs. Given that the government incurs the transport costs from the farm gate, the economic Farm Price would be the opportunity cost of the wheat purchased by the government. Also, the subsidies on bags need to be included in estimating net taxes on wheat, as follows (see Table 4.6 and Table 4.7):

Net taxes on wheat = Economic Farm Price
- Subsidies on bags - Official Price

Net taxes on HYV wheat = 8920 - (320 - 160) - 7830 = 930 SL/ton
and Net taxes on LYV wheat = 9280 - (320 - 160) - 8500 = 620 SL/ton

The above estimates of implicit taxes on wheat apply only to official government purchases. However, as mentioned earlier, only 40% of total HYV wheat output is sold to the government in good and normal years and 30% in drier years. The figures for LYV wheat are even lower, with an estimated 30% of total output sold to the government in good and normal years and 20% in drier years.

Therefore, in estimating the average tax paid per ton of additional wheat produced, an approach based on a weighted average needs to be used, as follows:

Average Net taxes on HYV wheat:
A) Good and normal years = 930 x 40% = 372 SL/ton
B) Dry and very dry years = 930 x 30% = 279 SL/ton

Average Net taxes on LYV wheat:
A) Good and normal years = 620 x 30% = 186 SL/ton
B) Dry and very dry years = 620 x 20% = 124 SL/ton

4.6 Barley Prices

4.6.1 Financial Prices of Barley Grain

The official price of barley for the 1989/1990 season was set at 5.5 SL/kg. As mentioned earlier, an additional 1.5 SL/kg was announced prior to harvest as an incentive to increase farmers' crop deliveries to the government. However this increase will not be included in the estimation of field prices given that it was announced after fertilizer application time.

To calculate barley grain producer prices, a weighted average between official and market prices is computed, as shown in Table 4.10. This is based on the assumption that market prices would be 20% higher than official prices in a normal year. This percentage would increase to 40% and 60% during dry and very dry years, respectively. During good years, on the other hand, market prices tend to be very close to official prices.

Therefore, in comparison to wheat prices, barley grain prices are much more susceptible to fluctuations in rainfall than wheat prices.

Table 4.10: FINANCIAL PRICES OF BARLEY GRAIN
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
	(SL/Ton)			
Official Price:	5500	5500	5500	5500
Margin between Market and Official Price (%):	0	+20	+40	+60
Market Price:	5500	6600	7700	8800
Official Sales as a % of Total Output:	50	40	30	25
PRODUCER PRICE[2]:	5500	6160	7040	7975
Transport Costs[3]:	-80	-96	-112	-120
FARM PRICE:	5420	6064	6928	7855
Harvesting costs as % of Gross Revenues:	8	10	12	15
Harvesting Costs:	-434	-606	-831	-1178
Loading and Unloading Costs:	-60	-60	-60	-60
Government-Supplied Bags[3]:	-80	-64	-48	-40
Market Bags[3]:	-160	-192	-224	-240
FIELD PRICE:	4686	5142	5765	6337

1/ See Table 3.1 for the definitions of rain scenarios.
2/ Weighted average between official and market prices.
3/ These costs are already adjusted to account for the relative shares of official vs market sales.
Sources: Based on informal interviews with farmers in northern Syria.

This is because barley is grown in the drier areas where rainfall fluctuations are more accentuated. Also, barley prices are very much affected by the erratic rainfall levels in the steppe. This is because of the close interrelationship between feed prices and the availability of natural pastures. Furthermore, barley prices are more sensitive to rainfall than wheat prices because little barley is imported to offset domestic production shortfalls. Similarly, the level of rainfall is also expected to affect the proportion of total barley output delivered to the government. As shown in Table 4.10, official deliveries are estimated to decline from around 50% of total output during good years down to 25% in very dry years.

4.6.2 Economic Prices of Barley Grain

As discussed earlier, barley poses some complications in deciding whether to treat it as traded or nontraded good. Until the late 1970's, Syria regularly exported substantial amounts of barley. These exports have been declining steadily due to increased domestic demand for feed driven by high meat prices.

During the 1980's, significant barley exports continued only in good years, while imports were on the increase especially during dry years such as 1984. As a result the government has attempted to ban barley imports to save on foreign exchange. However, after two consecutive dry years and a substantial increase in barley market prices, the government allowed some barley imports in 1990. Therefore, despite the current ban on barley imports, it is expected that such a ban would be partially lifted whenever there are signs of significant barley shortages.

I

L

Ba

FI

1/
Sou

Table 4.11: ECONOMIC PRICES OF BARLEY GRAIN
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
BORDER PRICES				
CIF ($US/ton):	--	160	160	160
FOB ($US/ton):	135	--	--	--
Local Expenses (10%):	-14	+16	+16	+16
PORT PRICE				
$US/ton:	121	176	176	176
SL/ton:	4840	7040	7040	7040
Transport Costs (Port to Warehouse):	-120	+120	+120	+120
PRODUCER PRICE:	4720	7160	7160	7160
Transport Costs (Farm to Warehouse):	-160	-160	-160	-160
FARM PRICE:	4560	7000	7000	7000
Harvesting costs as % of Gross Revenues:	8	10	12	15
Harvesting Costs:	-365	-700	-840	-1050
Loading and Unloading Costs:	-60	-60	-60	-60
Bags:	-320	-320	-320	-320
FIELD PRICE:	3815	5920	5780	5570

1/ See Table 3.1 for the definitions of rain scenarios.
Sources: Based on discussions with officials from the Soils Directorate.

Therefore, in dry and very dry years the estimation of the economic price of barley grain would be based on the import (CIF) price, while in good years the export (FOB) price would be used. In normal years, Syria is usually self-sufficient in barley. However, with the continued increase in the demand for meat, Syria is expected to import barley even during normal years. Thus, any increase in barley output due to fertilizer use would substitute for such barley imports. This would justify the use of the CIF price as the basis for estimating economic prices in normal years. The estimation of the economic prices of barley grain is presented in Table 4.11.

4.6.3 Financial Prices of Barley Straw

As in the case of wheat, fertilizer use on barley is also expected to increase both grain and straw yields. In fact, barley straw has a greater economic value than wheat straw given its higher nutritional content (see Nordblom and Thomson, 1987, p. 17). This is often reflected in an average market price for barley straw 25% higher than that of wheat straw. Except for the differences in market prices, the estimation of the field price of barley straw is identical with the procedure used for wheat straw, as shown in Table 4.12.

4.6.4 Financial and Economic Prices of Total Barley Output

For each ton of barley grain harvested, an estimated 530 kg of straw are produced (Nordblom and Thomson, 1987, p. 7). Based on this ratio, the value of straw is added to the estimated financial and economic field prices of barley grain (from Table 4.10 and Table 4.11) to obtain the field prices of total barley output (Table 4.13).

ex

me

fo

of

cur

(see

woul

would

gives

Table 4.12: FINANCIAL PRICES OF BARLEY STRAW
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
	(SL/Ton)			
MARKET PRICE:	2200	4000	7000	10000
Transport Costs:	-480	-480	-480	-480
FARM PRICE:	1720	3520	6520	9520
Harvesting costs as % of Gross Revenues:	50	50	50	60
Harvesting Costs:	860	-1760	-3260	-5712
Loading and Unloading Costs:	-60	-60	-60	-60
Bags:	-960	-960	-960	-960
FIELD PRICE:	0	740	2240	2788

1/ See Table 3.1 for the definitions of rain scenarios.
Sources: Based on informal interviews with farmers in northern Syria.

4.6.5 Net Savings in Foreign Exchange on Barley Grain

The contribution of additional barley production to the foreign exchange budget is based on the Port Price of barley grain. As mentioned earlier, barley is usually exported in good years. Thus, foreign exchange earnings from barley exports would equal the FOB price of barley grain minus all other export-related expenses paid in hard currencies. This would give a Port Price of 121 $US/ton in good years (see Table 4.11). In normal and dry years, additional barley output would substitute for barley imports. Thus, savings in foreign exchange would be equal to the CIF price plus import-related expenses, which gives a Port Price of 176 $US/ton.

Table 4.13: PRICES OF TOTAL BARLEY OUTPUT
Syria, October 1989.

	RAIN SCENARIOS[1]			
	GOOD	NORMAL	DRY	V. DRY
	(SL/Ton)			
(1) Financial Price of Barley Grain[2]:	4686	5142	5765	6337
(2) Economic Price of Barley Grain[3]:	3815	5920	5780	5570
(3) Straw Price[4]:	0	740	2240	2788
(4) Quantity of Straw Harvested per Ton of grain (tons):	0.53	0.53	0.53	0.53
(5) Straw Value per Ton of Grain (3)x(4):	0	392	1187	1478
FINANCIAL PRICE OF TOTAL BARLEY OUTPUT (1)+(5):	4686	5534	6952	7815
ECONOMIC PRICE OF TOTAL BARLEY OUTPUT (2)+(5):	3815	6312	6967	7048

1/ See Table 3.1 for the definitions of rain scenarios.
2/ From Table 4.10; 3/ From Table 4.11; 4/ From Table 4.12

The above port prices need to be further adjusted to reflect the share of total barley production sold to the government (see Table 4.10). This would allow the estimation of the amount of foreign exchange contributed by each additional ton of barley output:

Foreign exchange earnings from barley:

A) Good years = 121 $US/ton x 50% = 60.5 $US/ton
B) Normal years = 176 $US/ton x 40% = 70.4 $US/ton
C) Dry years = 176 $US/ton x 30% = 52.8 $US/ton
D) Very dry years = 176 $US/ton x 25% = 44.0 $US/ton

4.6.6 Net Taxes on Barley Grain

As in the case of wheat grain, the net taxes (or subsidies) on barley grain are calculated based on the economic Farm Price. This price is equal to 7000 SL/ton in normal and dry years (see Table 4.11). As discussed earlier, the estimation of the economic price of barley in good years is based on its export price. This would give an economic Farm Price of 4560 SL/ton, as shown in Table 4.11. Thus, net taxes on barley are computed as follows:

Net taxes on barley = Economic Farm Price
- Subsidies on bags - Official Price

In good years = 4560 - (320 -160) - 5500 = -1110 SL/ton
In normal and dry years = 7000 - (320 - 160) - 5500 = 1340 SL/ton

The above figures are further adjusted to reflect the share of total barley production sold to the government (see Table 4.10). This would allow the estimation of the average tax paid per ton of additional barley produced, as follows:

Average net taxes on barley:

A) Good years = -1100 x 50% = -550 SL/ton
B) Normal years = 1340 x 40% = 536 SL/ton
C) Dry years = 1340 x 30% = 402 SL/ton
D) Very dry years = 1340 x 25% = 335 SL/ton

4.7 Cotton Prices

4.7.1 Financial Price of Raw Cotton

Cotton is the most important export crop in Syria. Several detailed studies on cost of production and marketing have been conducted by the Cotton Bureau and the Cotton Marketing Organization (CMO). As mentioned earlier, the CMO has total monopoly on domestic marketing, ginning, and export of cotton, with insignificant quantities of raw cotton sold in the parallel market. Therefore, the official price will be the basis for estimating the financial field price of raw cotton.

Official prices for raw cotton for the 1990 season were set as follows: 19 SL/kg for deliveries before the end of October (base price); 17 SL/kg for deliveries before the end of November; and 15 SL/kg for later deliveries. Based on figures from the last five seasons (1984 to 1988), CMO officials estimated that the price received by farmers is, on average, equal to 90.7% of the base price. Thus, for a base price of 19,000 SL/ton, the average producer price for the 1990 season would be equal to 17,233 SL/ton. Transport and harvesting costs are subtracted from the average producer price to give a financial field price of 13,525 SL/ton (see Table 4.14).

4.7.2 Economic Price of Raw Cotton

The CMO makes its export price projections based on expected spot prices of cotton lint at the end of the season (December). In January 1990, for instance, the future price of lint cotton for March 1990 deliveries was 67.91 US cents/lb (FOB New York). The future price for December 1990 deliveries was 63.87 cents/lb, i.e., a decline of 4.04 cents/lb. Therefore, it was expected that the January 1990 spot price

Table 4.14: FINANCIAL AND ECONOMIC PRICES OF RAW COTTON
Syria, January 1990.

	FINANCIAL	ECONOMIC
BORDER PRICE[1] (FOB $US/ton):		572.1
Local Expenses (5%):		-28.6
PORT PRICE:		
($US/ton):		543.5
(SL/ton):		21740
Ginning Costs (5% of producer price):		-862
Interest (9% for 6 months):		-775
PRODUCER PRICE (SL/ton):	17233	20103
Transport Cost Differential[2]:	--	-100
Farmer's Transport Costs[2]:	-45	-45
FARM PRICE (SL/ton):	17188	19958
Harvest Labor Costs:	-2500	-2500
Transport Costs of Harvest Labor:	-750	-750
Bags:	-180	-267
Bagging:	-133	-133
Loading and Pressing:	-100	-100
FIELD PRICE (SL/ton):	13525	16208

1/ Includes transport costs from the gins to the port.
2/ Farmers pay for the first 100 Km. and the Cotton Marketing Organization pays the extra transport costs.
Sources: Based on discussions with officials from the Cotton Bureau and the Cotton Marketing Organization.

of 76.75 cents/lb (CIF Northern Europe) also would decline by 4.04 cents/lb to give an expected spot price of 72.71 cents/lb in December 1990. Shipping costs from the cotton gins in Syria to Northern Europe are estimated at 3.5 US cents/lb, which gives an FOB (Syria) price of 69.21 cents/lb, or 1524.4 $US/ton.

However, prices need to be expressed in terms of raw cotton rather than lint cotton. According to the CMO, one ton of raw cotton produces, after ginning, an average of 343.3 kg of lint cotton, 610 kg of cotton seeds, and 46.7 kg of waste. All the cotton seed produced in Syria is sold locally at an average price of 3.25 SL/kg, or 80 $US/ton (based on the exchange rate of 40 SL/$US). Therefore, the FOB price of raw cotton is estimated as follows:

FOB Price = (1524.4 x 0.3433) + (80 x 0.61) = 572.1 $US/ton

To estimate the economic field price of raw cotton, the costs of ginning, transport, harvesting, and other local costs are subtracted from the border price to give a field price of 16,208 SL/ton (see Table 4.14).

4.7.3 Foreign Exchange Earnings from Cotton

Since cotton marketing is completely controlled by the government, any increase in cotton production will be reflected by an equal increase in exports. Thus foreign exchange earnings from additional cotton production would be equal to the Port Price of raw cotton estimated at 543.5 $US/ton (see Table 4.14).

4.7.4 Net Taxes on Raw Cotton

As for the estimation of net taxes on raw cotton, this is done by subtracting the official price and the subsidies on transport and bags from the economic Producer Price, as follows (see Table 4.14):

Net taxes on raw cotton = Economic Producer Price
- Transport Subsidy - Subsidies on bags
- Official Price
= 20103 - 100 - (267-180) - 17233 = 2683 SL/ton

4.8 Corn Prices

4.8.1 Financial Price of Corn

The official price of corn grain for the 1989/1990 season is 7000 SL/ton, while the market price was expected to be 20% higher. Given that about 50% of all corn output is sold to the government, the weighted average producer price would be 7700 SL/ton (see Table 4.15). Transport, handling, and harvesting costs are subtracted from the average producer price to give a financial field price of 6910 SL/ton.

4.8.2 Economic Price of Corn

As for the estimation of economic prices, the expected 1990 import (CIF) price of corn was 170 $US/ton. After adding local expenses and transport costs, the economic producer price would amount to 7600 SL/ton (see Table 4.15). The field price is computed by subtracting farmers' costs, which would give an economic field price of 6340 SL/ton.

4.8.3 Foreign Exchange Savings from Corn

For an increase of one ton in corn output, the government receives 500 kg that would substitute for corn imports. Given a port price of

Table 4.15: FINANCIAL AND ECONOMIC PRICES OF CORN
Syria, March 1990.

	FINANCIAL	ECONOMIC
BORDER PRICE (CIF $US/ton):		170
Local Expenses (10%):		+17
PORT PRICE:		
($US/ton):		187
(SL/ton):		7480
Transport Costs (Port to Warehouse):		+120
Official Price:	7000	
Margin Between Market and Official Price (%):	+20	
Market Price:	8400	
Official Sales as a % of Total Output:	50	
PRODUCER PRICE (SL/ton)[1]:	7700	7600
Transport, Loading, and Unloading Costs:	-200	-200
FARM PRICE (SL/ton):	7500	7400
Harvesting Costs (10%):	-750	-740
Bags:	-240[2]	-320
FIELD PRICE (SL/ton):	6510	6340

1/ Weighted average between market and official prices.
2/ Weighted average between market and government-supplied bags.
Sources: Based on discussions with officials from the Soils Directorate.

187 $US/ton, the foreign exchange earnings for each additional ton of corn output would be equal to 93.5 $US (i.e., 187 $US/ton * 50%).

4.8.4 Net Taxes on Corn

The estimation of net taxes on corn is done by subtracting the official price and the subsidies on bags from the economic Producer Price, as follows:

Net taxes on corn = Economic Producer Price
- Subsidies on bags
- Official Price

= 7600 - (320 - 240) - 7000 = 520 SL/ton

Given that an estimated 50% of total corn production is sold to the government, the average net tax on corn would be equal to 260 SL/ton (i.e., 520 SL/ton * 50%).

4.9 Sugar Beet Prices

4.9.1 Financial Price of Sugar Beets

The official price for sugar beet roots was set at 1250 SL/ton for the 1989/1990 season. The General Establishment for Sugar Refining (GESR) has total monopoly on sugar refining and it is the sole legal buyer of sugar beet roots. Although, in the past, farmers have been observed to sell their beets as feed for livestock, the recent increases in official prices have drastically reduced such practices.

Therefore, the official price is the actual price that most farmers receive. By subtracting harvest and transport costs from the official price, the financial field price would then be equal to 1025

Table 4.16: FINANCIAL AND ECONOMIC PRICES OF SUGAR BEET
Syria, March 1990.

	FINANCIAL	ECONOMIC
BORDER PRICE OF REFINED SUGAR (CIF $US/ton):		400
Local Expenses:		+25
PORT PRICE OF REFINED SUGAR:		
($US/ton):		425
(SL/ton):		17000
Transport Costs:		+120
Extraction and Refining Costs:		+1737
REFINERY PRICE OF REFINED SUGAR (SL/ton):		18857
PRODUCER PRICE OF SUGAR BEET ROOTS[1] (SL/ton):	1250	1544
Harvest and Transport Costs:	-225	-225
FIELD PRICE (SL/ton):	1025	1319

1/ One ton of sugar beet roots yields an average of 81.9 kg of refined sugar

Sources: Based on discussions with officials from the General Establishment for Sugar Refining.

SL/ton (Table 4.16). Given an estimated 225 SL/ton in harvesting and transport costs, the field price of sugar beet roots would be equal to 1025 SL/ton.

4.9.2 Economic Price of Sugar Beets

The most recent price of refined sugar imported by Syria was 400 $US/ton (CIF). It should be noted that international market prices of sugar frequently underestimate the true cost of production in the producer countries. In these countries heavy producer subsidies and frequent dumping of surplus production in the international market are common practices. Although the international price of sugar may not represent its true economic value, it still represents the opportunity cost of importing countries such as Syria. Thus, for the purpose of this study, the international market price will be the basis for estimating the economic price of sugar in Syria.

Adding an estimated 25 $US/ton in local expenses, this gives a border price of 425 $US/ton or 17,000 SL/ton. Adding transport, refining, and extraction costs would give an economic producer price of 18,857 SL/ton for refined sugar (Table 4.16). One ton of beet roots gives, on average, 81.9 kg of refined sugar (see General Establishment for Sugar Refining, 1989). Therefore, the economic producer price for beet roots is estimated at 1544 SL/ton. Subtracting transport and harvest costs would give an economic field price for beet roots equal to 1319 SL/ton.

4.9.3 Foreign Exchange Savings from Sugar Beets

Since sugar production and refining is completely controlled by the government, any increase in the production of refined sugar would lead to an equal decline in sugar imports. Thus, the additional production of one ton of refined sugar would result in 425 $US savings in sugar imports. Since one ton of sugar beet roots produces an average of 81.9 kg of refined sugar, the foreign exchange savings for each additional ton of sugar beet roots would amount to 34.81 $US (i.e., 425 $US/ton * 0.0819).

4.9.4 Net Taxes on Sugar Beets

Taxes on sugar beet roots are estimated by subtracting the official producer price from the economic producer price (or refinery price), as follows (see Table 4.16):

Net taxes on sugar beets = Economic Producer Price - Official Price
= 1544 - 1250 = 294 SL/ton.

4.10 Potato Prices

4.10.1 Financial Price of Potatoes

In the 1989/1990 season, potato prices were not fixed by the government. Therefore, the proper price to use in the estimation of financial field prices would be the expected wholesale potato price shortly after harvest time, expected to be around 6000 SL/ton. If transport, handling, and harvest costs are subtracted, this would give a financial field price of 4860 SL/ton (Table 4.17).

Table 4.17: FINANCIAL AND ECONOMIC PRICES OF POTATOES
Syria, March 1990.

	FINANCIAL	ECONOMIC
BORDER PRICE (FOB $US/ton):		200
Local Expenses (10%):		-20
PORT GATE PRICE ($US/ton):		180
PORT GATE PRICE (SL/ton):		7200
Transport Costs (SL/ton):		-100
EXPECTED WHOLESALE PRICE (SL/ton):	6000	7100
Transport Costs (SL/ton):	-100	-100
FARM GATE PRICE (SL/ton):	5900	7000
Harvesting, and Handling Costs (10%):	-590	-700
Bags (SL/ton):	-450	-450
FIELD PRICE (SL/ton):	4860	5850

Sources: Based on discussions with officials from the Soils Directorate.

4.10.2 Economic Price of Potatoes

Potato exports have increased during the past few years primarily due to the rapid devaluation of the Syrian Lira. The expected potato export price (FOB) for 1990 is 200 $US/ton. Subtracting 10% in local expenses would give a port price of 180 $US/ton, or 7200 SL/ton. If transport, handling, and harvest costs are subtracted, this would give an economic field price of 5850 SL/kg (Table 4.17).

4.10.3 Contribution of Potatoes to the Government's Foreign Exchange and General Budgets

In 1989, the potato marketing and export functions were completely transferred from the public to the private sector in an attempt to promote potato exports. Thus, any increase in potato production or exports will have no direct effects on the government's budget. This applies to the foreign exchange budget as well as the general budget.

4.11 Summary of Estimated Financial and Economic Prices

Table 4.18 provides a summary of financial and economic prices of the fertilizers and crops covered in this study. Net taxes (or subsidies) and foreign exchange earnings (or expenditures) are also presented in the same table. A comparison between the financial and economic prices indicates some significant distortions in domestic prices. This is particularly true for fertilizers, which are highly subsidized. In contrast, domestic crop prices are generally below their international market equivalent. As shown in Table 4.18, all crops are implicitly taxed, except for barley in good years and potatoes.

Table 4.18: SUMMARY OF FINANCIAL AND ECONOMIC PRICES, NET TAXES, AND FOREIGN EXCHANGE EARNINGS OF FERTILIZERS AND MAIN CROPS Syria, 1989/1990.

	FINANCIAL PRICES (SL/kg)	ECONOMIC PRICES (SL/kg)	NET TAXES[1] (SL/kg)	FOREIGN EXCHANGE EARNINGS[2] ($US/ton)
Fertilizers:				
- N:	12.10	16.81	-5.20	-339.0
- P_2O_5:	12.80	23.96	-11.70	-496.0
Crops:				
- HYV Wheat:				
Good:	7.07	7.65	0.37	89.6
Normal:	7.65	7.81	0.37	89.6
Dry:	8.63	8.19	0.28	67.2
V. Dry:	9.23	8.40	0.28	67.2
- LYV Wheat:				
Good:	7.75	7.97	0.19	69.9
Normal:	8.45	8.13	0.19	69.9
Dry:	9.54	8.51	0.12	46.6
V. Dry:	10.35	8.72	0.12	46.6
- Barley:				
Good:	4.69	3.82	-0.55	60.5
Normal:	5.53	6.31	0.54	70.4
Dry:	6.95	6.97	0.40	52.8
V. Dry:	7.82	7.05	0.34	44.0
- Raw Cotton:	13.53	16.21	2.68	543.5
- Corn:	6.51	6.34	0.26	93.5
- Sugar Beet Roots:	1.03	1.32	0.29	34.8
- Potatoes:	4.86	5.85	0.00	0.0

1/ Taxes minus subsidies.
2/ A negative sign indicates foreign exchange expenditures.

AN ECONOMIC ANALYSIS OF FERTILIZER ALLOCATION AND IMPORT POLICIES IN SYRIA

Volume II

By

Maurice Emile Saade

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1991

CHAPTER 5

FERTILIZER RECOMMENDATIONS UNDER NO CONSTRAINTS ON FERTILIZER SUPPLIES

This chapter presents the main findings related to fertilizer recommendations for the main crops in Syria. The principal assumption underlying all the results in this chapter is that farmers have unlimited access to fertilizers, given the prevailing prices. In other words, based on the optimum fertilizer rates estimated in this chapter, "ideal" recommendations are proposed. These optimum rates are defined as those maximizing net returns to fertilizer use. They are computed by equating marginal costs with marginal revenues calculated based on economic prices. These recommendations will constitute the maximum rates, which would need to be adjusted downward depending on the amounts of fertilizer supplies available. The issue of fertilizer recommendations under limited supplies will be discussed in the next chapter.

The chapter begins with a summary of the estimated production functions. Based on these functions economically optimum fertilizer rates are estimated. These rates will constitute the basis for proposing any adjustments in the current fertilizer recommendations for the main crops in Syria. Next, the economic feasibility of the proposed rates is discussed. The last section of this chapter presents comparisons between the proposed fertilizer rates and the current recommendations. This comparison is done in terms of impact on national and farm incomes, aggregate crop output, and the government foreign exchange and general budgets.

5.1 Summary of the Estimated Production Functions

Production functions for the main crops were estimated based on pooled analysis of available data from fertilizer trials undertaken in Syria since the 1960's. These crops are: (1) irrigated wheat; (2) rainfed high-yielding wheat varieties (HYV); (3) rainfed low-yielding or local wheat varieties (LYV); (4) rainfed barley; (5) irrigated cotton; (6) irrigated fall-planted sugar beets; (7) irrigated summer-planted sugar beets; (8) irrigated fall-planted potatoes; (9) irrigated spring and summer-planted potatoes; and (10) irrigated corn.

The estimated coefficients of the production functions and some of their statistical characteristics are presented in Table 5.1. A detailed discussion of the step-by-step estimations and the data sources were presented in an earlier report (Saade, El-Hajj, and Meda, forthcoming). The report also includes a discussion of the assumptions underlying each estimated function, alternative formulations, and evaluations of their statistical performance.

5.1.1 Statistical Performance of Estimated Functions

The acceptable range for the values of the coefficient of determination (adjusted R^2) is very difficult to determine based on previous studies. If the analysis is based on data from a single fertilizer experiment (i.e., with little variability in soil and

Table 5.1: ESTIMATED PRODUCTION FUNCTIONS FOR THE CROPS IN THE FERTILIZER ALLOCATION MODEL IN SYRIA

Crop:	Irrigated Wheat	Rainfed HYV Wheat	Rainfed LYV Wheat	Rainfed Barley
Parameter:				
Constant	2819.71 (142.8)***	-2701.7 (256.7)***	-837.17 (214.3)***	-3238.18(197.3)***
E	NA	18.7100 (1.006)***	5.0628 (0.687)***	24.9455 (1.091)***
E^2	NA	-0.0152 (0.001)***	NA	-0.0310 (0.001)***
N	16.3174 (2.744)***	2.5517 (2.628)NS	NA	0.2908 (3.754)NS
P	13.8260 (4.531)***	8.1082 (4.566)*	NA	6.0465 (2.503)**
EN	NA	0.0221 (0.004)***	0.0428 (0.017)**	0.0506 (0.008)***
EP	NA	0.0066 (0.006)NS	0.0222 (0.022)NS	-0.00127(0.005)NS
N^2	-0.0562 (0.014)***	-0.0559 (0.014)***	-0.2288 (0.129)*	-0.1117 (0.046)**
P^2	-0.1013 (0.040)**	-0.1003 (0.0432)**	-0.1400 (0.174)NS	-0.0408 (0.020)**
NP	0.0171 (0.018)NS	-0.0017 (0.0172)NS	NA	0.0263 (0.024)NS
ENP	NA	NA	0.00025(0.0003)NS	NA
Adj. R^2	0.099	0.510	0.468	0.656
Std. Error	1692.94	1060.69	516.44	472.99
n	1152	1352	288	672

- Figures in brackets are the standard errors of the coefficients.
- Significance levels: *** = 1%; ** = 5%; * = 10%; NS = not significant.
- NA = not applicable.
- Refer to chapter 3 for the definitions of the symbols in the equations.
- All fertilizer rates are in kg/ha; all yields are in kg/ha, except for sugar beets and potatoes (tons/ha).
- Total seasonal rainfall levels (E) are in mm/year.

Table 5.1 (cont'd):

Crop:	Cotton	Fall Sugar Beets	Summer Sugar Beets

Table 5.1 (cont'd):

Crop:	Cotton	Fall Sugar Beets	Summer Sugar Beets
Parameter:			
Constant	2581.36 (119.6)***	47.06 (1.887)***	29.61 (1.183)***
N	9.6854 (1.556)***	0.1424 (0.039)***	0.1506 (0.024)***
P	5.6493 (2.474)**	NA	NA
N^2	-0.0217 (0.006)***	-0.0003 (0.0002)*	-0.00036(0.0001)***
P^2	-0.0270 (0.015)*	NA	NA
NP	0.0097 (0.009)NS	NA	NA
Adj. R^2	0.164	0.076	0.147
Std. Error	1127.51	22.66	14.81
n	852	522	570

Table 5.1 (cont'd):

Crop:	Fall Potatoes	Summer Potatoes	Corn
Parameter:			
Constant	16.95 (0.878)***	17.79 (232.9)***	4451.65 (232.9)***
N	0.0439 (0.018)**	0.0437 (0.019)**	23.4785 (6.862)***
P	NA	NA	NA
N^2	-0.00012 (0.0001)NS	-0.00013 (0.0001)*	-0.0804 (0.042)*
P^2	NA	NA	NA
NP	NA	NA	NA
Adj. R^2	0.02834	0.02723	0.054
Std. Error	8.691	7.427	2824.66
n	372	240	594

climatic factors), then the typical adjusted R^2 would be within the 0.7 to 0.9 range. If, on the other hand, the analysis is based on data pooled from different locations and/or different years, then differences in soil and climatic factors would account for most of the variability in yield. Thus, the adjusted R^2 would be much lower since a relatively smaller percentage of the variance would be explained by differences in fertilizer rates.

The results from fertilizer trials on wheat and barley in northern Syria show that the value of the adjusted R^2 rarely exceeds 0.20, based on analysis of pooled data (see SD/ICARDA, 1989 and 1990). However, the specific value of the adjusted R^2 is largely dependent on the number of locations from which the data were pooled. Thus, the larger the number of locations, the lower the value of the adjusted R^2 is expected to be. Similar results also indicate that whenever rain is included in the estimated production function, the value of the adjusted R^2 obtained from the analysis of pooled data would be in the range of 0.40 to 0.60. This is expected since rainfall alone usually contributes at least 40% of the variance in yield.

The values of the adjusted R^2 for irrigated wheat and cotton (0.10 and 0.16, respectively) are within the expected 0.10 to 0.20 range. As for rainfed wheat and barley, the adjusted R^2 values obtained are: HYV wheat: 0.51; LYV wheat: 0.47; and barley: 0.66 (see Table 5.1). The production functions for sugar beets, potatoes, and corn were estimated in terms of yield response to nitrogen only. This is because in most of the fertilizer experiments on these crops the level of applied P_2O_5 was either fixed or included only two rates. The exclusion of P_2O_5 from the analysis is partially responsible for the low values of the adjusted R^2 obtained for these crops, particularly potatoes.

The signs of the estimated coefficients are all as expected, with two exceptions: The first one is the negative sign on the interaction term between rain and applied phosphate (EP) in the estimated function for barley. However, the estimated coefficient for this term is not statistically different from zero. This suggests that there is no statistical evidence of interactions between rainfall and applied phosphorus. The second questionable sign is the negative sign on the interaction term between N and P_2O_5 (NP) in the estimated function for rainfed HYV wheat. However, this term is relatively small to affect the results.

All terms, whether statistically significant or not, were kept in the estimated functions. The non-significant terms were included in the functions in order to reflect the underlying hypothesized biological relationships implicit in the formulation of the production function. These non-significant terms are not expected to affect the analysis given the small magnitude of the estimated coefficients.

5.1.2 Zone-Specific Production Functions for Rainfed Crops

Another point to note from Table 5.1 is the inclusion of rainfall (E) in the production functions for rainfed crops. As discussed earlier, the inclusion of rainfall in these functions allows the estimation of a specific production function for each Agricultural Stability Zone. This is done by substituting "E" in the original production function by the value for average rainfall for each zone, as follows:

Rainfed HYV wheat:

Zone 1b (E = 400 mm/year):

$$Y = 2350.28 + 11.3917\ N + 10.7482\ P - 0.0559\ N^2 - 0.1003\ P^2 - 0.0017\ NP$$

Zone 2 (E = 300 mm/year):

$$Y = 1543.28 + 9.1817\ N + 10.0882\ P - 0.0559\ N^2 - 0.1003\ P^2 - 0.0017\ NP$$

Rainfed LYV wheat:

Zone 1b (E = 400 mm/year):

$$Y = 1187.95 + 17.12\ N + 8.88\ P - 0.2288\ N^2 - 0.14\ P^2 + 0.10\ NP$$

Zone 2 (E = 300 mm/year):

$$Y = 681.67 + 12.84\ N + 6.66\ P - 0.2288\ N^2 - 0.14\ P^2 + 0.075\ NP$$

Zone 3 (E = 250 mm/year):

$$Y = 428.53 + 10.70\ N + 5.55\ P - 0.2288\ N^2 - 0.14\ P^2 + 0.0625\ NP$$

Rainfed Barley:

Zone 1b (E = 350 mm/year):

$$Y = 1695.245 + 18.0008\ N + 5.602\ P - 0.1117\ N^2 - 0.0408\ P^2 + 0.0263\ NP$$

Zone 2 (E = 250 mm/year):

$$Y = 1060.695 + 12.9408\ N + 5.729\ P - 0.1117\ N^2 - 0.0408\ P^2 + 0.0263\ NP$$

Zone 3 (E = 200 mm/year):

$$Y = 510.92 + 10.4108\ N + 5.7925\ P - 0.1117\ N^2 - 0.0408\ P^2 + 0.0263\ NP$$

It should be noted that in the above zone-specific production functions for wheat the values used for rainfall levels (E) refer to average or normal levels. On the other hand, rainfall levels in dry years were used in the barley production functions (refer to Table 3.1 for the definitions of rainfall scenarios). This is based on the "maximin" assumption, as discussed earlier. According to this assumption, risk-averse barley farmers make their fertilizer application decisions by assuming that a dry year would occur.

5.2 Estimation of Ideal Fertilizer Recommendations

Based on the estimated production functions, optimum N and P_2O_5 rates are computed by equating marginal costs with marginal revenues. Two sets of "optimum" rates are calculated: the first one is based on financial prices, while the second is based on economic prices of fertilizers and crops (Table 5.2). A main objective of this study is to propose fertilizer recommendations that would represent an economically efficient use of resources. Therefore, the fertilizer recommendations proposed in this study are based on the economic optima presented in Table 5.2.

A comparison between the proposed and the current recommendations indicates the need for some major readjustments in the current fertilizer recommendations. The estimated economic optima indicate that the current rates recommended for wheat should be reduced substantially, especially P_2O_5 rates. As shown in Table 5.2, the current P_2O_5 rates on all wheat categories exceed the rates that would give maximum yield. Indeed, the production functions suggest that the current recommended rates are so excessive as to cause a decline in yield if they are actually applied. The current N and P_2O_5 rates are particularly excessive for LYV wheat. These rates are, on average, twice as high as the proposed rates.

The opposite is true in the case of barley. The results in Table 5.2 indicate that current fertilizer recommendations for barley could be substantially increased. This is especially true in Zone 3

Table 5.2: OPTIMUM AND CURRENT FERTILIZER RATES (KG/HA)
Syria, 1989/1990

	Biological Maxima		Financial Optima		Economic Optima		Current Rates	
Crop:	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Irrigated Wheat:	160	80	140	70	135	65	150	100
Rainfed Wheat:								
HYV Zone 1:	100	55	90	45	80	40	100	80
HYV Zone 2:	80	50	65	40	60	35	80	60
LYV Zone 1:	50	50	45	40	40	35	80	60
LYV Zone 2:	35	35	30	25	25	20	60	60
LYV Zone 3:	30	25	25	20	20	15	30	30
Rainfed Barley:								
Zone 1:	90	100	80	65	75	45	50	40
Zone 2:	70	90	55	60	50	40	40	40
Zone 3:	55	90	45	55	40	35	20	20
Cotton:	250	150	230	130	225	120	200	150
Corn:	145	na[2]	135	na	130	na	120	80
Sugar Beets:								
Fall:	235	na	220	na	215	na	200	120
Summer:	210	na	195	na	190	na	180	120
Potatoes:								
Fall:	185	na	175	na	170	na	150	120
Summer:	170	na	160	na	155	na	120	120

1/ All rates rounded to the nearest 5 kg/ha.
2/ Not applicable, since production functions were estimated in terms of nitrogen only.

where, as suggested by the results, the proposed rates are almost twice as large as the current ones.

Besides wheat and barley, the differences between the proposed and current fertilizer recommendations are not large. The results indicate that the N rate on cotton should be increased from 200 kg/ha to 225 kg/ha, while the P_2O_5 rate should be reduced from 150 kg/ha to 120 kg/ha. As for corn, sugar beets, and potatoes, the current P_2O_5 rates are not modified given that the production functions were estimated in terms of response to N only. The results indicate that the current N rates on corn and sugar beets should be slightly increased by 10 to 15 kg/ha, while N rates on potatoes should be increased by 20 to 35 kg/ha.

5.3 Feasibility of Proposed Fertilizer Recommendations

5.3.1 Profitability of Proposed Rates

As discussed earlier, the main criterion used in assessing the profitability of the proposed fertilizer rates is the Value-Cost-Ratio (VCR). The VCR is the value of the increase in output due to fertilizer use divided by total fertilizer costs. A VCR greater than 1.5 is considered as an indicator that the investment in fertilizers is profitable and has an acceptable rate of return (see for example CIMMYT, 1988, p. 35, and FAO, 1981, p. 42). A VCR between 1.0 and 1.5 is an indication that the investment is profitable but the rate of return may be too low. A VCR below 1.0 indicates that the investment in fertilizers is not profitable. Fertilizer application on rainfed crops constitutes a riskier investment than on irrigated crops. Thus, the proposed rates on rainfed crops would be considered profitable only if the VCR is greater than 1.5 in dry years, and greater than 1.0 in very dry years[1].

VCR calculations for the proposed fertilizer rates on the crops included in this study are presented in Table 5.3. Two sets of VCR values are calculated: one set based on financial prices and the other based on economic prices. The financial VCR is an indicator of the profitability of the proposed fertilizer rates from the farmer's viewpoint. The economic VCR, on the other hand, would reflect the economic feasibility of the proposed rates from the viewpoint of the economy as a whole.

The results clearly indicate that all the proposed fertilizer rates would be considered profitable by farmers. The range of the financial VCR for irrigated crops is from 4.2 to 5.6, which is a clear indication of profitability. Although financial VCR's for rainfed crops are lower than for irrigated crops, they are consistently higher than the 1.5 minimum acceptable level. In dry years, the financial VCR for rainfed wheat and barley ranges from 2.9 to 4.9, while in very dry years the range is from 1.6 to 4.2. These figures clearly suggest that the proposed fertilizer rates on rainfed wheat and barley are profitable and do not constitute a risky investment for farmers.

Looking at the feasibility of the proposed rates from the economy's viewpoint, the economic VCR values indicate that all the proposed rates would be economically feasible (see Table 5.3). The range of VCR values for irrigated crops is from 2.6 for corn to 4.1 for fall-planted potatoes. As for rainfed wheat and barley, all the

---

[1] Refer to chapter 3 for a more detailed discussion of the use of the VCR as a criterion for assessing profitability.

Table 5.3: VALUE-COST-RATIOS OF FERTILIZER USE BASED ON PROPOSED RATES Syria, 1989/1990.

	Financial VCR				Economic VCR			
Crop:	Good	Normal	Dry	V. Dry	Good	Normal	Dry	V. Dry
Irrigated Wheat:		5.6				3.7		
Rainfed Wheat:								
HYV Zone 1:	4.9	4.2	4.2	3.8	3.4	2.8	2.5	2.2
HYV Zone 2:	3.9	3.8	3.7	3.3	2.7	2.4	2.2	1.9
LYV Zone 1:	7.6	5.6	4.9	3.7	4.9	3.4	2.7	2.0
LYV Zone 2:	5.2	4.4	3.6	2.4	3.3	2.6	2.0	1.2
LYV Zone 3:	4.6	3.8	2.9	1.6	2.9	2.3	1.6	0.8
Rainfed Barley:								
Zone 1:	4.9	4.3	4.6	4.2	2.5	3.1	2.9	2.4
Zone 2:	3.5	3.5	3.6	3.2	1.8	2.5	2.3	1.8
Zone 3:	3.1	3.1	3.2	2.8	1.6	2.2	2.0	1.5
Cotton:		5.2				4.0		
Corn:		4.3				2.6		
Sugar Beets:								
Fall:		4.2				3.4		
Summer:		4.2				3.4		
Potatoes:								
Fall:		5.4				4.1		
Summer:		5.2				3.9		

1/ See Table 3.1 for the definitions of rainfall scenarios.

calculated VCR values in dry years are above the minimum 1.5 limit. In very dry years, VCR values for rainfed crops are all above the 1.0 limit, except for LYV wheat in Zone 3, with a VCR of 0.8.

When wheat and barley farmers were asked for the reasons for not increasing their current fertilizer application rates, a frequent response was that higher rates would "burn" the crop in the event of a dry year. Therefore, in assessing the riskiness of the proposed rates on rainfed crops, an additional criterion was added to the analysis. According to this criterion, the proposed rates should not result in any yield decline in the event of a dry year. Fertilizer rates that would maximize yield in dry and very dry years were estimated for the rainfed

Table 5.4: COMPARISON OF PROPOSED FERTILIZER RATES ON RAINFED CROPS WITH MAXIMUM RATES IN DRY AND VERY DRY YEARS
Syria, 1989/1990

	Biological Maxima (kg/ha)				Proposed Rates (kg/ha)	
	Dry[1]		Very Dry[1]			
Crop:	N	P_2O_5	N	P_2O_5	N	P_2O_5
Rainfed Wheat:						
HYV Zone 1:	91	51	81	50	80	40
HYV Zone 2:	72	48	62	47	60	35
LYV Zone 1:	41	40	33	33	40	35
LYV Zone 2:	27	26	21	20	25	20
LYV Zone 3:	21	20	15	14	20	15
Rainfed Barley:						
Zone 1:	92	98	81	95	75	45
Zone 2:	69	92	57	89	50	40
Zone 3:	57	89	45	87	40	35

1/ See Table 3.1 for the definitions of rainfall scenarios.

crops. These "biological" maxima are compared to the proposed rates on rainfed crops as shown in Table 5.4. The results show that none of the proposed rates would cause any yield decline in dry years. However, the results suggest that the proposed fertilizer rates on LYV wheat may lead to a decline in yield in the event of a very dry year.

It is clear from the above discussion that the proposed fertilizer rates are economically feasible for all crops included in this study. This is true for farmers and from the viewpoint of the economy as a whole. The above analysis has also shown that investments in the proposed fertilizer rates are relatively safe, even for rainfed crops. The only concern is about the riskiness of the proposed rates on LYV wheat, especially in Zone 3. This concern could be addressed by lowering the proposed N and/or P_2O_5 rates on LYV wheat. However, it was decided not to modify these proposed rates since, based on the experience of agronomists from the Soils Directorate, it was suspected that these rates may be already too low.

5.3.2 Sensitivity Analysis

The issue of risk associated with the proposed fertilizer rates was partially addressed in the above section. The requirement for minimum VCR values during dry and very dry years addresses some of the risk concerns associated with yield uncertainty of rainfed crops. Although yield variability due to rainfall fluctuations is the most important source of uncertainty, variability in fertilizer and output prices constitute another, though less important, source of uncertainty. In Syria, fertilizer prices and most crop prices are set by the government and they are announced at the beginning of the season.

Therefore, farmers face limited price uncertainty, which is not expected to affect our conclusions about the profitability of the proposed fertilizer rates.

However, price uncertainty is an important factor to consider in assessing the feasibility of the proposed fertilizer rates from the viewpoint of the economy as a whole. The economic prices of the crops and fertilizers included in this study are all based on international market prices. These prices are often characterized by a high degree of variability over time.

Fertilizer allocation decisions are usually made at the beginning of the season, based on international market prices prevailing at that time. However, the economic returns to the proposed fertilizer rates are obtained six to nine months later. During this lag period fertilizer and/or crop prices may change significantly. This would cast a certain degree of uncertainty on the economic feasibility of the proposed rates. Futures markets could be used to hedge against such price variability. The Cotton Marketing Organization (CMO) is the only Syrian government agency that regularly monitors changes in agricultural commodity prices in international spot and futures markets. However, the CMO has no experience in futures contracts and relies on futures prices only as indicators of price trends.

Therefore, a sensitivity analysis is needed to assess the impact of possible changes in fertilizer and crop prices on the estimated economic VCR values for the proposed fertilizer rates. The magnitude of the variability in international market prices can be measured by calculating the coefficient of variation (CV) over a given period of time. Table 5.5 shows the estimated CV's for international market

Table 5.5: COEFFICIENT OF VARIATION IN INTERNATIONAL FERTILIZER AND CROP PRICES

Commodity	Coefficient of Variation (%)
Urea (1975-1985)	21
Triple Superphosphate (TSP) (1975-1985)	24
Wheat (1970-1989)	34
Barley (1970-1989)	38
Cotton Lint (1970-1989)	36
Corn (1970-1989)	32
Raw Sugar (1970-1989)	73
Potatoes (1970-1989)	40

Sources: International fertilizer prices from Lele, Christiansen, and Kadiresan, 1989, p. 41. International crop prices from FAO Production Yearbook, various years.

prices of urea and Triple Superphosphate (TSP) between 1975 and 1985, and for crop prices between 1970 and 1989. As can be noted from Table 5.5, the CV's for urea and TSP prices range from 20% to 25%, while those for crop prices range from 30% to 40%, except for sugar prices, with a CV of 73%.

Since the CV is equal to the standard deviation divided by the mean, it is then possible to compute for each proposed N-P combination a range of VCR values associated with either one or two standard deviations of mean fertilizer or crop prices. Assuming a normal distribution for international market prices, probability statements can be made based on the "empirical rule", which states (Hoshmand, 1988, p. 110):

> For a symmetrical, bell-shaped frequency distribution (normal distribution), approximately 68% of the observations will fall within one standard deviation of the mean; about 95% of the observations will fall within two standard deviations of the mean; and practically all (99.7%) will fall within three standard deviations of the mean.

To simplify the sensitivity analysis, the above coefficients of variation are rounded to 25% for fertilizer prices, 70% for sugar prices, and 35% for the other crop prices. Accordingly, the range of VCR values obtained for a 25% increase or decrease in fertilizer prices would represent approximately 68% of all possible VCR values associated with price variations. If fertilizer prices increase or decrease by 50%, the resulting range of VCR values would correspond to about 95% of all possible VCR values. Similarly, a 35% increase or decrease in international crop prices (except for sugar) would give a VCR range corresponding to about 68% of all possible VCR values associated with variation in crop prices. The range of VCR values obtained for a 70% increase or decrease in crop prices would represent approximately 95% of all possible VCR values (68% for sugar prices).

The sensitivity analysis also takes into consideration the combined variability in yields and prices. Thus, for rainfed crops, VCR calculations for changes in fertilizer or crop prices are computed under the various rainfall scenarios. However, it should be noted that the sensitivity analysis does not address simultaneous changes in fertilizer and crop prices. Thus, the analysis would not cover the extreme scenarios of a combination of higher crop prices and lower fertilizer prices, or higher fertilizer prices and lower crop prices. Given that there is no empirical evidence to suggest that international fertilizer and crop prices are negatively or positively correlated, the exclusion of these extreme scenarios is not expected to significantly affect the results.

The above ranges of VCR values associated with the proposed fertilizer rates were computed for all the crops included in this study.

The results in Table 5.6 clearly suggest that the variability in international fertilizer prices would not significantly affect the economic feasibility of the proposed fertilizer rates. Even with a 50% increase in fertilizer prices the economic VCR would remain above the 1.0 limit, except for LYV wheat in very dry years. Therefore, the probability that a change in international fertilizer prices would make the proposed rates economically unfeasible is less than 2.5% (looking only at the lower tail of the distribution).

On the other hand, given the relatively higher CV's of international crop prices, the variability of these prices would have a greater impact on the economic feasibility of the proposed rates. This is shown in Table 5.6, where the results suggest that a 35% decline in wheat, barley, and corn prices would not affect the profitability of the proposed rates. Therefore, the probability that changes in international crop prices would make the proposed rates economically unfeasible is approximately 16% (looking only at the lower tail of the distribution). Only in the case of changes in the international prices of cotton and potatoes that this probability would decline to less than 2.5%.

Therefore, it is possible to conclude from the above sensitivity analysis that risk due to variability in international prices, would have a very limited impact on the economic feasibility of the proposed fertilizer recommendations. This is particularly true for changes in the international market prices of fertilizers, cotton, and potatoes.

Table 5.6: ESTIMATED RANGE OF ECONOMIC VALUE-COST-RATIOS OF PROPOSED FERTILIZER RATES DUE TO CHANGES IN INTERNATIONAL FERTILIZER AND CROP PRICES

Crop:	Mean VCR	Range of Economic VCR: Due to Changes in Fertilizer Prices ∓ 25 %	Due to Changes in Fertilizer Prices ∓ 50 %	Due to Changes in Crop Prices ∓ 35 %	Due to Changes in Crop Prices ∓ 70%
Irrigated Wheat:	3.7	2.9-4.9	2.4-7.3	2.4-5.0	1.1-6.2
Rainfed Wheat:					
- HYV Zone 1:					
Good:	3.4	2.7-4.5	2.3-6.8	2.2-4.6	1.0-5.8
Normal:	2.8	2.2-3.7	1.8-5.5	1.8-3.7	0.8-4.7
Dry:	2.5	2.0-3.4	1.7-5.1	1.7-3.4	0.8-4.3
Very Dry:	2.2	1.8-3.0	1.5-4.5	1.5-3.0	0.7-3.8
- HYV Zone 2:					
Good:	2.7	2.2-3.6	1.8-5.4	1.8-3.7	0.8-4.6
Normal:	2.4	1.9-3.2	1.6-4.9	1.6-3.3	0.7-4.1
Dry:	2.2	1.8-2.9	1.5-4.4	1.4-3.0	0.7-3.8
Very Dry:	1.9	1.5-2.6	1.3-3.8	1.2-2.6	0.6-3.3
- LYV Zone 1:					
Good:	4.9	3.9-6.5	3.2-9.7	3.2-6.5	1.5-8.3
Normal:	3.4	2.7-4.5	2.3-6.8	2.2-4.6	1.0-5.8
Dry:	2.7	2.2-3.6	1.8-5.4	1.8-3.7	0.8-4.6
Very Dry:	2.0	1.6-2.6	1.3-3.9	1.3-2.6	0.6-3.3
- LYV Zone 2:					
Good:	3.3	2.7-4.4	2.2-6.6	2.2-4.5	1.0-5.6
Normal:	2.6	2.1-3.5	1.8-5.3	1.7-3.6	0.8-4.5
Dry:	2.0	1.6-2.7	1.3-4.0	1.3-2.7	0.6-3.4
Very Dry:	1.2	1.0-1.7	0.8-2.5	0.8-1.7	0.4-2.1
- LYV Zone 3:					
Good:	2.9	2.3-3.9	2.0-5.9	1.9-4.0	0.9-5.0
Normal:	2.3	1.8-3.0	1.5-4.5	1.5-3.0	0.7-3.8
Dry:	1.6	1.3-2.1	1.1-3.2	1.0-2.1	0.5-2.7
Very Dry:	0.8	0.7-1.1	0.6-1.7	0.5-1.1	0.3-1.4

(Continued)

Table 5.6 (Cont'd.).

Crop:	Mean VCR	Range of Economic VCR: Due to Changes in Fertilizer Prices ∓ 25 %	∓ 50 %	Due to Changes in Crop Prices ∓ 35 %	∓ 70%
Barley:					
- Zone 1:					
Good:	2.5	2.0-3.4	1.7-5.0	1.6-3.4	0.8-4.3
Normal:	3.1	2.5-4.2	2.1-6.3	2.0-4.2	0.9-5.4
Dry:	2.9	2.3-3.9	1.9-5.8	1.5-3.9	0.9-5.0
Very Dry:	2.4	1.9-3.2	1.6-4.8	1.2-3.2	0.7-4.1
- Zone 2:					
Good:	1.8	1.4-2.4	1.2-3.5	1.1-2.4	0.5-2.7
Normal:	2.5	2.0-3.3	1.7-5.0	1.6-3.4	0.7-3.7
Dry:	2.3	1.8-3.0	1.5-4.5	1.5-3.1	0.7-3.4
Very Dry:	1.8	1.4-2.4	1.2-3.6	1.2-2.4	0.5-2.6
- Zone 3:					
Good:	1.6	1.3-2.1	1.0-3.2	1.0-2.1	0.5-2.7
Normal:	2.2	1.8-2.9	1.5-4.4	1.4-3.0	0.7-3.7
Dry:	2.0	1.6-2.6	1.3-3.9	1.3-2.7	0.6-3.4
Very Dry:	1.5	1.2-2.0	1.0-3.1	1.0-2.1	0.5-2.6
Cotton:	4.0	3.2-5.3	2.6-7.9	2.6-5.4	1.2-6.8
Corn:	2.6	2.1-3.5	1.7-5.2	1.7-3.5	0.8-4.5
Sugar Beets:					
Fall:	3.4	2.7-4.5	2.3-6.8	2.2-4.6	1.0-5.8
Summer:	3.4	2.7-4.5	2.3-6.8	2.2-4.6	1.0-5.8
Potatoes:					
Fall:	4.1	3.3-5.4	2.7-8.2	2.7-5.5	1.2-6.9
Summer:	3.9	3.1-5.2	2.6-7.8	2.5-5.3	1.2-6.6

1/ See Table 3.1 for the definitions of rainfall scenarios.

5.4 Financial vs Economic Optimum Fertilizer Rates

As mentioned earlier, the proposed fertilizer recommendations were based on the estimated economic optimum rates, i.e., the rates computed based on economic prices. The underlying assumption for this approach is the objective of achieving an economically efficient allocation of resources, from the viewpoint of the economy as a whole. However, the final decision on fertilizer allocation is a political decision that may be subject to influences from many potential interest groups, particularly farmers.

Therefore, if the above objective is modified to maximize farmers' income, then fertilizer recommendations would have to be based on the financial optima. Thus, the objective of this section is to compare the economic impact of these financial optima with the proposed rates based on economic optimum rates. This comparison would provide estimates of the potential costs to the economy, should the government decide that the objective of fertilizer policy is to maximize farmers' income.

As can be noted from Table 5.2, the estimated financial optimum fertilizer rates are, on the average, 5 kg/ha higher than the economic optima. The only exception is P_2O_5 rates on barley, where the differences are more significant, amounting to 20 kg/ha. The financial optima represent, by definition, the rates that would maximize farmers' net returns from fertilizer use. In other words, these rates are based on equating the farmer's marginal costs and marginal revenues. However, this does not necessarily imply that these financial optima would satisfy the minimum rate of return and the risk concerns of farmers.

To address these concerns, the financial VCR values associated with the economic and financial optima are compared in Table 5.7. This

Table 5.7: FINANCIAL VALUE-COST-RATIOS OF FERTILIZER USE BASED ON ECONOMIC AND FINANCIAL OPTIMUM RATES
Syria, 1989/1990.

	Financial VCR based on Economic Optimum Rates				Financial VCR based on Financial Optimum Rates			
Crop:	Good	Normal	Dry	V. Dry	Good	Normal	Dry	V. Dry
Irrigated Wheat:		5.6				5.4		
Rainfed Wheat:								
HYV Zone 1:	4.9	4.2	4.2	3.8	4.6	3.9	3.8	3.4
HYV Zone 2:	3.9	3.8	3.7	3.3	3.7	3.5	3.4	3.1
LYV Zone 1:	7.6	5.6	4.9	3.7	6.9	4.9	4.1	2.9
LYV Zone 2:	5.2	4.4	3.6	2.4	4.7	3.9	3.0	1.7
LYV Zone 3:	4.6	3.8	2.9	1.6	4.1	3.2	2.2	0.9
Rainfed Barley:								
Zone 1:	4.9	4.3	4.6	4.2	4.3	3.8	4.1	3.7
Zone 2:	3.5	3.5	3.6	3.2	3.0	3.1	3.2	2.8
Zone 3:	3.1	3.1	3.2	2.8	2.7	2.7	2.8	2.5
Cotton:		5.2				5.0		
Corn:		4.3				4.2		
Sugar Beets:								
Fall:		4.2				4.1		
Summer:		4.2				4.1		
Potatoes:								
Fall:		5.4				5.3		
Summer:		5.2				5.1		

1/ See Table 3.1 for the definitions of rainfall scenarios.

comparison shows that the VCR values for the financial optimum rates would be slightly lower than those associated with the economic optima. Nevertheless, the financial optimum rates would have VCR values above the 1.5 limit for all crops, except for LYV wheat in Zone 3 with a VCR of 0.9. Therefore, the financial optimum fertilizer rates would represent profitable and relatively safe investments for farmers. The only exception is the rates on LYV wheat in Zone 3, which may be too risky given the possible financial losses in very dry years.

5.4.1 Impact of Economic and Financial Optimum Rates on Aggregate Crop Production

Another reason policy-makers may want to base fertilizer recommendations on financial instead of economic optima is the current policy objective of reducing food imports and increasing agricultural exports. In Syria, wheat imports represent the most important food import item, with 1.5 million tons imported in 1989 (Arab Agriculture, 1990, p. 70). Cotton, on the other hand, represents the major source of agricultural export earnings, with 85 thousand tons of lint cotton exported in 1988/89 (Jaber, 1989, p. 192). Thus, policy makers may favor the higher financial optimum fertilizer rates in the hope of reducing wheat imports and increasing cotton exports.

To estimate the impact of the economic and financial optimum rates on aggregate crop production in Syria, yield estimates are made based on the production functions presented in Table 5.1. These yield estimates are computed by solving the production equation for the calculated economic and financial optimum N and P_2O_5 values. It should be noted that, throughout this analysis, the impact of fertilizer application will be measured in terms of the increase in yield over the unfertilized treatment. This is done by basing the analysis on the difference between the estimated yield and the intercept term in the production functions. The main reason for this approach is to minimize the potential bias in the results caused by what is often referred to as the yield gap. This refers to the commonly observed large differences between yield estimates based on experimental data and actual yields obtained by farmers (see, for example, ICARDA/FRMP, 1988, pp. 143-150).

To estimate the impact of fertilizer application on aggregate crop production, the increase in yield due to fertilizer use is multiplied by the total fertilized area planted to each crop. Based on discussions with agronomists from the Soils Directorate, it is estimated that all areas planted to irrigated crops and to HYV wheat are currently fertilized. In contrast, it is estimated the percentage of total LYV wheat area fertilized is approximately 90% in Zone 1, 70% in Zone 2, and 50% in Zone 3. The corresponding figures for barley are 50% in Zone 1, 40% in Zone 2, and 30% in Zone 3. The estimated percentages for barley probably overestimate the current fertilizer use by barley farmers. However, it is assumed that if barley farmers had a greater access to fertilizer, then more farmers would start applying fertilizer on barley. Thus, the above percentages for barley should be viewed as realistic targets rather than figures representing current fertilization practices.

As shown in Table 5.8, the financial optimum fertilizer rates on wheat would result in an additional 28 thousand tons in total wheat output in a normal year, as compared to the lower economic optimum rates. This increase in wheat production would represent approximately

Table 5.8: IMPACT OF ECONOMIC AND FINANCIAL OPTIMUM FERTILIZER RATES ON AGGREGATE CROP PRODUCTION
Syria, 1989/1990

Crop:	Aggregate Production Increase[1] in a Normal Year ('000 tons) Economic Optima	Financial Optima	Net Change
Irrigated Wheat:	482	488	6
Rainfed HYV Wheat Zone 1:	237	245	8
Rainfed HYV Wheat Zone 2:	104	108	4
Rainfed LYV Wheat Zone 1:	67	69	2
Rainfed LYV Wheat Zone 2:	93	100	7
Rainfed LYV Wheat Zone 3:	14	16	2
TOTAL WHEAT	997	1025	28
Rainfed Barley Zone 1:	25	27	2
Rainfed Barley Zone 2:	183	205	22
Rainfed Barley Zone 3:	92	107	15
TOTAL RAINFED BARLEY	300	339	39
Cotton:	284	287	3
Corn:	118	119	1
Fall Sugar beets:	257	258	1
Summer Sugar beets:	228	229	1
Fall Potatoes:	52	52	0
Spring and Summer Potatoes:	39	39	0

1/ Increase over the unfertilized treatment.

1.1% increase over the current average wheat output of 2.5 million tons. Similarly, in comparison to the economic optimum fertilizer rates, the financial optima would lead to an increase of 39 thousand tons in aggregate barley production in a normal year. This additional barley output would represent an extra 3.5% in total barley production over the current average level of 1.1 million tons. The results in Table 5.8 also indicate that the difference in the impact of the economic and financial optima on the aggregate output of cotton, corn, sugar beets, and potatoes, is very limited. Cotton production would increase by only 3000 tons (0.6% increase), sugar beets by 2000 tons (0.2% increase), corn by 1000 tons (0.9% increase), and no change in potato production.

Therefore, the use of the higher fertilizer rates implied by the financial optima, instead of the economic optima, would increase aggregate crop output, particularly barley and wheat. However, this increase in production would be relatively small, leading to a slight reduction in food imports and an insignificant increase in exports. However, this increase in aggregate output would be accompanied by an increase in fertilizer use and, thus, in fertilizer imports.

5.4.2 Impact of Economic and Financial Optimum Fertilizer Rates on National Income

If fertilizer recommendations were based on financial optima instead of economic optima, aggregate N requirements for the crops in this study would increase by 7% and P_2O_5 requirements would increase by 18% (see Table 5.9). These additional fertilizer requirements would necessitate an extra 600 million SL worth of fertilizer imports, representing a 12% increase in total fertilizer costs. The value of the

Table 5.9: AGGREGATE ECONOMIC IMPACT OF ECONOMIC AND FINANCIAL OPTIMUM FERTILIZER RATES
Syria, 1989/1990

	Economic Optima	Financial Optima	Net Change
Fertilizer Requirements:			
N (tons):	163,691	175,102	11,411
P_2O_5 (tons):	96,977	114,007	17,030
	ECONOMIC PRICES (Million SL)		
Fertilizer Costs:	5,075	5,675	600
Gross Returns:			
- Good Year:	16,622	17,235	613
- Normal Year:	16,255	16,784	529
- Dry Year:	15,708	16,112	404
- Very Dry Year:	14,771	15,017	246
Net Returns:			
- Good Year:	11,547	11,560	13
- Normal Year:	11,180	11,109	-71
- Dry Year:	10,633	10,437	-196
- Very Dry Year:	9,696	9,342	-354
	FINANCIAL PRICES (Million SL)		
Fertilizer Costs:	3,222	3,578	356
Gross Returns:			
- Good Year:	15,399	16,021	622
- Normal Year:	14,983	15,474	491
- Dry Year:	15,214	15,617	403
- Very Dry Year:	14,700	14,951	251
Net Returns:			
- Good Year:	12,177	12,443	266
- Normal Year:	11,761	11,896	135
- Dry Year:	11,992	12,039	47
- Very Dry Year:	11,478	11,373	-105

1/ See Table 3.1 for the definitions of rainfall scenarios.

additional crop output would be equal to 529 million SL in a normal year. Therefore, the use of financial instead of economic optimum fertilizer rates would result in a net loss in national income, or "dead-weight loss", amounting to 71 million SL in normal years and up to 354 million SL in very dry years.

5.4.3 Impact of Economic and Financial Optimum Fertilizer Rates on Farm Income

The results in Table 5.9 also show the impact of the economic and financial optimum fertilizer rates on farm income. The additional fertilizer use implied by the financial optima would cost farmers an additional 356 million SL. These additional expenditures would result in an increase in the value of crop production amounting to 491 million SL in normal years. Therefore, in a normal year, farm income would increase by 135 million SL, with a range of 47 million SL in dry years to 266 million SL in good years.

In the event of a very dry year, however, the net returns from using the financial optimum fertilizer rates would be 105 million SL below those obtained by applying the lower economic optimum rates. Thus, although the financial optima would increase farm income, the variability in farm income would also increase. This is shown in Table 5.9, where financial net returns from fertilizer use based on the financial optimum rates would vary from 11,373 million SL in very dry years to 12,443 million SL in good years, i.e., a range of 1070 million SL. If we divide this range by net returns in a normal year (11,896 million SL), this gives a ratio of 0.09. This ratio can be used as a proxy for measuring variability in net returns to fertilizer use.

In comparison, financial net returns based on the economic optima would vary from 11,478 million SL in very dry years to 12,177 million SL in good years, i.e., a range of 699 million SL. Dividing this range by net returns in normal years (11,761 million SL) would give a ratio of 0.06. Thus, the variability in net returns to fertilizer use would increase by about 50% (from 6% to 9%) if the financial optima were used as a basis for fertilizer recommendations instead of the economic optima.

5.4.4 Impact of Economic and Financial Optimum Fertilizer Rates on Foreign Exchange Earnings

The higher fertilizer use associated with the financial optimum rates implies 12 million $US more in fertilizer import expenditures than the economic optimum rates (see Table 5.10). These additional expenditures would increase the value of net crop exports by 3 to 8 million $US. Therefore, if financial optima are used instead of the proposed economic optima, net foreign exchange earnings would decline by an amount ranging from 4 million $US in good years to 9 million $US in very dry years.

5.4.5 Impact of Economic and Financial Optimum Fertilizer Rates on the Government Budget

Finally, the increase in fertilizer use associated with the application of the financial optimum rates would result in an increase in government expenditures on subsidies. As shown in Table 5.11, these expenditures would be 258 million SL higher than those associated with the use of economic optima. The corresponding increase in revenues from indirect taxes on crops would amount to 38 million SL in a normal year.

Table 5.10: IMPACT OF ECONOMIC AND FINANCIAL OPTIMUM FERTILIZER RATES ON FOREIGN EXCHANGE EARNINGS
Syria, 1989/1990

	Economic Optima	Financial Optima	Net Change
		(Million $US)	
Import Value of Fertilizer:	104	116	12
Value of Increased Crop Exports and Reduced Imports[1]:			
- Good Year:	301	309	8
- Normal Year:	289	296	7
- Dry Year:	254	258	4
- Very Dry Year:	244	247	3
Net Increase[1] in Foreign Exchange Earnings:			
- Good Year:	197	193	-4
- Normal Year:	186	180	-6
- Dry Year:	150	142	-8
- Very Dry Year:	140	131	-9

1/ Relative to no fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.

Table 5.11: IMPACT OF ECONOMIC AND FINANCIAL OPTIMUM FERTILIZER RATES ON THE GOVERNMENT BUDGET
Syria, 1989/1990

	Economic Optima	Financial Optima	Net Change
		(Million SL)	
Expenditures on Fertilizer Subsidies:	1,986	2,244	258
Increase[1] in Revenues from Indirect Taxes on Crops:			
- Good Year:	1,113	1,111	-2
- Normal Year:	1,431	1,469	38
- Dry Year:	1,265	1,290	25
- Very Dry Year:	1,212	1,231	19
Net Increase[1] in Government Expenditures:			
- Good Year:	873	1,133	260
- Normal Year:	555	775	220
- Dry Year:	721	954	233
- Very Dry Year:	774	1,013	239

1/ Increase due to fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.

Table 5.11: IMPACT OF ECONOMIC AND FINANCIAL OPTIMUM FERTILIZER RATES ON THE GOVERNMENT BUDGET
Syria, 1989/1990

	Economic Optima	Financial Optima	Net Change
		(Million SL)	
Expenditures on Fertilizer Subsidies:	1,986	2,244	258
Increase[1] in Revenues from Indirect Taxes on Crops:			
- Good Year:	1,113	1,111	-2
- Normal Year:	1,431	1,469	38
- Dry Year:	1,265	1,290	25
- Very Dry Year:	1,212	1,231	19
Net Increase[1] in Government Expenditures:			
- Good Year:	873	1,133	260
- Normal Year:	555	775	220
- Dry Year:	721	954	233
- Very Dry Year:	774	1,013	239

1/ Increase due to fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.

Therefore, if fertilizer recommendations were to be based on financial instead of economic optima, government expenditures would increase by an amount ranging from 220 million SL to 260 million SL.

5.4.6 Financial vs Economic Optima: Summary

In summary, if policy makers were to decide to base fertilizer recommendations on financial instead of economic optimum rates, the main effect of such a decision would be a net income transfer from the government budget (the foreign exchange budget in particular) to farmers. In a normal year, net government expenditures would increase by 220 million SL (see Table 5.11) resulting in 135 million SL increase in farm income (i.e, increase in financial net returns in a normal year; see Table 5.9). The 85 million SL difference between these two figures would be partially accounted for by the 71 million SL in dead-weight loss (i.e., decline in economic net returns in a normal year; see Table 5.9). The remaining 14 million SL would represent income transfers from the government to other sectors of the economy, particularly fertilizer and crop traders in the parallel market.

Thus, if income redistribution in favor of farmers is considered an important policy objective, then other income distribution strategies based on direct income transfers to farmers might be more economically efficient. Moreover, the 12 million $US in additional fertilizer imports, because of the higher financial optimum fertilizer rates, would offset any gains from the slightly lower barley and wheat imports and the minor increase in cotton exports. The net effect would be a decline in foreign exchange earnings by 6 million $US in a normal year (see Table 5.10). Therefore, basing fertilizer recommendations on the economic instead of the financial optima would be the most economically rational approach. This is especially true under the current situation of chronic fertilizer shortages, limited foreign exchange resources, and government budget deficits.

5.5 Current vs Proposed Fertilizer Recommendations

In this section, the impact of the proposed fertilizer recommendations, based on economic optima, is compared to that of the current rates recommended by the Soils Directorate. This is done in order to estimate the impact of the shift from the current to the proposed recommendations on yields and aggregate crop production, national and farm incomes, and the government's foreign exchange and general budgets.

5.5.1 Impact of Current and Proposed Fertilizer Rates on Aggregate Crop Production

The current and proposed fertilizer rates on the crops covered by this study were presented in Table 5.2. Fertilizer rates that would maximize yield, or biological maximum rates, are also included in Table 5.2. A closer look at the current recommended rates on wheat indicates that all P_2O_5 rates and most N rates exceed the corresponding biological maximum rates. In other words, given the quadratic formulation of the production functions, the application of the current rates on wheat may result in a yield decline (Phase III of the production function).

This may be an accurate representation of actual yield responses to excessive levels of nitrogen. However, in the case of phosphorus, rates that are higher than the maximum level would rarely cause a decline in yield. The most commonly observed yield response to excess P_2O_5 is that of a plateau maximum, with yield declines only because of extremely high P_2O_5 applications (Lanzer, Paris, and Williams, 1987, p. 2). Such a response would have been more appropriately modeled using other functional forms, such as the Mitscherlich function or the linear response and plateau (LRP) function proposed by Cate and Nelson (1971).

Therefore, in assessing the impact of the current fertilizer rates on wheat output, it is more realistic to ignore the possibility of yield depression and to assume that a yield plateau would be obtained whenever these rates exceed the biological maximum rates. Based on this assumption, the increase in aggregate wheat output as a result of applying the current fertilizer rates would amount to 1045 thousand tons in a normal year (Table 5.12). In comparison, the proposed fertilizer rates on wheat would result in 997 thousand tons of additional wheat output. Thus, compared to the current rates, the proposed fertilizer rates on wheat would lead to a decline in aggregate wheat output in a normal year by about 48 thousand tons. This is equivalent to an average 3% increase in current wheat import levels.

The results in Table 5.12 also indicate that increasing the current fertilizer rates on barley would result in a net increase of 57 thousand tons. This is equivalent to an increase of about 5% in total barley output in a normal year. Approximately two-thirds of this additional barley output would originate in Zone 3, where the proposed rates are almost twice as large as the current ones.

In the case of cotton, the proposed fertilizer rates imply an increase in the current N rate and a reduction in the rate of P_2O_5. The

Table 5.12: IMPACT OF CURRENT AND PROPOSED FERTILIZER RATES ON AGGREGATE CROP PRODUCTION
Syria, 1989/1990

Crop:	Aggregate Production Increase[1] in a Normal Year ('000 tons)		
	Proposed Rates	Current Rates	Net Change
Irrigated Wheat:	482	494	-12
Rainfed HYV Wheat Zone 1:	237	249	-12
Rainfed HYV Wheat Zone 2:	104	113	-9
Rainfed LYV Wheat Zone 1:	67	70	-3
Rainfed LYV Wheat Zone 2:	93	103	-10
Rainfed LYV Wheat Zone 3:	14	16	-2
TOTAL WHEAT	997	1045	-48
Rainfed Barley Zone 1:	25	20	5
Rainfed Barley Zone 2:	183	167	16
Rainfed Barley Zone 3:	92	56	36
TOTAL RAINFED BARLEY	300	243	57
Cotton:	284	278	6
Corn:	118	116	2
Fall Sugar beets:	257	253	4
Summer Sugar beets:	228	226	2
Fall Potatoes:	52	51	1
Spring and Summer Potatoes:	39	36	3

1/ Increase over the unfertilized treatment.

net impact of these adjustments in cotton rates would be an increase of 6,000 tons in total cotton output, which represents about 1.2% of aggregate cotton production in Syria. Similarly, increasing the current N rate for corn would increase production by 2000 tons, or about 1.8% increase in total output. As for sugar beets, an increase in the current N rates would result in 6,000 tons of additional output, representing about 0.6% increase in total production. Finally, increasing the current N rates for potatoes would increase output by 4,000 tons, an increase of about 1% in total production.

5.5.2 Impact of Current and Proposed Rates on National Income

The above results clearly indicate that the shift from the current to the proposed fertilizer rates would have a somewhat limited impact on aggregate crop production. However, the most significant impact would be in the substantial reduction in aggregate fertilizer requirements. As shown in Table 5.13, most of this reduction would come from the drastic decline in fertilizer use on wheat. Total N use on wheat would decline by 30 thousand tons, while P_2O_5 use would decline by 42 thousand tons. A further decline of 5.2 thousand tons in P_2O_5 use on cotton would bring the total reduction in P_2O_5 use to 47 thousand tons. These drastic declines are offset somewhat by the increase in N and P_2O_5 use on barley and N use on cotton, besides the minor increases in N use on corn, sugar beets, and potatoes.

Therefore, the shift from the current to the proposed fertilizer rates would result in a net reduction in total fertilizer use by approximately 17 thousand tons of N and 45 thousand tons of P_2O_5. This would represent a 10% decline in total N requirements for the crops

Table 5.13: AGGREGATE FERTILIZER REQUIREMENTS BASED ON CURRENT AND PROPOSED RATES
Syria, 1989/1990

Crop:	Aggregate Fertilizer Requirements (tons)					
	Proposed Rates		Current Rates		Net Change	
	N	P_2O_5	N	P_2O_5	N	P_2O_5
Irrigated Wheat:	36156	17408	40173	26782	-4017	-9374
Rainfed Wheat:						
HYV Zone 1:	23148	11574	28935	23148	-5787	-11574
HYV Zone 2:	10832	6319	14443	10832	-3611	-4513
LYV Zone 1:	4451	3895	8903	6677	-4452	-2782
LYV Zone 2:	7957	6366	19098	19098	-11141	-12732
LYV Zone 3:	1480	1110	2220	2220	-740	-1110
TOTAL WHEAT:	84024	46672	113772	88757	-29748	-42085
Rainfed Barley:						
Zone 1:	1604	963	1069	856	535	107
Zone 2:	12937	10349	10349	10349	2588	0
Zone 3:	6962	6092	3481	3481	3481	2611
TOTAL BARLEY:	21503	17404	14899	14686	6604	2718
Cotton:	39150	20880	34800	26100	4350	-5220
Corn:	9050	5569	8354	5569	696	0
Sugar Beets:						
Fall:	3305	1844	3074	1844	231	0
Summer:	2780	1756	2633	1756	147	0
Potatoes:						
Fall:	2210	1560	1950	1560	260	0
Summer:	1669	1292	1292	1292	377	0
GRAND TOTAL	163691	96977	180775	141564	17084	44587

Table 5.14: AGGREGATE ECONOMIC IMPACT OF PROPOSED AND CURRENT FERTILIZER RATES
Syria, 1989/1990

	Proposed Rates	Current Rates	Net Change
	ECONOMIC PRICES (Million SL)		
Fertilizer Costs:	5,075	6,431	-1356
Gross Returns:			
- Good Year:	16,622	16,917	-295
- Normal Year:	16,255	16,139	116
- Dry Year:	15,708	15,420	288
- Very Dry Year:	14,771	14,327	444
Net Returns:			
- Good Year:	11,547	10,487	1060
- Normal Year:	11,180	9,709	1471
- Dry Year:	10,633	8,990	1643
- Very Dry Year:	9,696	7,896	1800
	FINANCIAL PRICES (Million SL)		
Fertilizer Costs:	3,222	3,999	-777
Gross Returns:			
- Good Year:	15,399	15,610	-211
- Normal Year:	14,983	14,931	52
- Dry Year:	15,214	14,953	261
- Very Dry Year:	14,700	14,226	474
Net Returns:			
- Good Year:	12,177	11,611	566
- Normal Year:	11,761	10,932	829
- Dry Year:	11,992	10,953	1039
- Very Dry Year:	11,478	10,226	1252

1/ See Table 3.1 for the definitions of rainfall scenarios.

included in this study and a 46% reduction in P_2O_5 requirements. These drastic reductions would decrease aggregate fertilizer costs by 1356 million SL, which would constitute a potential 27% savings in total fertilizer costs (Table 5.14). These savings in fertilizer costs are the net result of the following: (1) reduced N and P_2O_5 use on wheat by 1509 million SL; reduced P_2O_5 use on cotton by 125 million SL; (2) increased N and P_2O_5 use on barley by 176 million SL; and (3) increased N use on cotton, corn, sugar beet, and potatoes by 102 million SL.

As discussed earlier, the shift from the current to the proposed recommendations would result in minor reductions in wheat output but would slightly increase the production of other crops, particularly barley. The net effect of these changes in production would be an increase in the economic value of aggregate output by 116 million SL in normal years (Table 5.14). However, in good years, the shift to the proposed rates would lead to a 295 million SL decline in the economic value of aggregate output. Thus, by adding the savings in fertilizer costs to the changes in the value of output, the net impact of the shift to the proposed rates on the GDP would be equal to 1.5 billion SL in a normal year. This is equivalent to an average increase of 2.6% in the agricultural GDP, estimated at 56.9 billion SL in 1988 (Al-Akhrass, 1990, p. 6).

5.5.3 Impact of Current and Proposed Rates on Farm Income

The results in Table 5.14 also show the impact of the shift from the current to the proposed fertilizer rates on aggregate farm income (i.e., costs and returns based on financial prices). As noted earlier, the main impact of this shift would be the significant reduction in aggregate fertilizer use. This would translate into a 777 million SL decline in farmers' fertilizer costs. In a good year, this shift to the proposed rates would reduce the value of aggregate farm output by 211 million SL. However, in normal and dry years, the value of aggregate farm output would increase by an amount ranging from 52 million SL in normal years to 474 million SL in very dry years. Thus, in a normal year, the net impact of the shift from the current to the proposed fertilizer rates would be an increase of 829 million SL in aggregate farm income.

In addition to increasing farm income the shift to the proposed rates also would reduce the variability in farm income. As shown in Table 5.14, financial net returns from fertilizer use based on the current rates would vary from 10,226 million SL in very dry years to 11,611 million SL in good years, i.e., a range of 1385 million SL. If this range is divided by net returns in a normal year (10,932 million SL), this gives a ratio of 0.13. As discussed earlier, the corresponding ratio for the financial net returns based on the proposed rates is equal to 0.06. Thus, the variability in financial net returns to fertilizer use would decline by more than half (from 13% to 6%) as a result of shifting fertilizer recommendations from the current to the proposed rates.

5.5.4 Impact of Current and Proposed Rates on Foreign Exchange Earnings

As mentioned earlier, the main impact of the shift from the current to the proposed rates would be the substantial decline in

Table 5.15: IMPACT OF PROPOSED AND CURRENT FERTILIZER RATES ON FOREIGN EXCHANGE EARNINGS
Syria, 1989/1990

	Proposed Rates	Current Rates	Net Change
		(Million $US)	
Import Value of Fertilizer:	104	131	27
Value of Increased Crop Exports and Reduced Imports[1]:			
- Good Year:	301	300	-1
- Normal Year:	289	286	-3
- Dry Year:	254	249	-5
- Very Dry Year:	244	239	-5
Net Increase[1] in Foreign Exchange Earnings:			
- Good Year:	197	169	-28
- Normal Year:	185	154	-31
- Dry Year:	150	118	-32
- Very Dry Year:	140	107	-33

1/ Relative to no fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.

aggregate fertilizer use. This decline would lead to 27 million $US in reduced fertilizer imports (see Table 5.15). Also, the shift to the proposed rates would result in a slight increase in the value of net crop exports (increased exports and reduced imports) ranging from one to five million $US. Therefore, the net impact of the shift from the current to the proposed rates would be an increase in foreign exchange earnings ranging from 28 to 33 million $US. This would represent an increase of about 16% in total foreign exchange reserves, which amounted to 191 million $US at the end of 1988 (International Financial Statistics, April 1991, p. 510).

5.5.5 Impact of Current and Proposed Rates on the Government Budget

The drastic reduction in fertilizer use as a result of the shift to the proposed rates would lead to an equally drastic reduction in fertilizer subsidies. As shown in Table 5.16, these subsidies would decline from 2,596 million SL under the current rates to 1,986 million SL under the proposed rates, a 24% decline in fertilizer subsidies. Also, government revenues from the indirect taxes on crops would slightly increase because of the shift to the proposed rates, except in good years.

Therefore, the net impact of the shift to the proposed rates would be a decline in government expenditures ranging from 636 million SL in very dry years to 642 million SL in normal years. In good years, this decline would be smaller (559 million SL) since indirect taxes on crops

Table 5.16: IMPACT OF PROPOSED AND CURRENT FERTILIZER RATES ON THE GOVERNMENT BUDGET
Syria, 1989/1990.

	Proposed Rates	Current Rates	Net Change	% Change
		(Million SL)		
Expenditures on Fertilizer Subsidies:	1,986	2,596	-610	-23.5
Increase[1] in Revenues from Indirect Taxes on Crops:				
- Good Year:	1,113	1,164	-51	-4.4
- Normal Year:	1,431	1,399	32	2.3
- Dry Year:	1,265	1,237	28	2.3
- Very Dry Year:	1,212	1,186	26	2.2
Net Increase[1] in Government Expenditures:				
- Good Year:	873	1,432	-559	-39.0
- Normal Year:	555	1,197	-642	-53.6
- Dry Year:	721	1,360	-639	-47.0
- Very Dry Year:	774	1,410	-636	-45.1

1/ Increase due to fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.

are usually lower than in normal and drier years[1]. These reductions in expenditures are equivalent to a decline of 39% to 54% in net government spendings associated with fertilizer use on the crops covered by this study. Also, these declines in expenditures would represent a reduction of approximately 1.7% in total government expenditures (excluding capital and military spendings), estimated at 35.7 billion SL in 1989 (Bouzo, 1990, p. 48).

5.5.6 Current vs Proposed Fertilizer Recommendations: Summary

In summary, the above analysis clearly indicates that the shift from the current to the proposed fertilizer recommendations would greatly enhance the economic efficiency of fertilizer use in Syria. Such a shift would increase the agricultural GDP by an average of 1.5 billion SL per year, or a 2.6% increase. This shift also would increase farmers' income by an average of 829 million SL, in addition to significantly reducing the variability in farm income.

The shift to the proposed fertilizer rates would substantially reduce aggregate fertilizer requirements, especially P_2O_5 requirements, which would decline by 46%. This would imply substantial declines in fertilizer imports and, thus, savings in foreign exchange amounting to 31 million $US, or a 16% increase in total foreign exchange reserves. Also, net government expenditures associated with fertilizer use would decline by an amount ranging from 559 to 642 million SL, which is equivalent to a 39% to 54% decline.

---

[1] In good years the export price is used as the basis for computing indirect taxes on barley. Since the official barley price is slightly higher than the export price, barley would be implicitly subsidized in good years (refer to the discussion in chapter 4).

The only potential disadvantage of the shift from the current to the proposed fertilizer rates is the decline in total wheat production. However, this decline would be somewhat limited, amounting to an average 2% decrease in total wheat output. Also, this reduction in wheat output would be offset by expected increases in aggregate output of other crops, particularly barley.

5.6 Chapter Summary

This chapter presented the main findings related to "ideal" fertilizer rates, i.e., the rates to be recommended if there were no constraints on fertilizer supplies. These rates were computed based on the estimated production functions and based on the true economic value of fertilizers and crops. The results have clearly shown that these proposed fertilizer recommendations would constitute profitable and reasonably safe investments for farmers and for the economy as a whole.

The analysis also examined the possibility of increasing the proposed fertilizer rates so as to maximize farmers' income from fertilizer use (i.e., optimum rates computed based on financial prices). Such an increase would result in limited increases in aggregate crop production, but the main effect would be a net income transfer from the government budget to farmers amounting to 136 million SL. This would cost the government an average of 220 million SL and would result in a net loss (dead-weight loss) of 71 million SL to the economy as a whole.

A comparison between the proposed and current fertilizer rates has indicated the need for some major readjustments in the current recommendations. Current fertilizer rates on wheat need to be substantially reduced, while barley rates need to be increased significantly. The differences between the proposed and current fertilizer recommendations for the other crops are close. The results indicate that the N rate on cotton should be increased, while the rate of P_2O_5 should be reduced. As for corn, sugar beets, and potatoes, N rates should be increased, whereas the current P_2O_5 rates are not modified since the production functions were estimated in terms of response to N only.

The shift from the current to the proposed fertilizer recommendations would greatly enhance the economic efficiency of fertilizer use in Syria. Such a shift would increase the agricultural GDP by an average of 1.5 billion SL and farmers' income by 829 million SL. This is mainly due to substantial reductions in aggregate fertilizer requirements, which would reduce fertilizer imports by 27 million $US and fertilizer subsidies by 610 million SL. The only disadvantage of such a shift would be the somewhat limited decline (about 2%) in total wheat production. However, this reduction in wheat output would be offset by expected increases in aggregate output of other crops, particularly barley.

It should be noted that all the above estimates of the impact of the proposed fertilizer recommendations are hypothetical. In other words, these estimates would be relevant only under the ideal situation of unlimited fertilizer supplies. Despite this hypothetical nature of the analysis in this chapter, the results and conclusions could have some important practical implications.

Although fertilizer shortages have become a normal occurrence over the past few years, policy makers and government planners continue to treat fertilizer shortages as temporary aberrations. Thus, most planning aspects of fertilizer policy are still based on the hypothetical situation, or "base scenario", of unlimited fertilizer supplies. Depending on the magnitude of fertilizer shortages at the beginning of the season, government planners would then modify this base scenario by reducing some or all the recommended rates by a given percentage. However, if the recommended fertilizer rates in the base scenario are inaccurate, then fertilizer allocations computed by taking a given percentage of the recommended rates are also likely to be inaccurate and, thus, economically inefficient.

Also, the results and conclusions based on the above mentioned base scenario would provide policy makers and government planners with more accurate estimates of the potential impact of fertilizer use under ideal circumstances. These estimates would be particularly useful in providing more realistic targets in medium- and long-term planning of future fertilizer use in Syria.

CHAPTER 6

FERTILIZER ALLOCATION STRATEGIES UNDER LIMITED FERTILIZER SUPPLIES

The analysis in the previous chapter was based on the assumption that there exist sufficient fertilizer supplies to satisfy all the optimum fertilizer requirements calculated based on the rates that would maximize net economic returns. However, this is not the case since the actual quantities of fertilizer distributed to farmers have often been below the planned fertilizer requirements. This is due to technical and managerial problems facing domestic fertilizer production, and import restrictions because of increasing foreign exchange constraints facing Syria since the mid-1980's. Thus, the estimated differences in economic impact between the current and proposed fertilizer recommendations are hypothetical. The calculated increases in agricultural GDP, farm income, and foreign exchange earnings should be viewed as maximum potential gains. They would be attainable only if the government could ensure that all the estimated fertilizer requirements would be available to farmers.

The main objective of this chapter is to analyze the impact of the constraints on fertilizer supplies and to compare alternative fertilizer allocation strategies under varying levels of available supplies. Given the constrained optimization nature of the problem, most of the analyses in this chapter will be based on the fertilizer allocation linear programming (LP) model discussed in chapter 3.

This chapter starts with a brief overview of the fertilizer supply situation in Syria during the past few years. The next section addresses the issue of the accuracy of the LP model. This is done by comparing the results of the model under unlimited supplies with the unconstrained optimization solutions presented in chapter 5. This is followed by an analysis of the impact of limited fertilizer supplies on aggregate crop production, agricultural GDP, farm income, foreign exchange earnings, and government expenditures. The next section addresses the issue of fertilizer pricing and its potential role in strategies aimed at reducing the constraints on fertilizer supplies. This is followed by a comparison of alternative fertilizer allocation strategies for the winter season, under existing levels of limited fertilizer supplies. The chapter concludes with a summary of the main findings.

6.1 Constraints on Fertilizer Supplies

As mentioned above, the amount of fertilizer actually distributed to farmers has often been below planned requirements. These gaps between planned and actual fertilizer use have become more accentuated in recent years. As discussed in chapter 2, between 1984/85 and 1988/1989 the percentage of planned fertilizer requirements actually used declined steadily from 91% to 55% for N, and from 89% to 53% for P_2O_5 (refer to Table 2.9). It should be noted that this decline occurred in spite of a gradual increase in actual fertilizer use. Therefore, the increasing difference between planned and actual use is partly due to the rapid increase in planned requirements, especially in 1987/88 and 1988/89.

As discussed earlier, the reason for the large increases in planned requirements since 1987/88 is the change in the rules used by the Soils Directorate (SD) in estimating fertilizer requirements (refer to the discussion in chapter 2). Planned requirements based on this new rule assume that all areas planted to field crops are fertilized. However, this would overestimate total requirements given that significant areas of field crops, particularly barley, are not currently fertilized.

In this study, more realistic assumptions were made about the percentage of barley and wheat areas actually fertilized, based on which optimum fertilizer requirements were estimated (see chapter 5). Thus, for the crops included in this study, optimum requirements in 1989/90 were estimated at 164 thousand tons of N and 96 thousand tons of P_2O_5. When the requirements of fruit trees and other crops not included in this study are added, optimum requirements would amount to 245 thousand tons of N and 148 thousand tons of P_2O_5 (see Appendix B). Actual fertilizer use in 1988/89 was 161 thousand tons of N and 109 thousand tons of P_2O_5, or approximately 60% of optimum requirements (refer to Table 2.9).

In 1989/90, total fertilizer use declined to 154 thousand tons of N and 95 thousand tons of P_2O_5. Such a decline, however, could not be predicted at the beginning of the 1989/90 season, especially given the upward trend in fertilizer use during the preceding years. Therefore, in estimating fertilizer availability at the beginning of the 1989/90 season, it was assumed that the level of actual fertilizer use would be at least equal to that of 1988/89, i.e., around 60% of optimum requirements. This assumption will be the basis for most analyses presented in this chapter.

6.2 A Test of Accuracy of the Fertilizer Allocation Model

6.2.1 LP vs Calculus Solutions of the Unconstrained Problem

As discussed earlier, the fertilizer allocation model was developed based on separable programming (SP) techniques. SP approximates the curvilinear shape of the production functions by subdividing each function into several linear segments. Since SP is an approximation technique the results may differ from the true analytic solution that would be obtained if the problem was solved using calculus techniques.

Theoretically, the fertilizer allocation problem could be solved using constrained optimization calculus techniques. In practice, however, such techniques could be very difficult to use given the complexity and large number of variables included in the fertilizer allocation problem. SP provides a more feasible approach to solving this problem. Furthermore, this approach can closely approximate the calculus results if a reasonable number of segments are used to approximate the production functions.

One way to test the accuracy of the allocation LP model is to solve the model with the assumption of unlimited fertilizer supplies, and then compare the solution with that obtained by unconstrained optimization. This comparison is done using both economic and financial prices. As shown in Table 6.1 (compare the results in columns 1 and 3 for the economic optima, and in columns 2 and 4 for the financial

Table 6.1: OPTIMUM FERTILIZER RATES BASED ON CALCULUS AND LP SOLUTIONS.

	Unconstrained Calculus Solutions				Unconstrained LP Solutions				Constrained[2] LP Solution	
	Economic Prices		Financial Prices		Economic Prices		Financial Prices		Financial Prices	
Crop:	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Irrigated Wheat:	136	65	142	72	135	65	140	70	134	65
Rainfed Wheat:										
HYV Zone 1:	82	38	87	45	80	40	90	45	80	40
HYV Zone 2:	62	35	67	41	60	35	70	40	60	35
LYV Zone 1:	41	36	43	42	40	35	40	40	40	35
LYV Zone 2:	27	21	29	26	25	20	30	25	30	25
LYV Zone 3:	21	14	23	20	20	15	20	20	20	15
Rainfed Barley:										
Zone 1:	74	46	79	66	70	45	80	65	70	45
Zone 2:	51	40	55	60	50	40	60	65	50	40
Zone 3:	39	37	44	57	40	35	40	65	40	35
Cotton:	226	118	231	129	225	120	230	130	220	112
Corn:	130	80[3]	135	80[3]	115	71	125	77	115	71
Sugar Beets:										
Fall:	216	120[3]	218	120[3]	200	112	205	114	190	106
Summer:	192	120[3]	193	120[3]	175	111	180	114	170	107
Potatoes:										
Fall:	171	120[3]	173	120[3]	160	113	165	116	155	109
Summer:	157	120[3]	159	120[3]	145	112	150	116	140	108

1/ All fertilizer rates are in kg/ha.

2/ Assuming the same aggregate fertilizer requirements obtained by the unconstrained LP solution based on economic prices.

3/ Current recommended rates.

optima), the LP solutions for optimum fertilizer rates on wheat, barley, and cotton are very close to the analytic solutions, with differences averaging less than 5 kg/ha. However, the LP solutions for optimum N rates on corn, sugar beets, and potatoes are consistently lower than the analytic solutions, with differences of up to 18 kg/ha. Therefore, it is possible to conclude that the LP model is accurate in estimating optimum fertilizer rates on wheat, barley, and cotton, but would slightly underestimate optimum N rates on corn, sugar beets, and potatoes.

As mentioned earlier, the production functions for corn, sugar beets, and potatoes were estimated in terms of N only, given the peculiarities of the data sets. Therefore, the current P_2O_5 rates on these crops were assumed to be the economically optimum rates, given the assumption of unlimited supplies. Under limited supplies, the LP model was set up to estimate optimum P_2O_5 rates on these crops by assuming a constant $N:P_2O_5$ ratio. Thus, the model would estimate optimum N rates first, and would then compute optimum P_2O_5 rates based on the fixed-ratio assumption.[1]

6.2.2 LP Solution vs Farmers' Optima

Another issue that needs to be addressed is whether the optimum fertilizer rates computed based on economic prices would also be optimal from the farmers' viewpoint. In other words, given that fertilizer allocations are based on economic prices while farmers' decisions are based on financial prices, farmers may decide to reallocate their

---

[1] Refer to chapter 3 for a more detailed discussion.

rations to maximize their net returns. Given these possible reallocations by farmers, actual fertilizer use may not necessarily represent an economically optimum allocation.

One way to check whether farmers' reallocations would be significantly different from the LP optimum solution is to solve the model based on financial prices. This is shown in Table 6.1, whereby the upper limits on fertilizer supplies were set to be exactly equal to the aggregate requirements obtained with the unconstrained LP solution based on economic prices. The results indicate that the difference between the two solutions are minimal (compare column 3 and column 5 in Table 6.1). These results suggest that farmers would apply the same rates on wheat and barley as those obtained with economic prices. The only exceptions are the rates on LYV wheat in zone 2, with 5kg/ha of N and P_2O_5 more than the unconstrained LP solution based on economic prices. These extra amounts would be obtained by reducing fertilizer rates on cotton, corn, sugar beets, and potatoes by an average of 5 kg/ha. Therefore, these farmers' reallocations are somewhat minor and, thus, they are not expected to cause any significant deviations from the economically optimal solutions.

6.3 Implications of the Constraints on Fertilizer Supplies

The fertilizer allocation model developed in this study is designed to answer two basic questions related to the problem of limited availability of fertilizers. The first question is how to allocate the limited fertilizer supplies among the various crops in a way that would give the highest economic returns to fertilizer use. In other words, given that total fertilizer supplies are lower than the actual requirements, the optimum rates estimated earlier are no longer feasible. These rates need to be adjusted downward in such a way as to maximize net economic returns from the use of the available quantities of fertilizer. The second question is to estimate the impact of the current restrictions on fertilizer imports on the economy as a whole, on farmers' income, and on the government's foreign exchange and general budgets.

6.3.1 Optimum Fertilizer Rates Under Limited Supplies

To answer the above two questions, and given that fertilizer supplies are expected to vary from year to year, optimum fertilizer rates are computed under several scenarios of fertilizer availability. The economic implications of these scenarios are then assessed by comparing them with those obtained under the "base" scenario of unlimited fertilizer supplies. For the crops included in the model, the base scenario (100% of total fertilizer requirements available) would require 164 thousand tons of N and 97 thousand tons of P_2O_5 (refer to chapter 5). The next step is to make gradually decreasing assumptions about the percentage of the above quantities actually available (90%, 80%, 70%, 60%, and 50%). Based on the allocation model, it is then possible to compute the optimum fertilizer rates that would satisfy the upper limits on supplies imposed by the above five constrained scenarios.

Optimum fertilizer rates for the base scenario and the five constrained scenarios are presented in Table 6.2. For instance, if we examine optimum P_2O_5 rate on irrigated wheat, this rate gradually declines from 65 kg/ha under unlimited supplies to 55 kg/ha if 70% of

Table 6.2: OPTIMUM FERTILIZER RATES (kg/ha) UNDER VARYING LEVELS OF FERTILIZER AVAILABILITY Syria, 1989/1990

	% of Total Fertilizer Requirements Available											
	100%		90%		80%		70%		60%		50%	
Crop:	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Irrigated Wheat:	135	65	130	60	120	60	100	55	100	54	100	50
Rainfed Wheat:												
HYV Zone 1:	80	40	70	35	60	35	50	30	40	30	35	24
HYV Zone 2:	60	35	50	35	40	30	33	29	28	25	20	20
LYV Zone 1:	40	35	40	35	30	30	30	25	30	25	30	20
LYV Zone 2:	25	20	20	17	20	15	20	15	20	10	10	10
LYV Zone 3:	20	15	20	15	20	10	10	10	10	10	0	0
Rainfed Barley:												
Zone 1:	70	45	70	40	60	30	50	15	50	10	0	0
Zone 2:	50	40	43	32	36	23	30	10	0	0	0	0
Zone 3:	40	35	30	30	20	15	20	10	0	0	0	0
Cotton:	225	120	210	110	200	106	180	100	180	90	140	70
Corn:	115	71	110	68	90	55	80	49	70	43	60	37
Sugar Beets:												
Fall:	200	112	190	106	170	95	160	89	150	84	130	73
Summer:	175	111	165	104	150	95	145	92	130	82	115	73
Potatoes:												
Fall:	160	113	155	109	140	99	135	95	130	92	115	81
Summer:	145	112	140	108	130	101	125	97	115	89	110	85

total requirements were available, and down to 50 kg/ha in the case of only 50% availability. It should be noted that optimum rates on rainfed crops are much more sensitive to declining fertilizer supplies than the rates on irrigated crops. For instance, if only 50% of total requirements were available, optimum rates for irrigated wheat would decline by about 28% relative to the base scenario. For rainfed crops, on the other hand, optimum rates would decline substantially if fertilizer supplies are reduced, particularly in the case of barley.

In fact, the model results show that, if fertilizer availability was around 60%, it would be uneconomical to allocate any fertilizer to barley in Zones 2 and 3. If this percentage is down to 50%, then fertilizer use on barley in Zone 1 also becomes uneconomical. Therefore, these results suggest that the current policy of not allocating fertilizers to barley in Zone 3 would be economically sound if fertilizer supplies were less than 70% of total requirements. As discussed earlier, average supplies over the last three years represented approximately 60% of actual fertilizer requirements. Under these circumstances, the results suggest that no fertilizer should be allocated to barley, except in Zone 1.

6.3.2 Impact of Limited Fertilizer Supplies on Aggregate Crop Production

To assess the impact of the current constraints on fertilizer supplies on crop production, the increase in production relative to no fertilizer use under unlimited supplies is compared to that obtained under the assumed 60% availability level. The results in Table 6.3 show that the impact of limited fertilizer supplies is much more significant

Table 6.3: AVERAGE CROP PRODUCTION INCREASE UNDER VARYING LEVELS OF FERTILIZER AVAILABILITY
Syria, 1989/1990

	% of Total Fertilizer Requirements Available					
	100%	90%	80%	70%	60%	50%
Crop:						
Irrigated Wheat:	482	474	465	433	432	427
Rainfed Wheat:						
HYV Zone 1:	237	224	212	191	173	153
HYV Zone 2:	104	99	88	81	73	58
LYV Zone 1:	67	67	60	58	58	54
LYV Zone 2:	93	84	82	82	74	53
LYV Zone 3:	14	14	13	10	10	0
TOTAL WHEAT	997	961	920	854	819	745
Rainfed Barley:						
Zone 1:	24	24	22	18	17	0
Zone 2:	183	164	140	110	0	0
Zone 3:	92	78	52	47	0	0
TOTAL BARLEY	299	266	214	175	17	0
Cotton:	284	278	273	263	259	224
Corn:	114	112	102	95	87	78
Sugar Beets:						
Fall:	253	249	239	232	225	207
Summer:	224	220	212	209	197	184
TOTAL SUGAR BEETS:	478	470	451	441	422	390
Potatoes:						
Fall:	51	51	49	49	48	45
Summer:	39	38	38	37	36	35
TOTAL POTATOES:	90	89	87	86	83	80

1/ All figures are in thousand tons and they refer to production increases in a normal year, relative to no fertilizer use.

on rainfed crops compared to irrigated crops. The results indicate that if irrigated crops were to receive their optimum fertilizer requirements, aggregate production would increase by an average of 5% over current production levels.

On the other hand, with an assumed 60% of total requirements currently available, fertilizer use on wheat would increase wheat output by 819 thousand tons relative to no fertilizer use. This increase would have amounted to 997 thousand tons under unlimited fertilizer supplies. Thus, the constraints on fertilizer supplies would result in 178 thousand tons in foregone wheat output. This represents a potential 7% increase in total wheat output, currently estimated at around 2.5 million tons, that is foregone because of reduced fertilizer use.

Similarly, under unlimited fertilizer supplies, fertilizer use on barley could potentially increase production by 299 thousand tons relative to no fertilizer use. In comparison, under current fertilizer availability levels barley output would increase by a mere 17 thousand tons relative to no fertilizer use (Table 6.3). Thus, the current constraints on fertilizer supplies would result in 282 thousand tons in foregone barley output. This represents a potential 25% increase over the current 1.1 million tons in total barley production that is foregone because of the limitations on fertilizer use. Therefore, the most visible negative impact of reduced fertilizer supplies would be on aggregate output of rainfed cereals, especially barley.

6.3.3 Impact of Limited Fertilizer Supplies on National Income

To examine the aggregate economic impact of the constraints on fertilizer supplies, fertilizer costs and gross returns from fertilizer use are compared for the above six scenarios. The most visible economic effect of reduced fertilizer supplies is the corresponding reduction in fertilizer costs. With existing levels of fertilizer supplies (i.e., 60% availability), fertilizer costs are equal to approximately 3.0 billion SL compared to 5.0 billion SL under unlimited supplies (Table 6.4).

However, these substantial reductions in fertilizer costs would be accompanied by even larger declines in gross returns due to lower fertilizer use. In normal years, gross economic returns under unlimited supplies would amount to 16.2 billion SL compared to 12.3 billion SL under the current constraints, a decline of 3.9 billion SL (see Table 6.4). Thus, in normal years, the net impact of the limited fertilizer supplies would be a decline in net economic returns from a potential level of 11.2 billion SL under unlimited supplies to 9.3 billion SL under current supply levels. In other words, if all fertilizer requirements were available, national income would increase by 1.9 billion SL in a normal year. This is equivalent to a potential 3.3% increase in the agricultural GDP.

6.3.4 Impact of Limited Fertilizer Supplies on Foreign Exchange Earnings

The above results clearly suggest that removing the current constraints on fertilizer supplies would have a substantial positive impact on Syrian agriculture. These constraints can be removed by either increasing fertilizer production or through additional fertilizer imports. Increasing fertilizer production would require solving the difficult technical, managerial, and financial problems facing the local

Table 6.4: AGGREGATE ECONOMIC IMPACT OF FERTILIZER USE UNDER VARYING LEVELS OF FERTILIZER AVAILABILITY
Syria, 1989/1990

	% of Total Fertilizer Requirements Available					
	100%	90%	80%	70%	60%	50%
Fertilizer Use ('000 tons):						
- N:	162	147	131	115	98	82
- P_2O_5:	96	87	77	67	58	48
	ECONOMIC PRICES (Million SL)					
Fertilizer Costs:	5,019	4,588	4,052	3,540	3,038	2,534
Gross Returns:						
- Good Year:	16,576	15,899	15,030	14,032	12,822	11,344
- Normal Year:	16,209	15,589	14,758	13,765	12,339	10,965
- Dry Year:	15,663	15,159	14,431	13,479	12,187	10,915
- Very Dry Year:	14,729	14,371	13,788	12,916	11,862	10,722
Net Returns:						
- Good Year:	11,557	11,341	10,978	10,492	9,783	8,810
- Normal Year:	11,190	11,031	10,706	10,225	9,301	8,431
- Dry Year:	10,645	10,601	10,378	9,939	9,148	8,381
- Very Dry Year:	9,710	9,813	9,736	9,376	8,823	8,188

1/ See Table 3.1 for the definitions of rainfall scenarios.

fertilizer plants. However, as expressed by officials from the General Fertilizer Company (GFC), the solution to these problems is a complex and slow process that might take several years to accomplish. Moreover, current plans to expand production capacity will also require several years to implement if and when they are approved by the government.

Therefore, the only short-term option to increasing fertilizer supplies is to increase imports. However, this would imply a substantial increase in foreign exchange expenditures that might further exacerbate the government's severe deficit in hard currencies. As shown in Table 6.5, if the government decides to import all the fertilizer needed to cover the gap between domestic production and total requirements, the import value of fertilizers would increase by 41 million $US (from 62 million $US under 60% fertilizer availability to 103 million $US under unlimited supplies).

These foreign exchange expenditures on additional fertilizer imports would consume about 20% of total foreign exchange reserves. This illustrates one of the main concerns of fertilizer policy in Syria. Policy makers have frequently raised the question of whether it would not be more economical to spend these substantial amounts of scarce foreign exchange on importing food, such as wheat, rather than on fertilizer imports. To answer this question, additional expenditures on fertilizer imports are compared to foreign exchange earnings from increased net crop exports (i.e, increased crop exports and reduced imports) as a result of higher fertilizer use.

The results in Table 6.5 show that, in a normal year, the value of net crop exports would increase from 235 million $US under 60% fertilizer availability to 289 million $US under unlimited supplies.

Table 6.5: IMPACT OF VARYING LEVELS OF FERTILIZER AVAILABILITY ON FOREIGN EXCHANGE EARNINGS
Syria, 1989/1990

	% of Total Fertilizer Requirements Available					
	100%	90%	80%	70%	60%	50%
			(Million $US)			
Import Value of Fertilizer:	103	93	83	72	62	52
Value of Increased Crop Exports and Reduced Imports[1]:						
- Good Year:	300	289	277	260	242	213
- Normal Year:	289	279	268	253	235	207
- Dry Year:	253	246	238	226	213	188
- Very Dry Year:	243	238	231	220	210	186
Net Increase[1] in Foreign Exchange Earnings:						
- Good Year:	197	196	194	188	180	161
- Normal Year:	186	186	185	181	173	156
- Dry Year:	150	153	155	153	151	137
- Very Dry Year:	141	145	148	147	148	134

1/ Relative to no fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.

Thus, net exports would increase by 54 million $US as a result of investing 41 million $US in additional fertilizer imports. Thus, foreign exchange earnings would increase by 13 million $US, which is equivalent to a 7% increase in foreign exchange reserves.

In dry and very dry years foreign exchange earnings from the additional net crop exports would be slightly below the expenditures on additional fertilizer imports. This is particularly true in very dry years when net increase in foreign exchange earnings under 60% fertilizer availability would amount to 148 million $US, compared to 141 million $US under unlimited supplies. This potential net loss of 7 million $US should not pose too much concern given that the probability of occurrence of a very dry year is only one in eight years (refer to Table 3.1). Such a net loss in foreign exchange earnings would be largely offset by increased earnings in normal and good years amounting to 13 million $US (186 - 173 million $US) and 17 million $US (197 - 180 million $US), respectively.

6.3.5 Impact of Limited Fertilizer Supplies on Farm Income

Under the current constraints on fertilizer supplies (i.e., 60% availability) aggregate financial net returns to fertilizer use in a normal year are equal to 9,456 million SL (see Table 6.6). In comparison, if farmers were to receive fertilizer allotments based on the optimum economic rates proposed in chapter 5, their aggregate net returns would amount to 11,753 million SL. Thus, the net impact of the current supply constraints on aggregate farm income would amount to 2,297 million SL in foregone income in a normal year. As shown in Table 6.6, farmers growing rainfed crops, particularly barley in the

Table 6.6 IMPACT OF VARYING LEVELS OF FERTILIZER AVAILABILITY ON FARMERS AGGREGATE NET RETURNS TO FERTILIZER USE
Syria, 1989/1990

	% of Total Fertilizer Requirements Available					
	100%	90%	80%	70%	60%	50%
Net Returns per Crop[1]:	(Million SL)					
Irrigated Wheat:	3,026	2,999	2,964	2,802	2,796	2,769
Rainfed Wheat:						
HYV Zone 1:	1,382	1,336	1,281	1,174	1,069	960
HYV Zone 2:	584	565	517	481	436	355
LYV Zone 1:	459	459	423	410	410	391
LYV Zone 2:	609	563	551	551	509	366
LYV Zone 3:	89	89	83	64	64	0
TOTAL RAINFED WHEAT:	3,122	3,010	2,855	2,679	2,383	2,033
Rainfed Barley:						
Zone 1:	104	103	95	82	80	0
Zone 2:	724	667	588	480	0	0
Zone 3:	344	300	212	198	0	0
TOTAL BARLEY:	1,173	1,070	895	760	80	0
Cotton:	3,100	3,070	3,039	2,953	2,922	2,584
Corn:	591	585	546	515	476	430
Sugar Beets:						
Fall:	202	201	196	192	187	174
Summer:	179	178	174	172	165	155
Potatoes:						
Fall:	206	205	201	199	197	187
Summer:	154	154	151	150	146	143
Aggregate Net Returns:						
- Good Year:	12,168	11,789	11,232	10,594	9,580	8,542
- Normal Year:	11,753	11,472	11,021	10,422	9,456	8,514
- Dry Year:	11,986	11,780	11,374	10,752	9,781	8,893
- Very Dry Year:	11,473	11,404	11,116	10,534	9,716	8,943

1/ Net returns in a normal year, based on financial prices.
2/ See Table 3.1 for the definitions of rainfall scenarios.

drier zones, would bear the largest part of this forgone income. In comparison, the constraints on fertilizer supplies would have a somewhat limited impact on the income of farmers growing irrigated crops.

6.3.6 Impact of Limited Fertilizer Supplies on Government Expenditures

Finally, the impact of limited fertilizer supplies on government expenditures is summarized in Table 6.7. Under the current 60% fertilizer availability level, government subsidies on fertilizers would amount to 1,188 million SL. Should the government decide to satisfy 100% of fertilizer requirements, fertilizer subsidies would amount to 1,964 million SL, an increase of 776 million SL.

On the other hand, increasing fertilizer supplies also would increase aggregate crop production. This would result in additional government revenues from implicit taxes on crops. As discussed earlier, these taxes are derived based on the difference between international and official prices, plus any other direct or indirect tax (or subsidy) on the crop in question (refer to chapter 4). Under the base scenario (100% fertilizer availability), these additional tax revenues would amount to 1,428 million SL in a normal year. This represents an increase of 302 million SL over the current levels of revenues from crop taxes. Therefore, net government expenditures in a normal year would decline from 536 million SL under the base scenario to 62 million SL under the current supply constraints. In other words, by limiting fertilizer supplies to 60% of total requirements, the government would be "saving" 474 million SL in a normal year.

Table 6.7: IMPACT OF VARYING LEVELS OF FERTILIZER AVAILABILITY ON THE GOVERNMENT BUDGET
Syria, 1989/1990.

	% of Total Fertilizer Requirements Available					
	100%	90%	80%	70%	60%	50%
	(Million SL)					
Expenditures on Fertilizer Subsidies:	1,964	1,783	1,584	1,384	1,188	991
Increase[1] in Revenues from Indirect Taxes on Crops:						
- Good Year:	1,110	1,098	1,093	1,057	1,126	1,010
- Normal Year:	1,428	1,379	1,317	1,240	1,126	992
- Dry Year:	1,261	1,225	1,180	1,118	1,041	918
- Very Dry Year:	1,209	1,180	1,143	1,086	1,028	910
Net Increase[1] in Government Expenditures:						
- Good Year:	854	685	490	327	62	-19
- Normal Year:	536	404	266	144	62	-1
- Dry Year:	703	558	403	266	147	73
- Very Dry Year:	755	603	441	298	160	81

1/ Increase due to fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.

6.3.7 Impact of Limited Fertilizer Supplies: Summary and Policy Implications

The above discussion clearly shows that, as long as fertilizer production levels cannot be increased, the most economically rational fertilizer policy would be to import all the fertilizer needed to fill the gap between current production levels and total fertilizer requirements. Compared to the current situation (approximately 60% of total optimum fertilizer requirements available), such a policy would result in an average 5% increase in aggregate output for most crops, and 25% increase in barley output. This would lead to an increase in cotton and potato exports and to a decline in the imports of barley, wheat, corn, and sugar.

In normal years, this increase in net crop exports would amount to 54 million $US, which would offset the 41 million $US in additional fertilizer imports, i.e., a net increase of 13 million $US in government foreign exchange earnings. The net impact on the economy would be an increase of 1,889 million SL in national income, or about 3.3% increase in the agricultural GDP.

An important precondition to implementing the above policy is the government's willingness and ability to spend an additional 776 million SL on fertilizer subsidies. The results have clearly shown that such additional government expenditures would make economic sense from the viewpoint of the economy as a whole. However, given the serious budgetary constraints facing the Syrian government, increasing expenditures on fertilizer subsidies would increase the government budget deficit. Given that the budget deficit is usually financed through inflationary expansion of the money supply, increased expenditures on fertilizer subsidies might further exacerbate the already high inflation rate. In Syria, the most direct effect of inflation is to reduce the purchasing power of public sector employees, who represent the majority of the urban middle and lower-middle classes. Thus, higher inflation would be highly unpopular and, thus, politically undesirable.

Therefore, any increase in expenditures on fertilizer subsidies would have to be either at the expense of reducing public expenditures on other sectors of the economy, or through tax increases. Other public investment opportunities may provide higher economic returns than those obtained from the additional expenditures on fertilizer subsidies. Also, the decision on how to allocate the limited public resources among the different sectors of the economy is essentially a political decision. Economic returns to investment often play only a secondary role in that decision.

6.4 Alternative Fertilizer Pricing Strategies

The above discussion clearly suggests that the burden of fertilizer subsidies on the government budget constitutes an important obstacle to removing the current constraints on fertilizer supplies. One way for the government to address this budgetary constraint is to tax away part of the gain in farm income arising from the increased fertilizer use. This can be done either by reducing output prices or increasing fertilizer prices. The issue of agricultural output pricing in Syria is beyond the scope of this study. Thus this section will focus on the option of increasing official fertilizer prices.

Higher fertilizer prices would reduce total expenditures on fertilizer subsidies. However, farmers may reduce their application rates in response to higher fertilizer prices. This, in turn, would lead to lower crop production and may result in reduced aggregate national income. Furthermore, higher fertilizer prices would increase farmers' production costs and may result in reduced farm income. Therefore, an important policy question is whether a strategy based on increasing fertilizer imports to satisfy 100% of fertilizer requirements, combined with higher fertilizer prices, would be more economically efficient than the current policy of subsidized but limited fertilizer supplies. If fertilizer prices are to be increased, then the next logical question is by how much? and what would be the impact of this price increase on aggregate crop production, farmers' income, and national income?

6.4.1 Fertilizer Normative Demand Functions

A key issue, which needs to be addressed before answering the above questions, is to determine the impact of any potential increase in fertilizer prices on farmers' decisions of how much fertilizer to apply. This is usually done by estimating fertilizer demand functions based on time series data on fertilizer prices and actual quantities consumed. However, there are two main problems in applying such an approach to the Syrian fertilizer market. First, fertilizer consumption data are available only on aggregate consumption, with no data on actual fertilizer use by crop. This does not allow for the estimation of crop-specific fertilizer demand functions and, thus, would provide little information as to the impact of fertilizer prices on yields. The second problem is that the level of fertilizer supplies is probably the most important determinant of fertilizer consumption in Syria, with fertilizer prices playing only a secondary role.

An alternative approach to estimating fertilizer demand functions is the estimation of "normative" demand functions (see, for example, Hsu, 1972). These functions are computed from the estimated yield response functions to fertilizer application, rather than being directly estimated from data on fertilizer prices and quantities. As discussed earlier, given a quadratic production function of the following general form (refer to chapter 3)

$$Y = a_0 + a_1 N + a_2 P + a_3 N^2 + a_4 P^2 + a_5 NP$$

where Y is yield, and N and P are the applied fertilizer rates, the optimum levels of N and P (N^* and P^*) can be calculated as follows (see Appendix E in Nordblom and Al-Ashram, 1989):

$$N^* = \frac{a_5(W_p/P_y - a_2) - 2a_4(W_n/P_y - a_1)}{a_5^2 - 4a_3 a_4}$$

$$P^* = \frac{a_5(W_n/P_y - a_1) - 2a_3(W_p/P_y - a_2)}{a_5^2 - 4a_3 a_4}$$

Where W_n is the price of N
W_p is the price of P_2O_5
P_y is the output price

The above two equations can be rewritten as follows:

$$N^* = \frac{2\, a_1\, a_4 - a_2\, a_5}{a_5^2 - 4\, a_3\, a_4} - \frac{2\, a_4/P_y}{a_5^2 - 4\, a_3\, a_4} W_n + \frac{a_5/P_y}{a_5^2 - 4\, a_3\, a_4} W_p$$

$$P^* = \frac{2\, a_2\, a_3 - a_1\, a_5}{a_5^2 - 4\, a_3\, a_4} - \frac{2\, a_3/P_y}{a_5^2 - 4\, a_3\, a_4} W_p + \frac{a_5/P_y}{a_5^2 - 4\, a_3\, a_4} W_n$$

Or,

$$N^* = b_0 + b_1 W_n + b_2 W_p \tag{6.1}$$

$$P^* = c_0 + c_1 W_p + c_2 W_n \tag{6.2}$$

Where,

$$b_0 = \frac{2\, a_1\, a_4 - a_2\, a_5}{a_5^2 - 4\, a_3\, a_4}$$

$$b_1 = - \frac{2\, a_4/P_y}{a_5^2 - 4\, a_3\, a_4}$$

$$b_2 = c_2 = \frac{a_5/P_y}{a_5^2 - 4\, a_3\, a_4}$$

$$c_0 = \frac{2\, a_2\, a_3 - a_1\, a_5}{a_5^2 - 4\, a_3\, a_4}$$

$$c_1 = - \frac{2\, a_3/P_y}{a_5^2 - 4\, a_3\, a_4}$$

Equations 6.1 and 6.2 are the computed normative demand functions for N and P_2O_5 since they represent the relationships between fertilizer prices and the fertilizer rates that would maximize farmers' net returns from fertilizer use on a given crop. As discussed earlier, the prices that farmers are faced with in making their fertilization decisions are the financial field prices of fertilizers. The field price includes the official fertilizer price plus transport, handling, and application costs (refer to chapter 4). Thus, in the above two equations W_n and W_p refer to field prices. However, in assessing the impact of increasing official fertilizer prices on fertilizer use, the appropriate demand function should be expressed in terms of official prices instead of field prices. The relationship between field prices and official prices can be expressed as follows:

$W_n = W_N + TC$

$W_p = W_P + TC$

where, W_n and W_p are fertilizer field prices, W_N and W_P the official prices, and TC the transport, handling, and application costs. Thus, Equations 6.1 and 6.2 can be rewritten as follows:

$$N^* = b_0 + TC(b_1 + b_2) + b_1 W_N + b_2 W_P \qquad (6.3)$$

$$P^* = c_0 + TC(c_1 + c_2) + c_1 W_P + c_2 W_N \qquad (6.4)$$

Based on equations 6.3 and 6.4, and given the estimated production functions presented in Table 5.1, demand functions for N and P_2O_5 were computed for all the crops included in this study (Table 6.8). Based on these demand functions, own-price (ϵ_N and ϵ_P) and cross-price ($\epsilon_{N,P}$) elasticities were calculated as shown in Table 6.8. These elasticities were computed using 1989/90 official fertilizer prices and the unconstrained optimum fertilizer rates based on these prices.

The computed own-price elasticities suggest that fertilizer demand is highly inelastic, with the demand for N significantly more inelastic than the demand for P_2O_5. This is a clear indication that any increase in fertilizer prices would have a relatively small impact on the fertilizer rates applied by farmers, particularly N rates. This impact shows some significant variation from crop to crop. Fertilizer rates on barley in Zones 2 and 3 are the most sensitive to changes in fertilizer prices, while the rates on irrigated wheat and cotton are the least sensitive. Consequently, the above results suggest that higher fertilizer prices would lead to a relatively smaller decline in crop output. However, this reduction in output would be the largest in the case of barley, followed by rainfed wheat, and irrigated crops.

Table 6.8: FERTILIZER NORMATIVE DEMAND FUNCTIONS AND PRICE ELASTICITIES: Syria, 1989/90

Equation Coefficients[1]:	Demand for N			Demand for P_2O_5			Price Elasticities		
	Constant	b_1	b_2	Constant	c_1	c_2	ϵ_N	ϵ_P	$\epsilon_{N,P}$
Irrigated Wheat:	156.334	-1.178	-0.099	80.809	-0.099	-0.654	-0.0883	-0.1026	-0.0079
Rainfed Wheat:									
HYV Zone 1:	99.963	-1.169	0.010	52.098	0.010	-0.652	-0.1431	-0.1655	0.0013
HYV Zone 2:	80.243	-1.169	0.010	48.975	0.010	-0.652	-0.1850	-0.1780	0.0017
LYV Zone 1:	47.726	-0.281	-0.100	48.348	-0.100	-0.458	-0.0688	-0.1239	-0.0261
LYV Zone 2:	33.091	-0.271	-0.073	32.238	-0.073	-0.442	-0.0986	-0.1906	-0.0280
LYV Zone 3:	26.593	-0.267	-0.060	25.346	-0.060	-0.436	-0.1240	-0.2523	-0.0294
Rainfed Barley:									
Zone 1:	91.072	-0.841	-0.271	95.847	-0.271	-2.304	-0.1142	-0.3968	-0.0390
Zone 2:	67.719	-0.841	-0.271	89.876	-0.271	-2.304	-0.1625	-0.4365	-0.0556
Zone 3:	56.043	-0.841	-0.271	86.891	-0.271	-2.304	-0.2061	-0.4594	-0.0705
Cotton:	254.822	-1.774	-0.319	149.057	-0.319	-1.426	-0.0817	-0.1253	-0.0156
Corn:	144.172	-1.887	NA	NA	NA	NA	-0.1494	NA	NA
Sugar Beets:									
Fall:	234.182	-3.236	NA	NA	NA	NA	-0.1583	NA	NA
Summer:	206.540	-2.697	NA	NA	NA	NA	-0.1490	NA	NA
Potatoes:									
Fall:	181.247	-1.715	NA	NA	NA	NA	-0.1059	NA	NA
Summer:	166.535	-1.583	NA	NA	NA	NA	-0.1064	NA	NA

1/ b_1 and c_1 are the coefficients on the official price of N (W_N) in the demand equations (eq. 6.3, 6.4).
b_2 and c_2 are the coefficients on the official price of P_2O_5 (W_P) in the demand equations (eq. 6.3, 6.4).

6.4.2 Definition of Fertilizer Price Scenarios

Based on the above fertilizer demand functions and price elasticities, it is possible to estimate the impact of increasing fertilizer prices on crop output, farmers' income, national income, and the government's foreign exchange and general budgets. To do that, five alternative fertilizer price scenarios are defined as follows (see Table 6.9):

1. Scenario 1:

This scenario represents the existing situation with official prices of N and P_2O_5 set at 10.65 SL/kg and 11.30 SL/kg, respectively. These prices represent 67% and 49% of the true economic value of N and P_2O_5 fertilizers, which were estimated to equal 15.85 SL/kg and 23.00 SL/kg, respectively (refer to chapter 4). In other words, subsidies account for about 33% of the true cost of N and 51% of the true cost of P_2O_5. Also, this scenario assumes that only 60% of total fertilizer requirements are available and that the limited supplies would be allocated based on economic prices, as discussed earlier in this chapter.

2. Scenario 2:

This scenario assumes no change in current official fertilizer prices, combined with unlimited fertilizer supplies and unlimited farmers' access to these supplies at current prices. Thus, farmers are assumed to apply the fertilizer rates that would maximize their income. In other words, this scenario represents the ideal scenario from the viewpoint of farmers.

Table 6.9: DEFINITIONS OF FERTILIZER PRICE SCENARIOS

	Fertilizer Price Scenarios					
	Base	1	2	3	4	5
Official Prices						
N (SL/kg):	10.65	10.65	10.65	11.40	12.35	15.85
P_2O_5 (SL/kg):	11.30	11.30	11.30	16.50	17.97	23.00
% of 1989/1990 Official Prices:						
N:	100	100	100	107	116	149
P_2O_5:	100	100	100	146	159	204
% Subsidy[1]:						
N:	33	33	33	28	22	0
P_2O_5:	51	51	51	28	22	0
Constraints on Fertilizer Supplies:	No	Yes[2]	No	No	No	No
Optimization Based on Financial Prices:	No[3]	No[3]	Yes	Yes	Yes	Yes

1/ Refer to chapter 4.
2/ 60% of total fertilizer requirements assumed available.
3/ Based on economic Prices.

3. Scenario 3:

Under this scenario fertilizer supplies are also assumed to be unlimited, with farmers applying the fertilizer rates that would maximize their income. The official price of N is assumed to be 7% higher than the current price, while the official price of P_2O_5 would be 46% above the current price. The reason for assuming a larger increase in the price of P_2O_5, relative to the price of N, is the concern of reducing the level of subsidy on P_2O_5 down to approximately the same level as the subsidy on N. Thus, the above assumed fertilizer prices imply a decline in government subsidies down to about 28% of the true cost of both N and P_2O_5 fertilizers.

The assumed official fertilizer prices in this scenario were selected in such a way as to reduce subsidies to a point where they would be approximately equal to the increase in government revenues from indirect taxes on crops in a normal year. As mentioned earlier, these indirect taxes on crops refer to the difference between international and official prices, plus adjustments for other taxes (or subsidies) that affect the crop's cost of production (refer to chapter 4). Therefore, scenario 3 was defined in such a way that, in a normal year, net government expenditures associated with fertilizer use would be approximately equal to zero[1]. In other words, under this scenario farmers would be able to purchase all their fertilizer needs, given the assumed official prices, without any increase in net government expenditures.

---

[1] This result will be shown later (see Table 6.14).

4. Scenario 4: The assumptions of this scenario are very similar to those in Scenario 3. The only difference is that the official price of N is assumed to be 16% higher than the current price, while that of P_2O_5 would be 59% above the current price. These prices would reduce subsidies to about 22% of the true costs of N and P_2O_5 fertilizers.

Given that government revenues from indirect taxes are lower in good years compared to normal and drier years[1], the above assumed prices would ensure that expenditures on fertilizer subsidies would be approximately equal to the increase in tax revenues in a good year. In other words, this scenario would ensure that farmers will be able to purchase all their fertilizer needs, given the assumed official prices, without increasing net government expenditures even in good years. As will be shown later, in normal and drier years net government expenditures based on this scenario would actually decline (refer to Table 6.14).

5. Scenario 5: Under this scenario official fertilizer prices would be equal to their true economic value, which would lead to the complete elimination of fertilizer subsidies. This would require increasing the price of N by 49% and the price of P_2O_5 by 104%, compared to current official prices. Official crop prices are assumed to remain unchanged and, thus, indirect taxes on crops would substantially reduce government expenditures. In other words, this scenario represents the ideal scenario from the viewpoint of the government budget.

---

[1] Refer to chapter 4.

6.4.3 Optimum Rates under Alternative Fertilizer Price Scenarios

The above five fertilizer price scenarios are compared in terms of their impacts on fertilizer use, crop production, farmers' income, national income, and the government's foreign exchange and general budgets. These five scenarios are also compared to a "base" scenario, which is defined as the scenario that would maximize economic net returns from fertilizer use. This is the same base or ideal scenario defined in section 6.3, which assumes unlimited fertilizer supplies with optimum fertilizer rates computed based on economic prices.

Optimum fertilizer rates calculated based on the six examined scenarios are presented in Table 6.10. With the exception of the constrained scenario (Scenario 1), optimum fertilizer rates do not show great variations between the different scenarios. The rates obtained under Scenarios 2, 3, and 4 are slightly higher than the base scenario, while those obtained under Scenario 5 are slightly lower.

In other words, even with a 16% increase in the price of N and 59% increase in the price of P_2O_5 (Scenario 4), fertilizer use would be still slightly higher than the base scenario. Only when the price of P_2O_5 is doubled and the price of N is increased by about 50% (Scenario 5) that fertilizer use would be slightly lower than the base scenario. Therefore, as predicted by the low price elasticities, increasing fertilizer prices would have a somewhat limited impact on fertilizer use by farmers. The only exception to this observation seems to be in the case of P_2O_5 rates on barley. As suggested by the results in Table 6.10 and by the estimated price elasticities, these rates would decline by 40% to 45% if the price of P_2O_5 is doubled.

Table 6.10: OPTIMUM FERTILIZER RATES (kg/ha) UNDER VARYING LEVELS OF OFFICIAL FERTILIZER PRICES Syria, 1989/1990

	Base Scenario		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Crop:	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Irrigated Wheat:	135	65	100	54	142	72	141	69	140	68	135	64
Rainfed Wheat:												
HYV Zone 1:	80	40	40	30	87	45	87	41	86	41	82	37
HYV Zone 2:	60	35	28	25	67	41	67	38	66	37	62	34
LYV Zone 1:	40	35	30	25	43	42	43	40	42	39	41	36
LYV Zone 2:	25	20	20	10	29	26	29	24	28	23	27	21
LYV Zone 3:	20	15	10	10	23	20	23	17	22	17	21	14
Rainfed Barley:												
Zone 1:	75	45	50	10	79	66	77	55	76	51	72	39
Zone 2:	50	40	0	0	55	60	54	49	52	45	48	33
Zone 3:	40	35	0	0	43	57	42	46	41	42	36	30
Cotton:	225	120	180	90	231	129	229	122	227	120	219	111
Corn:	130	80	70	43	135	83	134	82	133	82	130	80
Sugar Beets:												
Fall:	215	120	150	84	218	122	217	121	216	121	210	117
Summer:	190	120	130	82	193	122	192	121	191	121	186	117
Potatoes:												
Fall:	170	120	130	92	173	122	172	121	171	121	168	119
Summer:	155	120	115	89	159	122	158	122	158	122	155	120

1/ See Table 6.9 for the definitions of fertilizer price scenarios.

6.4.4 Impact of Higher Fertilizer Prices on Aggregate Crop Output

Since higher fertilizer prices have a limited impact on fertilizer use, the impact on aggregate crop output is also expected to be limited. This is clearly shown in Table 6.11, where the results indicate that higher fertilizer prices would virtually have no impact on the production of cotton, corn, sugar beets, and potatoes. Under Scenarios 2, 3, and 4, wheat and barley production would increase slightly, compared to the base scenario, while barley output under Scenario 5 would be slightly lower than the base scenario. However, the most important thing to note from Table 6.11 is that the current situation of limited fertilizer supplies (Scenario 1) would result in significantly lower levels of aggregate output for all crops, in comparison with the other scenarios.

6.4.5 Impact of Higher Fertilizer Prices on National Income

It is clear, then, that higher fertilizer prices (i.e., Scenarios 3, 4 and 5) would have a limited impact on fertilizer use and crop production. Thus, the impact on national income is also expected to be limited. In fact, compared to the base scenario, net economic returns from fertilizer use would decline by an insignificant amount due to higher fertilizer prices. In normal years, net economic returns under Scenarios 3, 4, and 5 (11164, 11172, and 11156 million SL, respectively) are only 8 to 24 million SL lower than the base scenario (11180 million SL). In good years, net returns under these scenarios (Scenario 3: 11605 million SL; Scenario 4: 11605 million SL; and Scenario 5: 11588 million SL) would be 41 to 60 million SL higher than the base scenario (11547 million SL) (see Table 6.12).

Table 6.11: AVERAGE CROP PRODUCTION INCREASE UNDER VARYING LEVELS OF OFFICIAL FERTILIZER PRICES
Syria, 1989/1990

	Fertilizer Price Scenarios[1]					
	Base	1	2	3	4	5
Crop:						
Irrigated Wheat:	482	432	490	488	487	481
Rainfed Wheat:						
HYV Zone 1:	237	173	244	241	241	235
HYV Zone 2:	104	73	109	108	107	104
LYV Zone 1:	67	58	69	69	68	67
LYV Zone 2:	93	74	100	99	98	96
LYV Zone 3:	14	10	15	15	15	14
TOTAL WHEAT	997	819	1027	1020	1016	998
Rainfed Barley:						
Zone 1:	25	17	27	26	26	24
Zone 2:	183	0	205	196	191	173
Zone 3:	92	0	106	100	97	84
TOTAL BARLEY	300	17	338	322	313	282
Cotton:	284	259	287	285	284	280
Corn:	118	87	119	119	118	118
Sugar Beets:						
Fall:	257	225	258	258	258	256
Summer:	228	197	229	229	229	228
TOTAL SUGAR BEETS:	486	422	487	487	486	484
Potatoes:						
Fall:	52	48	52	52	52	52
Summer:	39	36	39	39	39	39
TOTAL POTATOES:	91	83	91	91	91	91

1/ See Table 6.9 for the definitions of fertilizer price scenarios.
2/ All figures refer to production increases (in thousand tons) relative to no fertilizer use.

Table 6.12: AGGREGATE ECONOMIC IMPACT OF FERTILIZER USE UNDER VARYING LEVELS OF FERTILIZER OFFICIAL PRICES
Syria, 1989/1990

	Fertilizer Price Scenarios[1]					
	Base	1	2	3	4	5
Fertilizer Use ('000 tons):						
- N:	164	98	174	173	171	163
- P_2O_5:	97	58	116	106	103	92
	ECONOMIC PRICES (Million SL)					
Fertilizer Costs:	5,075	3,038	5,702	5,444	5,330	4,933
Gross Returns:						
- Good Year:	16,622	12,822	17,220	17,049	16,935	16,521
- Normal Year:	16,255	12,339	16,792	16,607	16,502	16,089
- Dry Year:	15,708	12,187	16,138	15,966	15,885	15,524
- Very Dry Year:	14,771	11,862	15,062	14,912	14,864	14,580
Net Returns:						
- Good Year:	11,547	9,783	11,518	11,605	11,605	11,588
- Normal Year:	11,180	9,301	11,090	11,164	11,172	11,156
- Dry Year:	10,633	9,148	10,437	10,522	10,555	10,592
- Very Dry Year:	9,696	8,823	9,360	9,468	9,534	9,647

1/ See Table 6.9 for the definitions of fertilizer price scenarios.
2/ See Table 3.1 for the definitions of rainfall scenarios.

The results in Table 6.12 also clearly show that a strategy based on higher fertilizer prices coupled with farmers' unlimited access to fertilizers (i.e., Scenarios 3, 4 and 5), would be much more economically efficient than the current situation of limited supplies and heavily subsidized prices (Scenario 1). In a normal year, such a strategy would increase national income by at least 1855 million SL (difference in net economic returns between Scenario 5 and Scenario 1), relative to the current policy .

6.4.6 Impact of Higher Fertilizer Prices on Farm Income

Since higher fertilizer prices would have little impact on national income, their main effect would be to increase farmers' costs and to reduce government expenditures on fertilizer subsidies. Thus, the main impact of higher fertilizer prices is to redistribute income from farmers to the government budget (i.e., other sectors of the economy). As shown in Table 6.13, farmers' net returns would be highest under the current levels of fertilizer prices with unlimited supplies (Scenario 2). An increase of 7% in the price of N and 46% in the price of P_2O_5 (Scenario 3) would reduce farmers' net returns in a normal year by 442 million SL (11763 vs 11321 million SL), compared to the base scenario.

This potential loss in farm income would gradually increase with higher fertilizer prices, amounting to 764 million SL under Scenario 4 (11763 vs 10999 million SL) and 1858 million SL under Scenario 5 (11763 vs 9905 million SL). However, in spite of these substantial reductions in farm income relative to the base scenario, farmers' net returns would be still higher than under the current levels of fertilizer prices with

Table 6.13 IMPACT OF VARYING LEVELS OF FERTILIZER OFFICIAL PRICES ON FARMERS AGGREGATE NET RETURNS TO FERTILIZER USE
Syria, 1989/1990

	Fertilizer Price Scenarios[1]					
	Base	1	2	3	4	5
Net Returns per Crop[2]:			(Million SL)			
Irrigated Wheat:	3,027	2,796	3,040	2,941	2,879	2,661
Rainfed Wheat:						
HYV Zone 1:	1,382	1,069	1,392	1,327	1,286	1,145
HYV Zone 2:	584	436	594	557	535	463
LYV Zone 1:	459	410	465	442	432	394
LYV Zone 2:	610	509	630	589	570	503
LYV Zone 3:	89	64	91	84	81	69
TOTAL RAINFED WHEAT:	3,123	2,488	3,172	2,999	2,904	2,574
Rainfed Barley:						
Zone 1:	106	80	109	102	99	87
Zone 2:	725	0	763	691	654	544
Zone 3:	344	0	368	322	302	236
TOTAL BARLEY	1,175	80	1,241	1,116	1,055	867
Cotton:	3,101	2,972	3,106	2,992	2,924	2,687
Corn:	596	476	594	566	549	491
Sugar Beets:						
Fall:	202	187	201	192	186	167
Summer:	179	165	179	170	165	148
Potatoes:						
Fall:	206	197	205	198	193	178
Summer:	154	146	154	147	144	132
Aggregate Net Returns:						
- Good Year:	12,179	9,580	12,416	11,835	11,490	10,351
- Normal Year:	11,763	9,456	11,893	11,321	10,999	9,905
- Dry Year:	11,995	9,781	12,056	11,481	11,176	10,104
- Very Dry Year:	11,480	9,716	11,414	10,852	10,577	9,567

1/ See Table 6.9 for the definitions of fertilizer price scenarios.
2/ Net returns in a normal year, based on financial prices.
3/ See Table 3.1 for the definitions of rainfall scenarios.

limited supplies (Scenario 1). In fact, even with the complete elimination of subsidies (Scenario 5), farmers' net returns to fertilizer use in a normal year would amount to 9905 million SL, or 449 million SL higher than their current levels. It should be noted, however, that the elimination of subsidies would reduce the income of farmers growing irrigated crops in comparison to Scenario 1.

6.4.7 Impact of Higher Fertilizer Prices on the Government Budget

As mentioned earlier, the main impact of higher fertilizer prices would be to redistribute income from farmers to the government budget. Thus, the decline in farmers' income due to higher fertilizer prices (Scenarios 3, 4, and 5) would be coupled by a parallel decline in government expenditures. As shown in Table 6.14, fertilizer subsidies would gradually decline from 1986 million SL under the base scenario to 1455 million SL under Scenario 3, 1115 million SL under Scenario 4, and zero under Scenario 5. In comparison, the current levels of fertilizer subsidies (Scenario 1) would amount to 1188 million SL.

It should be noted that Scenarios 3 and 4 were defined in such a way as to achieve specific alternative impacts on net government expenditures. As discussed earlier, fertilizer prices under Scenario 3 were specified in such a way as to equate fertilizer subsidies with the increase in government revenues from indirect taxes on crops in a normal year. Prices under Scenario 4, on the other hand, would result in equating fertilizer subsidies with government revenues from indirect taxation in a good year. This is shown in Table 6.14, where the increase in revenues from indirect crop taxation under Scenario 3 would amount to 1454 million SL in a normal year, compared to 1455 million SL

Table 6.14: IMPACT OF VARYING LEVELS OF OFFICIAL FERTILIZER PRICES ON THE GOVERNMENT BUDGET
Syria, 1989/1990

	Fertilizer Price Scenarios[1]					
	Base	1	2	3	4	5
	(Million SL)					
Expenditures on Fertilizer Subsidies:	1,986	1,188	2,119	1,455	1,115	0
Increase[2] in Revenues from Indirect Taxes on Crops:						
- Good Year:	1,113	1,126	1,112	1,113	1,115	1,115
- Normal Year:	1,431	1,126	1,469	1,454	1,446	1,411
- Dry Year:	1,265	1,041	1,291	1,279	1,273	1,248
- Very Dry Year:	1,212	1,028	1,233	1,222	1,218	1,197
Net Increase[2] in Government Expenditures:						
- Good Year:	873	62	1,007	341	0	-1,115
- Normal Year:	554	62	650	1	-331	-1,411
- Dry Year:	721	147	828	176	-158	-1,248
- Very Dry Year:	773	160	886	232	-103	-1,197

1/ See Table 6.9 for the definitions of fertilizer price scenarios.
2/ Increase due to fertilizer use.
3/ See Table 3.1 for the definitions of rainfall scenarios.

in fertilizer subsidies. In contrast, fertilizer subsidies under Scenario 4 would be equal to 1115 million SL, which is approximately equal to the increase in tax revenues in a good year.

Therefore, Scenarios 4 and 5 would ensure that net government expenditures associated with fertilizer use would _decline_ if the government decides to adopt a strategy of unlimited fertilizer supplies. This is particularly important under Scenario 5, where net government expenditures would decline by 1115 to 1411 million SL. Under Scenario 3, on the other hand, ensuring unlimited fertilizer supplies would still constitute a burden on the government budget, except in normal years.

6.4.8 Impact of Higher Fertilizer Prices on Foreign Exchange Earnings

Although higher fertilizer prices will reduce the government budget deficit, foreign exchange expenditures on fertilizer imports would have to increase in order to ensure farmers' unlimited access to fertilizers. Under the current restrictions on imports (Scenario 1), the import value of fertilizers would amount to 62 million $US (Table 6.15). In comparison, strategies based on higher prices and unconstrained supplies (i.e., Scenarios 3, 4 and 5) would require increasing fertilizer imports by: 49 million $US under Scenario 3 (i.e., 111 - 62 million $US); 47 million $US under Scenario 4 (i.e., 109 - 62 million $US); and 39 million $US under Scenario 5 (i.e., 101 - 62 million $US).

These additional fertilizer imports would lead to higher levels of net crop exports (increased exports and reduced imports) whose value

Table 6.15: IMPACT OF VARYING LEVELS OF OFFICIAL FERTILIZER PRICES ON FOREIGN EXCHANGE EARNINGS
Syria, 1989/1990

	Fertilizer Price Scenarios[1]					
	Base	1	2	3	4	5
			(Million $US)			
Import Value of Fertilizer:	104	62	116	111	109	101
Value of Increased Crop Exports and Reduced Imports[2]:						
- Good Year:	301	242	309	306	304	298
- Normal Year:	289	235	296	293	292	286
- Dry Year:	254	213	258	256	255	251
- Very Dry Year:	244	210	247	246	245	241
Net Increase[2] in Foreign Exchange Earnings:						
- Good Year:	197	180	192	195	195	197
- Normal Year:	186	173	180	182	183	185
- Dry Year:	150	151	142	145	146	150
- Very Dry Year:	140	148	131	134	136	140

1/ See Table 6.9 for the definitions of fertilizer price scenarios.
2/ Relative to no fertilizer use.
3/ See Table 3.1 for the definitions of rainfall scenarios.

would offset the increased foreign exchange expenditures on fertilizer. For instance, under Scenario 3, the value of net crop exports would be 293 million $US in a normal year, compared to 235 million $US under limited fertilizer supplies (Scenario 1), a difference of 58 million $US. Such a difference would more than compensate for the 49 million $US increase in fertilizer imports, resulting in a 9 million $US gain in foreign exchange earnings.

Similar gains in foreign exchange would also be obtained under Scenarios 4 and 5 (see Table 6.15). Therefore, under the higher fertilizer price scenarios (Scenarios 3, 4 and 5) net foreign exchange earnings would be slightly higher than their current levels in spite of substantial increases in fertilizer imports needed to ensure farmers' unlimited access to fertilizers. However, this would be the case in normal and good years only. In dry and very dry years, net foreign exchange earnings under the current policy of subsidized but limited fertilizer supplies (Scenario 1) would be slightly higher than those obtained under Scenarios 3, 4 and 5. The differences, however, are very small and would be largely offset by increased foreign exchange earnings in normal and good years.

6.4.9 Impact of Alternative Fertilizer Price Scenarios: Summary and Policy Implications

The above results have clearly shown that a strategy based on ensuring unlimited fertilizer supplies and farmers' unlimited access to these supplies, combined with higher fertilizer prices, would be highly recommended. Compared to the existing situation of limited but heavily subsidized supplies, such a strategy would significantly increase aggregate crop output and farmers' income, would reduce government expenditures, and would slightly increase net foreign exchange earnings. The net impact of this strategy would amount to an increase of at least 1.8 billion SL in national income (Table 6.12), which is equivalent to a 3.2% increase in the agricultural GDP.

The question of how much fertilizer prices ought to increase is essentially a political question. From a pure economic efficiency viewpoint, increasing prices within the range covered by the above five scenarios would have a very limited impact on national income. The main impact of higher prices would be to redistribute income from farmers to the government budget. If the political objective is to reduce government spending to control inflation, then the complete elimination of fertilizer subsidies (Scenario 5) would be the answer. Given the existing indirect taxes on crops, such a scenario would imply that farmers may end up subsidizing the rest of the economy. Thus, farmers groups are expected to strongly oppose any such move, particulary farmers growing irrigated crops whose income would decline if fertilizer subsidies are eliminated. If, on the other hand, the objective is to maximize farmers' income, then fertilizer prices ought to remain unchanged (Scenario 2). This would require increasing fertilizer subsidies by about 900 million SL (see Table 6.14). Given the current constraints on the government budget, these extra expenditures could only come at the expense of public spendings in other sectors.

Therefore, a realistic solution to the fertilizer pricing problem would be closer to Scenarios 3 and 4. The difference in impact between these two scenarios would amount to about 330 million SL, which would be added to farm income under Scenario 3, or to government revenues under scenario 4. Thus, an "optimum" fertilizer pricing strategy would require an increase of 7% to 16% in the current official price of N and 46% to 59% in the price of P_2O_5. Such a strategy would be desirable only if the government allocates the foreign exchange needed to import enough fertilizer to fill the gap between domestic production and total fertilizer requirements.

6.5 Comparison of Alternative Fertilizer Allocation Strategies for the Winter Season

6.5.1 Constraints on Fertilizer Supplies for the Winter Season

The earlier comparison between the scenarios with varying levels of fertilizer supplies was based on total (winter and summer seasons) fertilizer requirements and availability (see section 6.3). However, constraints on fertilizer supplies have tended to be much more serious for fertilizer use on fall-planted crops (wheat, barley, and fall sugar beets and potatoes) than on spring-planted crops (cotton, corn, and summer sugar beets and potatoes). The peak period of fertilizer demand for winter crops, especially phosphate, occurs very early in the season (October-December). Therefore, any delays in importing fertilizers and/or any early disruptions in production would cause serious reductions in fertilizer availability for the winter season. In fact, for the past few years, the impact of fertilizer shortages was mostly felt during the winter season, with spring-planted crops usually receiving all their fertilizer requirements.

As mentioned earlier, fertilizer allocation strategies adopted by the Soils Directorate (SD) are based on a system of policy-based priorities (refer to chapter 2). According to this system irrigated crops, including irrigated wheat, should receive their optimum fertilizer requirements. As for rainfed crops, the first priority goes to HYV wheat followed by LYV wheat, with barley fertilization having the lowest priority. As discussed earlier, given the serious fertilizer availability constraints for the winter season, the main practical implication of the above ranking system is that fertilizer is rarely allocated to barley, especially in Zone 3.

To illustrate the kind of problems facing SD officials in planning fertilizer use on fall-planted crops, the fertilizer supply situation at the beginning of the 1989/90 season is described in some detail[1]. On September 1st, 1989, the SD estimates of fertilizer supplies for the coming winter season were 126.9 thousand tons of N and 97.6 thousand tons of P_2O_5. These estimates were based on existing stocks, realistic estimates of domestic fertilizer production between September 1st and December 31st, and fertilizer import contracts signed with foreign suppliers. In comparison, the SD estimated planned fertilizer requirements for the winter season at 175 thousand tons of N and 160 thousand tons of P_2O_5 (assuming all cropped areas will be fertilized). In other words, 73% of planned N requirements and 61% of planned P_2O_5 requirements were expected to be available for distribution to farmers for fall-planted crops.

Based on the above estimates of available fertilizer supplies, the SD formulated its fertilizer allocation plan for the 1989/90 winter season as follows:

---

[1] Based on discussions with officials from the Soils Directorate (SD) and internal documents from the SD and the Agricultural Cooperative Bank.

1. Irrigated wheat, sugar beets, and potatoes should receive all their current fertilizer recommended rates.
2. Rainfed HYV and LYV wheat in Zones 1, 2 and 3, should receive 80% of their current recommended rates.
3. Barley in Zone 2 should receive only 50% of its current recommended rates.
4. No fertilizer is allocated to barley in Zones 1, 3, and 4.[1]
5. Fertilizer allocations to fruit trees and vegetables are postponed until further notice, except fall-planted vegetables in the coastal areas, which should receive all their requirements.

Based on the current fertilizer recommendations, the above allocation plan for the 1989/90 winter season would have been feasible if the SD estimates of available supplies were realistic. These supply estimates were based on the assumption that all fertilizer imports would be delivered in time for distribution to farmers. However, due to delays in payments to foreign suppliers, only a very small proportion of fertilizer imports was delivered early enough to be applied on fall-planted crops.

Thus, actual quantities of fertilizer applied on fall-planted crops were around 78.4 thousand tons of N and 42 thousand tons of P_2O_5. Subtracting the requirements of vegetables in the coastal areas, actual fertilizer use by the winter crops included in this study would amount

---

[1] It is unclear why no fertilizer was allocated to barley in Zone 1. One possible explanation is that barley in Zone 1 is primarily grown for straw, with little amounts of grain sold through the official channels. As suggested by SD officials, fertilizer use for straw production is considered as a low priority in comparison to grain production.

to 77.8 thousand tons of N and 41.5 thousand tons of P_2O_5. The actual requirements of these crops, estimated in chapter 5, were 111 thousand tons of N and 67.5 thousand tons of P_2O_5. Therefore, actual fertilizer use represented about 70% of actual N requirements and 60% of P_2O_5 requirements.

The delays in the delivery of fertilizer imports were not totally unpredicted by SD officials when the allocation plan was formulated. That is why the plan specified that the fertilizer requirements of irrigated crops would be satisfied first, followed by rainfed wheat, with fertilizer distribution to barley farmers conditional on the early delivery of fertilizer imports. Thus, based on the above allocation priorities, the actual amounts of available fertilizer supplies could only satisfy the requirements of irrigated crops and only part of the requirements of rainfed HYV wheat. Although there exist no data on actual fertilizer use by crop, the above figures on actual fertilizer supplies clearly suggest that very little fertilizer was applied on LYV wheat and barley.

6.5.2 Fertilizer Allocation Strategies for the Winter Season

The main implication of the above fertilizer allocation strategy for the 1989/90 winter season is that very little fertilizer would be allocated to LYV wheat and barley. Thus, the question is posed as to the economic rationality of the above fertilizer allocation strategy. More specifically, one should ask whether, given the current fertilizer availability constraints, it would not be more economical to reduce fertilizer allocations to irrigated crops and to increase those for LYV wheat and barley, including barley in Zone 3?

To answer the above question, the fertilizer allocation model is used to compare the economic impact of alternative allocation strategies, given the quantities of fertilizer actually used during the 1989/90 winter season. For this purpose, three alternative fertilizer allocation strategies for the winter season are examined:

- Strategy A is the above mentioned strategy adopted by the SD.
- Strategy B is based on the same system of priorities as in Strategy A, but all the fertilizer rates are based on the new recommendations proposed in chapter 5 (refer to Table 5.2), rather than the current rates recommended by the SD.
- Strategy C is based on the principle of equating marginal revenues across all crops, with no a priori conditions. This strategy is essentially based on the solution obtained by the LP model for fertilizer allocation.

All the above strategies are based on actual fertilizer use on fall-planted crops in 1989/90, which amounted to about 77.8 thousand tons of N and 41.5 thousand tons of P_2O_5. These quantities are approximately equal to 70% of optimum N requirements and 60% of P_2O_5 requirements for the fall-planted crops included in this study. Fertilizer rates included in the above three strategies are presented in Table 6.16. Economically optimum fertilizer rates under unlimited supplies, or base scenario, are also presented for the sake of comparison.

As mentioned earlier, the current SD strategy (Strategy A) stipulates that irrigated crops should receive all their fertilizer

Table 6.16: FERTILIZER RATES UNDER ALTERNATIVE ALLOCATION STRATEGIES FOR THE WINTER SEASON
Syria, 1989/1990

	Fertilizer Rates (kg/ha)							
	Base Scenario		Strategy A[1]		Strategy B		Strategy C	
Crop:	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Irrigated Wheat:	135	65	150	100	135	65	111	55
Rainfed Wheat:								
HYV Zone 1:	80	40	75	24	64	32	60	30
HYV Zone 2:	60	35	60	20	48	28	40	25
LYV Zone 1:	40	35	0	0	20	18	30	25
LYV Zone 2:	25	20	0	0	13	10	20	10
LYV Zone 3:	20	15	0	0	10	8	10	10
Rainfed Barley:								
Zone 1:	75	45	0	0	0	0	50	10
Zone 2:	50	40	0	0	0	0	30	10
Zone 3:	40	35	0	0	0	0	0	0
Sugar Beets:	215	120	200	120	215	120	160	90
Potatoes:	170	120	150	120	170	120	135	95

1/ Refer to text for the definitions of fertilizer allocation strategies.

requirements, rainfed wheat should receive 80% of the current recommended rates, and barley in Zone 2 should receive 50% of its recommended rates. However, after the allocations for the irrigated crops were distributed, the quantities of fertilizer left would have been barely enough to cover the plan's stipulations for HYV wheat. In fact, as shown in Table 6.16, there would be enough fertilizer left to provide 75% of the recommended N rates on HYV wheat in Zones 1 and 2, and only about 33% of the recommended P_2O_5 rates.

Strategy B assumes the same set of priorities stipulated by the current SD fertilizer allocation strategy. The only difference is that Strategy B is based on the proposed fertilizer rates, which were computed by equating marginal costs with marginal revenues, based on the true economic value of crops and fertilizers (refer to chapter 5). Compared to the current recommendations, these proposed rates are significantly lower for wheat and higher for barley, sugar beets, and potatoes. Given the substantial reduction in the fertilizer rates on irrigated wheat in particular, enough fertilizer would be left to apply 80% of the proposed rates on rainfed HYV wheat. However, the remaining fertilizer quantities would allow the application of only 50% of the proposed rates on LYV wheat, instead of the stipulated 80%. As in the case of Strategy A, there would be no fertilizer left for barley fertilization.

Unlike the above two strategies, Strategy C imposes no a priori conditions. Therefore, it is more flexible since it allows for reducing the fertilizer rates on irrigated crops. As shown in Table 6.16, this would, in turn, allow more fertilizer to be allocated to LYV wheat and to barley in Zones 1 and 2. However, as with the above two strategies, no fertilizer would be allocated to barley in Zone 3. This provides further support to the current policy of excluding barley in Zone 3 from the fertilizer allocation plan. It should be noted that fertilizer rates on irrigated crops are only 15% to 25% lower than their corresponding rates under the base scenario. Therefore, by reducing the rates on irrigated crops by a relatively small percentage, enough fertilizer would be left to allow for moderate levels of fertilization on barley.

6.5.3 Impact of Alternative Fertilizer Allocation Strategies on Aggregate Crop Output

The impact of the three fertilizer allocation strategies on aggregate crop production is presented in Table 6.17. The results indicate that the current high rates of fertilization on irrigated wheat would contribute only 3000 tons more in wheat output than the much lower rates under the proposed base scenario. On the other hand, the lower rates on rainfed HYV wheat and the lack of fertilization of LYV wheat would result in 210 thousand tons in foregone wheat output.

This foregone wheat output due to limited fertilizer supplies would be less than 100 thousand tons had Strategy B been adopted instead of the current strategy. By applying the proposed lower rates on irrigated wheat under Strategy B, enough fertilizer would be left to fertilize LYV wheat. This would lead to the production of an additional 113 thousand tons of wheat compared to the current SD strategy. Similarly, under Strategy C wheat output would be 91 thousand tons higher than the output produced under the current strategy, but it would be 22 thousand tons lower than in Strategy B. Also, since the output of

Table 6.17: IMPACT OF ALTERNATIVE FERTILIZER ALLOCATION STRATEGIES ON AGGREGATE PRODUCTION OF FALL-PLANTED CROPS
Syria, 1989/1990

	Average Increase[1] in Aggregate Output ('000 tons)			
	Base Scenario	Strategy A	Strategy B	Strategy C
Crop:				
Irrigated Wheat:	482	485	482	449
Rainfed Wheat:				
HYV Zone 1:	237	213	214	206
HYV Zone 2:	104	92	93	84
LYV Zone 1:	67	0	45	58
LYV Zone 2:	93	0	61	74
LYV Zone 3:	14	0	9	10
TOTAL RAINFED WHEAT:	515	305	421	431
TOTAL WHEAT	997	790	903	881
Rainfed Barley:				
Zone 1:	25	0	0	17
Zone 2:	183	0	0	110
Zone 3:	92	0	0	0
TOTAL BARLEY	300	0	0	127
Sugar Beets:	257	253	257	232
Potatoes:	52	51	52	49

1/ Increase relative to no fertilizer use.
2/ Refer to text for the definitions of fertilizer allocation strategies.

irrigated wheat under Strategy B is 33 thousand tons higher than Strategy C, there would be less uncertainty about aggregate wheat production under Strategy B.

The impact of the three allocation strategies on barley production is more straightforward than their impact on wheat output. Since no fertilizer would be allocated to barley under Strategies A and B, there would be 300 thousand tons in foregone output in comparison to the base scenario. In contrast, under Strategy C fertilizer allocation to barley in Zones 1 and 2 would result in the production of 127 thousand tons more than the unfertilized barley under Strategies A and B.

Table 6.17 also shows the impact of the above mentioned allocation strategies on the production of fall-planted sugar beets and potatoes. The results show that under Strategies A and B aggregate output of these two crops would be essentially the same as in the base scenario. However, under Strategy C, sugar beet production would be 25 thousand tons lower than the base scenario, while potato output would decline by an insignificant amount.

In summary, the above discussion has shown that the constraints on fertilizer supplies for fall-planted crops would result in 207 thousand tons in foregone wheat output and 300 thousand tons in foregone barley output, based on the current SD fertilizer allocation strategy (Strategy A). Under Strategy B, aggregate output of barley, sugar beets, and potatoes would be the same as the current strategy, but wheat production would be 113 thousand tons higher. This is a clear indication that Strategy B would be superior to the current SD strategy. Barley production under Strategy C would be 127 thousand tons higher than the other two strategies. However, this increase in barley output would be at the expense of wheat and sugar beet production, which would be slightly lower than under Strategy B.

6.5.4 Impact of Allocation Strategies on National Income

The impact of the three fertilizer allocation strategies on national income is summarized in Table 6.18. The results show that, for approximately the same investment in fertilizer, the resulting increase in the economic value of crop production would be highest under Strategy C. In other words, the value of the additional 127 thousand tons in barley output would more than compensate for the slight decline in wheat and sugar beet production relative to Strategy B.

In normal years, net economic returns under Strategy C (6047 million SL) would exceed those under Strategy B (5473 million SL) by 574 million SL. These net returns would be 1532 million SL higher than those obtained under the current SD strategy (i.e., 6047 - 4515 million SL). Therefore, the results clearly indicate that Strategy C would be the most economically rational fertilizer allocation strategy.

The results in Table 6.18 also show that the combined economic impact of the constraints on fertilizer supplies and the inefficiencies of the current SD allocation strategy would amount to 2375 million SL in a normal year (difference between the base scenario and Strategy A). This would be equivalent to an increase of approximately 4.2% in the agricultural GDP. This economic impact can be broken down into three separate components:[1]

[1] All figures refer to net economic returns in normal years (refer to Table 6.18).

Table 6.18: AGGREGATE ECONOMIC IMPACT OF ALTERNATIVE FERTILIZER ALLOCATION STRATEGIES FOR THE WINTER SEASON Syria, 1989/1990

	Base Scenario	Strategy A	Strategy B	Strategy C
Fertilizer Use:				
N (tons):	111,042	77,731	75,958	77,801
P_2O_5 (tons):	67,480	40,742	40,905	40,049
		ECONOMIC PRICES (Million SL)		
Fertilizer Costs:	3,483	2,283	2,257	2,267
Gross Returns:				
- Good Year:	10,704	7,174	8,272	8,705
- Normal Year:	10,374	6,798	7,730	8,315
- Dry Year:	9,827	6,775	7,595	8,051
- Very Dry Year:	8,890	6,601	7,283	7,533
Net Returns:				
- Good Year:	7,258	4,891	6,015	6,438
- Normal Year:	6,890	4,515	5,473	6,047
- Dry Year:	6,343	4,492	5,338	5,783
- Very Dry Year:	5,407	4,318	5,026	5,266

1/ See Table 3.1 for the definitions of rainfall scenarios.
2/ Refer to text for the definitions of fertilizer allocation strategies.

1. Impact of the constraints on fertilizer supplies for the winter season amounting to 843 million SL (difference between the base scenario and Strategy C).
2. Impact of a priori conditions imposed by the priority-based SD allocation strategy, amounting to 574 million SL (difference between Strategies B and C).
3. Impact of basing fertilizer allocation decisions on the current SD recommended rates, which would amount to 958 million SL (difference between Strategies A and B).

6.5.5 Impact of Allocation Strategies on Farm Income

Similar conclusions can be reached as to which allocation strategy would contribute most to farm income. As shown in Table 6.19, under Strategy C, farmers' net returns in a normal year would be approximately 1.5 billion SL higher than net returns under the current SD strategy, and 500 million SL higher than Strategy B. The combined impact of limited fertilizer supplies and allocation inefficiencies on farm income would amount to approximately 2.6 billion SL in a normal year (difference in farmers net returns between the base scenario and Strategy A).

It should be noted that although Strategy C would substantially increase aggregate farm income in comparison to the current SD strategy, farmers growing irrigated crops would be worse off under Strategy C. This is especially true in the case of farmers growing irrigated wheat. The results clearly suggest that reducing the rates on irrigated wheat would not affect yields and, thus, would not affect farmers' gross returns. However, these farmers would be losing part of their

Table 6.19 IMPACT OF ALTERNATIVE FERTILIZER ALLOCATION STRATEGIES FOR THE WINTER SEASON ON FARMERS NET RETURNS TO FERTILIZER USE Syria, 1989/1990

	Base Scenario	Strategy A	Strategy B	Strategy C
Net Returns per Crop[1]:		(Million SL)		
Irrigated Wheat:	3,027	2,878	3,026	2,888
Rainfed Wheat:				
HYV Zone 1:	1,382	1,280	1,291	1,253
HYV Zone 2:	584	526	540	498
LYV Zone 1:	459	0	325	410
LYV Zone 2:	610	0	422	509
LYV Zone 3:	89	0	61	64
TOTAL RAINFED WHEAT:	3,123	1,806	2,638	2,734
Rainfed Barley:				
Zone 1:	106	0	0	80
Zone 2:	725	0	0	480
Zone 3:	344	0	0	0
TOTAL BARLEY	1,175	0	0	560
Sugar Beets:	202	200	202	192
Potatoes:	206	202	206	199
Aggregate Net Returns:				
- Good Year:	8,148	5,092	6,181	6,767
- Normal Year:	7,732	5,086	6,072	6,573
- Dry Year:	7,964	5,520	6,452	6,904
- Very Dry Year:	7,449	5,606	6,423	6,716

1/ Net returns in a normal year, based on financial prices.
2/ Refer to text for the definitions of fertilizer allocation strategies.
3/ See Table 3.1 for the definitions of rainfall scenarios.

fertilizer allotments, which they could have applied to other crops and fruit trees or sold on the parallel market.

6.5.6 Impact of Allocation Strategies on Foreign Exchange Earnings

The three alternative allocation strategies would require essentially the same amount of foreign exchange expenditures on fertilizer imports. However, as shown in Table 6.20, the differences in the value of net crop exports (increased exports and reduced imports) are substantial. Compared to the current SD strategy (Strategy A), the value of net crop exports under Strategy C are 13 million $US higher in normal years. Therefore, the shift from the current SD strategy to an allocation strategy based on equating marginal revenues across all crops (Strategy C) would increase net foreign exchange earnings in a normal year by 14 million $US (i.e., 47 - 33 million $US). This increase would range from 5 million $US (i.e., 15 - 10 million $US) in very dry years to 16 million $US (i.e., 55 - 39 million $US) in good years.

6.5.7 Impact of Allocation Strategies on the Government Budget

Finally, the impact of the three alternative fertilizer allocation strategies on government expenditures is presented in Table 6.21. Expenditures on fertilizer subsidies under the three strategies are essentially the same. However, given the differences in the composition of aggregate output between these strategies, revenues from indirect taxes on crop output would also differ. As mentioned earlier, the difference in aggregate output between Strategies A and B would be an additional 113 thousand tons of wheat produced under Strategy B. Thus, given that wheat is implicitly taxed, government revenues in a normal

Table 6.20: IMPACT OF ALTERNATIVE FERTILIZER ALLOCATION STRATEGIES FOR THE WINTER SEASON ON FOREIGN EXCHANGE EARNINGS
Syria, 1989/1990

	Base Scenario	Strategy A	Strategy B	Strategy C
	(Million $US)			
Import Value of Fertilizer:	71	47	46	46
Value of Increased Crop Exports and Reduced Imports[1]:				
- Good Year:	127	85	95	101
- Normal Year:	116	80	88	93
- Dry Year:	80	59	64	66
- Very Dry Year:	71	57	60	61
Net Increase[1] in Foreign Exchange Earnings:				
- Good Year:	56	39	49	55
- Normal Year:	45	33	42	47
- Dry Year:	9	13	18	20
- Very Dry Year:	0	10	14	15

1/ Relative to no fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.
3/ Refer to text for the definitions of fertilizer allocation strategies.

Table 6.21: IMPACT OF ALTERNATIVE FERTILIZER ALLOCATION STRATEGIES FOR THE WINTER SEASON ON THE GOVERNMENT BUDGET Syria, 1989/1990.

	Base Scenario	Strategy A	Strategy B	Strategy C
	(Million SL)			
Expenditures on Fertilizer Subsidies:	1,367	881	874	873
Increase[1] in Revenues from Indirect Taxes on Crops:				
- Good Year:	255	392	416	313
- Normal Year:	574	367	389	437
- Dry Year:	407	283	296	321
- Very Dry Year:	355	272	284	293
Net Increase[1] in Government Expenditures:				
- Good Year:	1,112	489	458	560
- Normal Year:	793	514	485	436
- Dry Year:	960	598	578	552
- Very Dry Year:	1,012	609	590	580

1/ Increase due to fertilizer use.
2/ See Table 3.1 for the definitions of rainfall scenarios.
3/ Refer to text for the definitions of fertilizer allocation strategies.

year would be 22 million SL higher under Strategy B (i.e., 389 - 367 million SL).

As mentioned earlier, under Strategy C there would be more barley and less wheat produced relative to Strategy B (see Table 6.17). Given that, during normal and drier years, indirect taxes on wheat are lower than those on barley, government revenues under Strategy C would be 48 million SL higher than under Strategy B (i.e., 437 - 389 million SL). During good years, barley is implicitly subsidized (refer to the discussion in chapter 4) and, thus, government revenues under Strategy C would be lower than the other two strategies (see Table 6.21). Therefore, except in good years, Strategy C would result in the smallest increase in government expenditures associated with fertilizer use. In normal years these expenditures would amount to 436 million SL compared to 514 million SL under the current SD strategy, a net decline of 78 million SL.

6.5.8 Alternative Fertilizer Allocation Strategies for the Winter Season: Summary and Policy Implications

The above analysis has clearly shown that an allocation strategy based on equating marginal revenues across all crops (Strategy C) would be the most appropriate strategy for fall-planted crops, given the existing constraints on fertilizer supplies. Such a strategy would require reducing the optimum fertilizer rates on irrigated crops by 15% to 25%. This would leave enough fertilizer to be allocated to LYV wheat and to barley in Zones 1 and 2. However, under the current constraints on fertilizer supplies, fertilization of barley in Zone 3 would not be economical. The reduction of fertilizer rates on irrigated crops would have a somewhat minor negative impact on aggregate production. However, this decline would be compensated by the substantial increase in rainfed wheat and barley output. In a normal year, this proposed strategy would increase wheat and barley output by 91 and 127 thousand tons, respectively, compared to the current SD strategy.

If the current SD strategy is replaced by the proposed strategy, national income in a normal year would increase by 1532 million SL, which is equivalent to a 2.7% increase in the agricultural GDP. Also, in normal years, farm income would increase by 1487 million SL, foreign exchange earnings would increase by 14 million $US, and government expenditures would decline by 78 million SL.

6.6 Chapter Summary

The main objective of this chapter was to analyze the impact of the constraints on fertilizer supplies and to compare alternative fertilizer allocation strategies under the current fertilizer supply constraints. Based on the linear programming model presented in chapter 3, the results in this chapter provided an illustration of how fertilizers would be allocated among competing crops under varying levels of the constraints on fertilizer supplies. These results were also used to estimate the impact of the constraints on fertilizer supplies on aggregate crop production, national income, farm income, and the government's foreign exchange and general budgets.

Current fertilizer supplies constitute approximately 60% of total fertilizer requirements of fall and spring-planted crops. The analysis has shown that the main effect of these supply constraints would be a substantial reduction in the fertilizer rates applied on rainfed crops, particularly on barley. In fact, the results clearly suggest that barley fertilization in Zone 3 would be uneconomical under the current constraints on fertilizer supplies. Thus, approximately 282 thousand tons of barley and 178 thousand tons of wheat would be foregone because of reduced fertilizer application.

Although fertilizer import costs would decline by 41 million $US, the value of increased crop imports would amount to 54 million $US in a normal year, a 13 million $US decline in foreign exchange earnings. This would imply a reduction of 1.9 billion SL in national income, while farm income would decline by 2.3 billion SL. These foregone incomes could be potentially obtained if the government would decide to import enough fertilizer to fill the gap between domestic production and total requirements. However, this would require an additional 600 to 800 million SL in fertilizer subsidies. Given the current severe constraints on the government budget, such a substantial increase in government expenditures would be very difficult to implement. A feasible policy option would be to increase official fertilizer prices, which are currently highly subsidized, particularly the price of P_2O_5.

The analysis has shown that, with unlimited fertilizer supplies, an increase of 7% to 16% in the price of N and 45% to 60% in the price of P_2O_5 would have a limited effect on fertilizer use, aggregate crop output, foreign exchange earnings, and national income. The main impact would be to redistribute income from farmers to the government budget. However, the unlimited access to fertilizer would allow farmers to increase their output, which would lead to higher revenues that would offset any increase in fertilizer costs.

Compared to the current situation of constrained fertilizer use, farmers' income would increase by at least 1.5 billion SL in a normal year, in spite of the higher fertilizer prices. On the other hand, total expenditures on fertilizer subsidies would not be significantly affected, while government revenues from indirect taxes on crops would substantially increase due to higher crop output. Thus, the net effect would be a reduction in net government expenditures associated with fertilizer use.

Given the frequent disruptions in domestic production and delays in imports, fertilizer shortages in the past few years have had serious effects on fall-planted crops in particular. Thus, the analysis focused on comparing alternative fertilizer allocation strategies for the winter season, with the 1989/90 season as an example. The current strategy adopted by the Soils Directorate (SD) gives priority to the fertilization of irrigated crops, followed by rainfed HYV wheat, LYV wheat, and barley. Based on this strategy, and given available fertilizer supplies for the 1989/90 winter season, no fertilizer would be left to be allocated to barley or LYV wheat.

In contrast, a strategy based on equating marginal revenues across all crops, with no a priori conditions, would allow moderate fertilization levels for LYV wheat and for barley in Zones 1 and 2. Such a strategy would require reducing fertilizer rates on irrigated crops by 15% to 25%, which would result in relatively minor declines in aggregate output. However, such declines would be offset by the substantial increases in wheat and barley production amounting to 91 thousand tons and 127 thousand tons, respectively.

Thus, a shift from the current SD strategy to the above proposed strategy would significantly improve the economic efficiency of fertilizer application on fall-planted crops. Given the existing levels of fertilizer supplies, such a shift would increase farm income by approximately 1.5 billion SL in a normal year, an increase of about 2.7% in agricultural GDP. Furthermore, this shift would increase foreign exchange earnings by 14 million $US and reduce net government expenditures associated with fertilizer use by 78 million SL. Therefore, this proposed fertilizer allocation strategy would be the most economically rational strategy from the viewpoint of the economy as a whole and for farmers, in addition to being feasible under the government's foreign exchange and budgetary constraints.

CHAPTER 7

SUMMARY, POLICY IMPLICATIONS AND FUTURE RESEARCH

7.1 The Research Objectives and Approach: A Recapitulation

The main purpose of this study was to develop a national model for the centrally planned allocation of limited fertilizer supplies in Syria. This economic decision model was developed as a tool to be used by Syrian decision makers to plan more economically efficient annual fertilizer allocation schemes. Also, the model was used to estimate the economic impact of the proposed fertilizer allocation strategy in comparison with the current strategy adopted by the government. Furthermore, the model served as the main analytical framework for estimating the economic implications of the current constraints on fertilizer supplies, and for evaluating possible means for removing these constraints.

The main underlying hypothesis of this proposed model is that a fertilizer allocation strategy based on equating marginal revenues across all crops is more economically efficient than the current government strategy. The current strategy is strongly influenced by policy concerns such as national food self-sufficiency and the balance of trade deficit. Thus, priority in fertilizer allocation is given to major export crops (e.g. cotton) and to crops that substitute for the main food imports (e.g. wheat). Also, fertilizer allocation to irrigated crops has priority over rainfed crops, particularly rainfed barley in the drier zones, which is rarely allocated any fertilizer.

Given the constrained optimization nature of the fertilizer allocation problem, the economic model was formulated in terms of a linear programming (LP) model. The objective function consists of maximizing the economic value of the increase in aggregate crop output due to fertilizer application, minus the value of total fertilizer quantities used. The main constraint in the model is the upper limit imposed on aggregate fertilizer supplies available for distribution to farmers during a given growing season. Such a formulation of the model allows for estimating economically optimum fertilizer rates for all crop activities covered by the model, under alternative levels of available supplies.

The model's input/output matrix is based on the results of fertilizer experiments undertaken in Syria between 1965 and 1989. These experiments provided sufficient reliable data to estimate quadratic production functions for the most important crops grown in Syria: wheat, cotton, barley, sugar beets, potatoes, and corn. These crops account for approximately two-thirds of total fertilizer consumption. Given the limited use of potassium fertilizers in Syria, only nitrogen (N) and phosphate (P_2O_5) fertilizers were included in the model.

The first step in the research approach consisted of estimating production functions for the crops in the model. Based on these functions, economically optimum fertilizer recommendations for each crop were computed. These recommendations were calculated by equating marginal costs with marginal revenues, assuming no constraints on fertilizer supplies and based on the true economic value of fertilizers

and crops. In the next step, linear approximations of the estimated quadratic production functions were obtained by dividing the functions into linear segments, which were then incorporated into the LP model using separable programming methods.

The optimum solution of the LP model provided estimates of the fertilizer rates that would maximize national economic net returns to fertilizer use under the existing constraints on aggregate supplies. These rates were then compared to the rates stipulated in the current allocation strategy adopted by the government. The policy objective of maximizing net economic returns from fertilizer use was used as the key criterion in evaluating alternative allocation strategies. These strategies were also compared in terms of their contribution to achieving other important policy objectives, including: (1) increasing aggregate crop output, (2) increasing farmers' income, (3) reducing foreign exchange expenditures, and (4) reducing the government budget deficit.

The same criteria were used in assessing the impact of the current constraints on fertilizer supplies. This was done by comparing the results of the model under the current supply levels with those obtained under the ideal scenario of unconstrained supplies. These comparisons constituted the basis for identifying some of the obstacles to achieving the objectives of fertilizer policy and for assessing possible means to removing these obstacles.

7.2 Summary of the Major Findings

7.2.1 Fertilizer Recommendations under Unconstrained Supplies

Fertilizer recommendations were defined as the economically optimum rates under no constraints on aggregate fertilizer supplies. These rates were computed by equating marginal costs with marginal revenues based on the estimated production functions and the true economic value of fertilizers and crops. The results showed that these proposed recommendations would be profitable for farmers and economically feasible from the viewpoint of the economy as a whole. Furthermore, a sensitivity analysis of the results, using a minimum Value-Cost-Ratio (VCR) criterion of 1.5, clearly suggested that the proposed recommendations would constitute reasonably safe investments for farmers and for the economy as a whole.

A comparison between the proposed and current recommendations clearly indicated the need for some major readjustments in the current recommendations, particularly on wheat and barley. Current fertilizer rates on wheat, especially P_2O_5 rates, need to be substantially reduced. The current N and P_2O_5 rates on low-yielding wheat varieties (LYV) are particularly excessive. These rates are, on the average, twice as large as the rates proposed in this study. In contrast, fertilizer rates on barley need to be increased significantly, especially P_2O_5 rates. This is particularly true in the drier areas (Zone 3)[1], where the proposed N and P_2O_5 rates are almost twice as large as the current ones. The

[1] Refer to chapter 2 for the definitions of agro-climatic zones.

differences between the proposed and current fertilizer recommendations for the other crops are close.[1]

7.2.2 Alternative Fertilizer Allocation Strategies

The constraints on fertilizer supplies during the past few years were generally more serious during the winter season (fall-planted crops) than for spring-planted crops, which usually receive all their fertilizer requirements. Thus, the analysis focused on comparing alternative fertilizer allocation strategies for the winter season only. Using the 1989/90 winter season as an example, three alternative fertilizer allocation strategies were examined:

- Strategy A:

This is the allocation plan adopted by the government for the 1989/90 winter season. It stipulates that irrigated crops should receive all their fertilizer recommendations, rainfed wheat should receive 80% of the recommended rates, and barley in the wetter areas should receive 50% of the recommended rates. No fertilizer was allocated to barley in the drier areas (Zone 3). However, given the delays in the delivery of fertilizer imports, the actual quantities of fertilizer available were barely sufficient to satisfy the plan's stipulations for irrigated crops and only part of the stipulations for rainfed high-yielding wheat varieties (HYV). No fertilizer was left to be applied on local wheat varieties (LYV) or barley.

---

[1] Refer to Table 5.2 for a listing of the proposed and current fertilizer recommendations.

- Strategy B:

This strategy is based on the same set of priorities stipulated by Strategy A, but all the fertilizer rates are based on the proposed recommendations estimated in this study, rather than the current recommendations. Given that the proposed recommendations are significantly lower for wheat, particularly irrigated wheat, enough fertilizer would be left to apply 80% of the proposed rates on rainfed HYV wheat, as stipulated by the plan. However, the remaining fertilizer quantities would allow the application of only 50% of the proposed rates on LYV wheat, instead of the stipulated 80%. As in the case of Strategy A, there would be no fertilizer left for barley fertilization.

- Strategy C:

This strategy is based on the optimum solution obtained by the LP fertilizer allocation model. It is based on the principle of equating marginal revenues across all crops, with no a priori conditions. Therefore, this strategy is more flexible since it allows for reducing the fertilizer rates on irrigated crops. Given the available supplies, the results indicated that an economically optimal allocation would require reducing the unconstrained optimum rates on irrigated crops by 15% to 25%. This would allow moderate fertilization levels for LYV wheat and for barley in the wetter areas (Zones 1 and 2). However, as with the above two strategies, no fertilizer would be allocated to barley in the drier areas (Zone 3).

A comparison of the economic impact of the above three strategies showed that a strategy based on equating marginal revenues across all crops (Strategy C) would give the highest economic net returns to the use of the limited fertilizer supplies. In a normal year, these economic net returns would amount to 6.1 billion Syrian Liras (SL)[1], compared to 4.5 billion SL under the current government strategy (Strategy A). This represents a 35% increase in the economic efficiency of fertilizer use and an increase of 2.7% in the agricultural GDP. Also, compared to Strategy A, farm income under Strategy C would increase by an average of 1.5 billion SL and foreign exchange earnings by 14 million $US, while net government expenditures would decline by 68 million SL.

7.2.3 Implications of the Constraints on Fertilizer Supplies

The main effect of the current constraints on fertilizer supplies is the substantially reduced fertilizer use on rainfed cereals, particularly barley. Thus, an average of 282 thousand tons of barley and 178 thousand tons of wheat are foregone because of the current constraints on fertilizer use. As noted earlier, the results clearly suggest that barley fertilization in the drier areas (Zone 3) would be uneconomical under the current constraints on fertilizer supplies.

The value of the additional crop imports needed to compensate for this foregone crop output would amount to 54 million $US in a normal year. This represents 13 million $US more than the 41 million $US in additional fertilizer imports needed to satisfy total fertilizer requirements. This implies a decline of 7% in foreign exchange reserves, a reduction of 1.9 billion SL in national income, and a 2.3 billion SL decline in farm income. These economic losses could be regained if the government adopts a policy of allocating enough foreign

---

[1] 1 $US = 40 SL (refer to chapter 4).

exchange to import all the fertilizer needed to fill the gap between domestic production and optimum requirements.

An important precondition to implementing this policy is the government's willingness and ability to increase its current expenditures on fertilizer subsidies by 600 to 800 million SL. Given the current severe constraints on the government budget, such a substantial increase in expenditures would be difficult to implement. A potential solution to this problem is to reduce fertilizer subsidies by raising official fertilizer prices. These prices are currently highly subsidized, representing only 67% and 49% of the true economic value of N and P_2O_5 fertilizers, respectively. However, higher fertilizer prices may force farmers to reduce their fertilizer application rates. This, in turn, could lead to lower crop output and may result in reduced aggregate national income. Also, higher prices would increase farmers' production costs and may, thus, result in reduced farmers' income. Consequently, an important policy question is whether a strategy based on increasing fertilizer imports to satisfy total requirements, in conjunction with higher fertilizer prices, would be more economically efficient than the current policy of subsidized but limited fertilizer supplies.

The analysis has shown that, with unconstrained fertilizer supplies, an increase of about 7% to 15% in the price of N and 45% to 60% in the price of P_2O_5 would have a limited effect on fertilizer use, aggregate crop output, foreign exchange earnings, and national income. The higher fertilizer prices would increase farmers' fertilizer costs. However, the unlimited access to fertilizer would allow farmers to increase their output and lead to higher revenues that would offset any increase in fertilizer costs. Compared to the current situation of constrained fertilizer use, farmers' income would increase by at least 1.5 billion SL in a normal year, in spite of higher fertilizer prices. Most of this gain in farm income would benefit farmers growing rainfed crops, particularly barley.

The combination of lower fertilizer subsidies and increased fertilizer use by farmers would result in a situation where total expenditures on fertilizer subsidies would not be significantly different from their current levels. In contrast, government revenues from indirect taxes on crops would substantially increase due to higher crop output. Thus, as shown by the results, the net effect would be a reduction in net government expenditures associated with fertilizer use, amounting to at least 60 million SL in a normal year.

7.3 Policy Implications

7.3.1 Fertilizer Policy Objectives and Options

The main stated objective of fertilizer policies in Syria is to increase agricultural production, which in turn would increase the income of farmers, increase food self-sufficiency, and reduce the balance of trade deficit by increasing agricultural exports and reducing imports. Currently, there are three main constraints preventing the full implementation of such policies: (1) technical and managerial problems facing domestic fertilizer production; (2) limited foreign exchange resources available for importing fertilizers; and (3) heavy fertilizer subsidies that constrain the government budget.

During the past few years, the government has resorted to limiting fertilizer imports in an effort to reduce its foreign exchange deficit and the trade deficit in general. Such a strategy can be effective only if domestic fertilizer production levels are increased to substitute for any decline in imports. This could be achieved by solving the problems facing fertilizer production and/or by expanding production capacity. However, the recent downward trends in fertilizer production clearly suggest that production problems are likely to continue to hamper the Syrian fertilizer industry for the next few years. Also, any planned expansion in production capacity would require several years to implement and would still be subject to the same foreign exchange constraints facing fertilizer imports.

Therefore, the option of increasing fertilizer production levels is feasible only in the medium or long run. In the meantime, any reduction in fertilizer imports could only lead to fertilizer shortages. In fact, the combined quantities of fertilizer domestically produced and imported are at present barely sufficient to satisfy 60% to 70% of aggregate fertilizer quantities demanded by farmers, given the existing heavily subsidized prices. The results of this study showed that these fertilizer shortages have resulted in reduced aggregate crop production, including export crops and crops that substitute for major food imports. These declines in net crop exports offset any savings in foreign exchange due to lower fertilizer imports. Therefore, as indicated by the results, the net impact of the current policy of limited fertilizer imports is to further exacerbate the balance of trade deficit and the government's foreign exchange deficit. Furthermore, this policy significantly reduces the aggregate income of farmers and national income in general.

Therefore, the results of this study clearly suggest that the objectives of fertilizer policies would be more effectively achieved if current fertilizer import and allocation policies are modified. Based on these results, several policy options involving various possible adjustments or modifications to current policies are examined. These policy options are: (1) current fertilizer allocation strategy based on the proposed fertilizer recommendations; (2) equimarginal allocation of limited supplies; (3) unrestricted fertilizer imports at current official prices; and (4) unrestricted fertilizer imports with higher official prices.

7.3.2 Current Fertilizer Allocation Strategy Based on the Proposed Fertilizer Recommendations

The current approach used by Syrian government planners in allocating the limited fertilizer supplies among various crops is to reduce the recommended rates by a given percentage. This percentage varies from crop to crop depending on the amounts of fertilizer available and depending on the importance of the crop based on the set of policy-determined priorities discussed earlier. Therefore, the accuracy of the current fertilizer allocation strategy depends to a large extent on the accuracy of the fertilizer recommendations.

The results of this study have indicated the need for some major readjustments in the current recommendations, particularly those on wheat and barley. Should the government decide to maintain the current restrictions on fertilizer imports and to continue allocating the limited supplies based on the existing priority system (i.e., Strategy B), then the mere readjustments in the fertilizer recommendations would substantially enhance the efficiency of fertilizer use in Syria. As shown by the results, this would increase national income by an average of 958 million SL per year.

7.3.3 Equimarginal Allocation of Limited Fertilizer Supplies

A further improvement in the efficiency of fertilizer use can be obtained by replacing the current priority-based strategy for allocating the limited fertilizer supplies with a strategy based on equating marginal revenues across all crops. Such a strategy can be implemented using the linear programming allocation model developed in this study. The results have shown that if this model is used as a basis for allocating the limited fertilizer supplies, national income would increase by an additional 574 million SL (i.e., in addition to the 958 million SL increase in national income due to the proposed readjustments in the fertilizer recommendations).

It should be noted that the abandonment of the policy-determined priority system for fertilizer allocation does not contradict the policy priorities themselves. These priorities are based on the policy objectives of increasing national food self-sufficiency (mainly in wheat) and reducing the balance of trade deficit. The results have indicated that these policy objectives would be better achieved under the proposed allocation strategy. Compared to the current government strategy, the proposed strategy would increase wheat and barley output and foreign exchange earnings. Therefore, the results of this study have clearly demonstrated that an allocation strategy based on equating marginal revenues across all crops would ensure a more efficient use of the limited fertilizer resources as well as increasing wheat self-sufficiency and reducing the balance of trade and foreign exchange deficits.

7.3.4 Unrestricted Fertilizer Imports at Current Official Prices

A further step that the government could take to improve the efficiency of fertilizer use is to allocate sufficient foreign exchange to allow for importing the fertilizer quantities needed to fill the gap between domestic production and total requirements. It should be noted that such a policy would not necessarily eliminate the need for fertilizer rationing. This is because fertilizer recommendations and aggregate requirements were computed with the objective of maximizing net returns to the economy as a whole rather than farmers' net returns from fertilizer use. Farmers' optimum rates are generally higher than the proposed economic rates and, thus, the quantities demanded by farmers are likely to exceed the calculated total requirements. Also, rationing would be necessary since unlimited access to the heavily subsidized fertilizers may encourage smuggling to neighboring countries where fertilizers are more expensive.

As mentioned earlier, that such a policy would require approximately 41 million $US in additional fertilizer imports. As a result, the value of increased net crop exports (increased exports and reduced imports) would amount to 54 million $US in a normal year. Therefore, the net impact of the current policy of restricted fertilizer imports would be to reduce the government's net foreign exchange earnings. This is in contradiction with the initial objective of reducing the government's foreign exchange deficit by restricting fertilizer imports.

Therefore, as long as domestic production cannot satisfy all of Syria's fertilizer requirements, the results of this study clearly suggest that the government ought to increase fertilizer imports to cover the difference. This policy of unrestricted fertilizer imports would increase national income by an average of 843 million SL. The combined economic impact of lifting import restrictions, the equimarginal allocation of fertilizers, and the proposed readjustments in the fertilizer recommendations would amount to an average of 2375 million SL per year. This is equivalent to an increase of 4.2% in the agricultural GDP.

Although such a policy option would substantially enhance the efficiency of fertilizer use in Syria and the productivity of the agricultural sector in general, there exist two potential obstacles to implementing this policy. The first obstacle is the centrally planned allocation of the scarce foreign exchange resources. This implies that fertilizer imports are competing with other sectors of the economy that are equally constrained by import restrictions on raw materials, equipment, spare parts, and so forth. This is particularly important given the magnitude of the additional fertilizer imports needed, which would consume up to 20% of total foreign exchange reserves.

The results of this study have demonstrated that the economic returns to the additional fertilizer imports can be substantial. However, investing the scarce foreign exchange resources in other sectors of the economy might result in even higher returns than fertilizer imports. Also, the decision on how to allocate the scarce foreign exchange among the different sectors of the economy is essentially a political decision, with economic returns to investment often playing only a secondary role in that decision. Thus, the scope of this study is limited to estimating the potential economic impact of the proposed policy of increased fertilizer imports. However, it is up to policy makers to decide whether this impact is sufficiently large to justify the implementation of such a policy.

The second obstacle to implementing a policy of increased fertilizer imports is the heavy burden of fertilizer subsidies on the government budget. Such a policy would require the government to spend up to 800 million SL in additional fertilizer subsidies. However, given the serious budgetary constraints facing the Syrian government, increasing expenditures on fertilizer subsidies would exacerbate the government budget deficit.

Given that the government budget deficit is usually financed through inflationary expansion of the money supply, increased expenditures on fertilizer subsidies might further exacerbate the already high inflation rate. In Syria, the most direct effect of inflation is to reduce the purchasing power of public sector employees, who constitute the majority of the urban middle and lower-middle classes. Thus, higher inflation would be highly unpopular and, hence, politically undesirable. Therefore, any increase in expenditures on fertilizer subsidies would have to be either at the expense of reducing public expenditures on other sectors of the economy, or through tax increases. As with the allocation of foreign exchange resources, the decision of how to allocate public spendings is influenced by relative economic returns to public investments in each sector as well as political factors.

7.3.5 Unrestricted Fertilizer Imports with Higher Official Prices

It is clear from the above discussion that the burden of fertilizer subsidies on the government budget constitutes an important obstacle to implementing a policy of increased fertilizer imports. This budgetary constraint can be eliminated if official fertilizer prices are increased. As shown by the results, an increase of about 7% to 15% in the current price of N and 45% to 60% in the price of P_2O_5 would ensure that the current expenditures on subsidies would remain approximately the same.

Furthermore, these substantial reductions in subsidies would bring domestic fertilizer prices closer to their international market equivalents. With the proposed higher prices, subsidies would still represent 20 to 30% of the true value of fertilizers. However, this subsidy level would significantly reduce the incentives for smuggling fertilizers out of Syria. Thus, a policy of increased fertilizer imports in conjunction with higher official prices would not require fertilizer rationing. In other words, farmers would be able to purchase all the fertilizer they need to maximize their net returns.

Given the differences between farmers' prices and the true value of fertilizers and crops, this unlimited access to fertilizers may result in an economically inefficient use of fertilizers. However, the results have shown that, with the higher fertilizer prices, farmers' optimum rates would be very close to the calculated economic optima. Also, it should be noted that the proposed increase in the price of P_2O_5 is more drastic than for N. This is because the current price of P_2O_5 represents only 49% of its true economic value, compared to 67% in the case of N. Recent research findings strongly suggest that farmers may be applying excessive P_2O_5 rates, particularly on wheat (Soils Directorate/ICARDA, 1988, pp. 10-13). Therefore, the more drastic increase in the price of P_2O_5 may dissuade farmers from applying excessive P_2O_5 rates.

The results of this study suggest that the proposed higher prices would have a limited effect on the fertilizer rates that would maximize farmers' net returns. Farmers' unlimited access to fertilizers would allow them to apply these rates and to increase their revenues from the higher yields. These higher revenues would offset the increase in fertilizer costs. Therefore, in spite of higher fertilizer prices, farmers' net returns would be higher than under the current situation of subsidized but limited fertilizer use.

It should be noted that the above results were based on the fertilizer demand equations computed based on the estimated production functions. These demand equations were formulated in terms of the effect of fertilizer prices on the quantities of fertilizer applied. However, fertilizer prices are not the only factors affecting the demand for fertilizers. Other factors, such as crop prices and the farmer's cash flow situation, could be equally important. Furthermore, the normative demand equations computed in this study were derived from production functions based on data from fertilizer research experiments, which are seldom representative of farmers conditions and constraints.

The above discussion suggests that the results of this study should be viewed with caution, especially with regard to farmers' response to higher fertilizer prices. Thus, if the proposed price increases are to be implemented, this should be done gradually over several years. If there is evidence that farmers are reducing their fertilizer rates in response to higher prices, compared to the current rates under limited supplies, then a re-evaluation of the price-increase policy would become necessary.

This cautionary note on the possible negative impact of higher fertilizer prices is particularly relevant with respect to crops, such as barley, where fertilizer use is still limited. The Ministry of Agriculture and Agrarian Reform has recently initiated a program to promote barley fertilization through demonstration plots located in the main barley-growing regions. Also, major efforts by the Agricultural Extension Directorate to encourage farmers to adopt barley fertilization are planned for the next few years. The success of these efforts depends to a large extent on the high rate of return that farmers would expect from barley fertilization. The results of this study have confirmed previous research findings showing that barley fertilization is profitable and reasonably safe (see Soils Directorate/ICARDA, 1990). However, higher fertilizer prices will reduce the farmers' expected rate of return and may, thus, act as a disincentive to fertilizer use.

The rate of return to barley fertilization can be increased through higher official barley prices that would offset the increase in fertilizer prices. However, such an option may not be feasible given its potential heavy burden on the government budget. Also, higher official barley prices would contribute to a further increase in feed costs, which could have a serious negative impact on livestock production in Syria. Furthermore, higher feed prices may encourage livestock producers to rely more on natural pastures as substitute sources of feed. This could further exacerbate the already serious problem of overgrazing in the steppe. Therefore, given the importance of barley in Syrian agriculture and its complex linkages with the rest of the economy, the option of increasing official barley prices should be examined in a much broader context than the limited objective of encouraging fertilizer use on barley. This is beyond the scope of this study and can only be addressed through a comprehensive empirical analysis of the barley sub-sector.

Thus, there might be a strong argument in favor of maintaining the lower fertilizer prices as long as a large number of farmers do not apply fertilizer on their crops. However, cheap fertilizers may lead to excessive use on crops, such as irrigated wheat and cotton, where application rates may be already too high. This would not only result in uneconomical uses of the limited fertilizer resources, but may also lead to water pollution problems such as the nitrate buildup in the watertable.

One possible solution to the above dilemma, which needs to be addressed in future evaluation of fertilizer price policies, would be to implement a two-price system for fertilizer sales. According to this system, a portion of total fertilizer supplies would be allocated to farmers at current low prices, while the remaining supplies would be sold at the higher prices. This system would be similar to the present system of fertilizer rationing and allocation. The only difference is that farmers would have the option of purchasing all their fertilizer needs at the higher prices, if their rations are not sufficiently large to maximize their net returns.

A two-price system for fertilizers would ensure that all farmers would have unlimited access to fertilizers. Such a system could also be useful in easing the transition from low to high fertilizer prices.

Thus, while prices are gradually being increased, farmers would still have access to cheap fertilizer rations that would dampen the impact of higher prices. However, as long as subsidized fertilizers are rationed, the fertilizer parallel market would continue to operate. The importance of the parallel market would depend to a large extent on the margins between the two sets of fertilizer prices. If these margins are gradually reduced, then the parallel market could ultimately disappear.

A two-price system may also allow the government to promote fertilizer use on specific crops, such as barley, or to favor poorer farmers in the drier zones, as suggested by El-Sherbini and Sinha (1978, p. 94)[1]. It should be noted that if farmers make production decisions on the basis of marginal costs, and if their ration does not fulfill all their fertilizer needs, they will make their fertilizer application decisions based on the higher prices. Thus, a two-price system would not necessarily induce barley farmers to increase their fertilizer rates. On the other hand, the two-price system would reduce <u>average</u> fertilizer costs and would, thus, increase the average rate of return to barley fertilization. This would encourage farmers who are currently applying no fertilizer on barley to experiment with and ultimately adopt barley fertilization.

---

[1] See also Akinola (1987) for a similar suggestion concerning input subsidies in Africa.

7.3.6 Other Policy Issues

7.3.6.1 Role of Fertilizers in Increasing Wheat Self-Sufficiency

The policy objective of increasing national food self-sufficiency, particularly in wheat production, and the role of fertilizers in attaining this objective are important policy issues that deserve further discussion. The results of this study indicated that all the current fertilizer recommendations on wheat are excessive. Most of these rates, P_2O_5 rates in particular, are so excessive that they exceed the rates that would maximize yields.

Based on discussions with agronomists from the Soils Directorate, two important factors that contributed to this situation of possible excessive fertilizer use on wheat were identified. The first factor is that most of the wheat recommendations were computed based on fertilizer trials conducted in the early 1970's. These trials were performed on research and farm plots not previously fertilized. Thus, the calculated rates for the most part reflect initial low soil fertility levels. By the late 1980's, after two decades of fertilizer application by farmers, there is clear evidence of substantial buildup of soil nutrients, particularly phosphate, resulting in a reduced response of wheat to fertilizer application (ICARDA/FRMP, 1988, pp. 10-13).

The second factor that contributed to the excessive fertilizer recommendations on wheat is the political pressure on policy makers. Given that wheat self-sufficiency is an important political issue in Syria, policy makers and planners at the Ministry of Agriculture and Agrarian Reform are under constant political pressure to increase wheat self-sufficiency. Thus, fertilizer requirement and allocation decisions during the past decade were often influenced by such political pressure, leading to the gradual increase in the recommended fertilizer rates on wheat.

The results of this study strongly suggest that the role of fertilizers in increasing wheat self-sufficiency in Syria has become increasingly limited. Therefore, the excessive use of the limited fertilizer supplies to further increase wheat yields could only lead to an inefficient use of resources. Policy makers, planners, and agronomists should explore other means to increasing aggregate wheat output. These include increasing the official price of wheat and intensifying the use of other inputs such as irrigation, high-yielding varieties, pest and weed control, cultural practices, and so forth.

7.3.6.2 Barley Fertilization in the Drier Zones

Another important issue, which is directly related to concerns about the potential excessive use of fertilizers on wheat, is the current policy debate on whether to reallocate some fertilizer from wheat to barley grown in the drier areas. This is based on results from recent fertilizer experiments on barley in northern Syria conducted jointly by the Soils Directorate and ICARDA. The results of these experiments suggest that barley fertilization in the drier areas (Zone 3) might be much more profitable and less risky than was previously thought (Soils Directorate/ICARDA, 1990). Based on these results, economic optimum rates on barley in Zone 2 were estimated at 54 and 49 kg/ha for N and P_2O_5, respectively, whereas optimum N and P_2O_5 rates on barley in Zone 3 were estimated at 56 and 44 kg/ha (ibid., p. A16, Table 20).

In contrast, the results of this study showed that, under the current constraints on total fertilizer supplies for fall-planted crops, optimum N and P_2O_5 rates on barley in Zone 2 would be 30 and 10 kg/ha, respectively, whereas barley fertilization in Zone 3 would be uneconomical. Therefore, the results of this study suggest that the current government policy of not allocating any fertilizer to barley in Zone 3 is economically sound given the existing constraints on aggregate fertilizer supplies. However, these results also suggest that fertilizer rates on wheat should be reduced to allow for moderate fertilization levels on barley in Zones 1 and 2.[1]

It should be noted that, in this study, the production functions for barley were estimated based on the assumption that barley farmers, being risk averse, would make their fertilizer application decisions by assuming a worst-case scenario (maximin assumption). That is, they would assume that the coming season is going to be a dry one and would, thus, apply the rates that would maximize their net returns in the event of a dry year. These rates are necessarily lower than those calculated based on the expectation of a normal year, had we assumed that barley farmers were risk neutral.

This assumption of worst-case scenario may be one of the reasons why the optimum rates on barley estimated in this study are lower than those estimated in the SD/ICARDA study mentioned earlier. Another possible reason for this discrepancy is that the optimum rates in the SD/ICARDA study were computed based on financial fertilizer and crop

---

[1] Refer to Table 6.15 (Strategy C) for the details of the proposed fertilizer reallocations from wheat to barley, given the current constraints on total fertilizer supplies available for the winter season.

prices, i.e., the actual prices faced by farmers. However, the results of this study showed that the use of financial prices may lead to an economically inefficient use of fertilizers. This is particularly true in the case of barley, where the relative product-to-fertilizer price ratio is substantially higher when calculated based on financial prices compared to a ratio based on economic prices.

Since the fertilizer recommendations on barley proposed in this study were based on somewhat conservative assumptions, these rates should, thus, be viewed as minimum levels. The results clearly suggested that there is ample space to gradually increase these rates in the future. Furthermore, an essential step in increasing fertilizer use on barley would be to expand fertilizer application to most barley areas. If the required fertilizer supplies are made available, the results have shown that the use of fertilizers by most barley farmers would result in an average production increase of 800 thousand tons over the current level of 1.1 million tons in aggregate barley output.

These potential increases in barley production are in line with stated government policy objectives. However, for these objectives to be attained, the government should follow a policy of ensuring the availability of sufficiently large fertilizer supplies to economically justify barley fertilization. Furthermore, the current efforts by the agricultural extension services to expand the adoption of barley fertilization should be intensified. Also, since barley is grown mostly in the drier and more remote areas of Syria, increasing farmers' access to fertilizer retail outlets would be crucial to the success of any policy aimed at increasing fertilizer use on barley.

The current government strategy to increase barley production is based on expanding its area of cultivation. This has meant expanding barley cultivation into the ecologically fragile lands of the steppe (Zone 5). Also, farmers are currently encouraged to replace the traditional barley-fallow rotation with continuous barley cultivation. This, however, may cause rapid depletion of soil nutrients and the buildup of diseases and insects, as suggested by discussions with agronomists from the Soils Directorate and ICARDA. This would ultimately lead to a decline in yields and, possibly, in total barley production. Therefore, in the long run, barley fertilization may constitute a more economically and ecologically sound policy option for a more sustainable growth in barley production in Syria.

7.4 Implications for Future Research

This study was entirely based on secondary data. No attempt was made to generate any primary data given the resource and time limitations. The existence of relatively large sets of fertilizer trial data made it possible to entirely rely on these secondary data in estimating the production functions which constitute the core of the fertilizer allocation model. Thus, the main idea was to make the best use of all the available fertilizer trial data. By relying on pooled statistical analysis techniques, it was possible to use data from different years and from different locations to come up with what we believe to be the most accurate estimates possible, given the existing data. Hence, the accuracy and relevance of the results presented in this study are largely dependent on the accuracy and relevance of the existing fertilizer trial data sets.

For this reason, future research efforts should concentrate on generating yield response data to fertilizer application that are more accurate and more representative of actual farm conditions. These research efforts on fertilizer yield responses should include the following:

1. Future fertilizer experiments should be designed to estimate fertilizer recommendations for more specific recommendation domains for each crop or variety. Most current recommendations are made for the country as a whole. However, yield responses to fertilizer application may vary tremendously from region to region and within the same region due to variation in soil type, rainfall levels and distribution, cultural practices, and so forth. Although some region-specific data already exist, especially in the case of wheat and cotton, most of these data are outdated and uneven in terms of quality and research design.

Thus, future research should include a more systematic and concentrated effort at designing experiments aimed specifically at the development of region-specific fertilizer recommendations. Such experiments should be undertaken on farmers' fields and be preferably managed by farmers themselves, with minimum interference from researchers, to ensure that yield response data are representative of actual farmers' conditions. After decades of fertilizer trials in research stations, with the likely buildup of soil nutrients, yield responses observed in experimental plots are probably becoming less and less representative of farmers' conditions. Furthermore, the design of these experiments should include measurements of the residual effects of fertilizer applications in order to incorporate fertilizer carry-over effects into the economic analysis of fertilizer use.

2. More attention should be given to fertilizer research on crops and fruit trees that have not been adequately studied yet, if at all. This is especially relevant with respect to fruit trees, such as olives, grapes, and citrus, which are becoming increasingly important in terms of total area, contribution to farm income, and their potential consumption of large quantities of fertilizer. The same lack of fertilizer trial data can also be observed with respect to barley in Zone 4, vegetables, food and feed legumes, forage crops, and natural pastures. Given that the fertilizer allocation model developed in this study should, ideally, include all fertilizer use activities, the exclusion of the above crop and fruit tree categories represents a serious weakness that ought to be addressed in the future.

3. Attempts should be made to try alternative formulations for estimating the production functions. The quadratic polynomial formulation gave generally acceptable results. The main problem encountered as a result of the quadratic formulation was in the case of wheat. When the estimated production functions for wheat were solved for the current excessive recommended rates, the results obtained suggested that yields would decline if these rates were actually applied.

Although most agronomists from the Soils Directorate and ICARDA seem to agree that the current rates are too high, they have questioned the validity of the yield-decline implication. They suggested that a more commonly observed response to very high fertilizer rates, especially phosphorus rates, is that of a yield plateau. This problem was addressed in this study by assuming that the current rates on wheat would give the same yield as that obtained by the lower yield-maximizing rates (refer to chapter 5). A more appropriate approach would have been to re-estimate the wheat production functions using other functional forms such as the Mitscherlich function or the linear response and plateau (LRP) function (refer to the discussion of functional forms in chapter 3).

Furthermore, alternative functional forms will be needed if the residual effect of applied fertilizers is to be incorporated into the analysis. This would allow more appropriate modeling of yield response to fertilizer application and would lead to more accurate economic analyses of fertilizer use. However, this would require the implementation of more accurate soil testing procedures by the Soils Directorate to generate the required data.

4. In addition to the basic reliance on on-farm fertilizer trials to determine optimum fertilizer recommendations, more use should be made of farm surveys to complement the information obtained from fertilizer trials. Farm surveys would be most useful in the case of crops where fertilizers have been used for a relatively long time. This is the case of most irrigated crops and rainfed HYV wheat in the wetter zones. Such surveys could provide a cost-effective method that will give a more accurate picture of what rates farmers actually apply and the yields obtained across agro-climatic regions. It is even possible to estimate yield response functions based on these surveys, provided that enough

variation exists within the survey sample to cover the entire range of the production function. If these surveys are repeated over several years, yield responses under varying rainfall levels can be estimated providing a strong empirical basis for risk analysis.

In addition to the above issues related to fertilizer trials, future research is needed in the area of price and cost estimations to allow for more accurate economic analyses of results from fertilizer experiments. Such research should focus on monitoring seasonal and regional variations in crop prices as well as prices of related agricultural byproducts (e.g., straw). This would allow the formulation of more accurate region-specific fertilizer recommendations. These price-monitoring efforts should cover the domestic parallel markets as well as prices in the international market, including spot and future prices. This would provide a more accurate basis for making price projections needed to be incorporated in the fertilizer allocation model. Other marketing-related issues that need to be addressed in the future include detailed studies to estimate storage and transport costs of crops and fertilizers. These would provide more accurate estimates of financial and economic field prices.

Future research should also examine the policy option of legalizing the private domestic trade in fertilizers. Such an option would be in line with recent political statements stressing the need for more coordination and complementarity between the activities of the public and private sectors. Private fertilizer marketing, especially retailing, could enhance farmers' accessibility to fertilizers and contribute to reducing many of the inefficiencies in the official fertilizer distribution system. This would be particularly relevant if fertilizer rationing is eliminated and subsidies are substantially reduced.

As for the fertilizer allocation model, several possible improvements can be suggested for future modifications in the model, provided that the relevant data requirements become available in the future. These improvements include the following:

1. Despite the current low levels of potassium fertilizer use in Syria, the inclusion of potassium fertilizer in the allocation model will become crucial in the future. This is important given the expected rapid increase in the application of potassium fertilizers, particularly on fruit trees. At present, most soils in Syria are considered sufficiently rich in potassium not to require the application of any potassium fertilizers on most crops, with the exception of root crops (e.g., sugar beets and potatoes). However, regular monitoring of soil potassium levels is needed in order to detect any signs of potassium depletion in the soil and, if needed, to recommend its application to prevent future potassium mining that may lead to serious yield declines.

2. The allocation model developed in this study does not differentiate between the costs of domestic and imported fertilizers. The use of import parity prices for all the fertilizer used in Syria was justified based on the fact that any increase or decline in fertilizer use would be reflected by an equal increase or decline in fertilizer imports. That is, the opportunity cost of fertilizer was assumed to be its import cost. Such an assumption can be maintained as long as Syria

remains an importer of fertilizer. However this situation is expected to change in the medium run given the plans to substantially increase current production capacity. Therefore, in few years, Syria might resume exporting significant amounts of its fertilizer output, which would require the use of export parity prices.

3. The model used in this study is static. The time dimension is not explicitly addressed either in the formulation of the response functions or in the design of the model itself. The current formulation of the model requires annual updating of the input/output coefficients, prices, and the upper limits on available fertilizer supplies. Although data on prices and fertilizer supplies are readily available, updating of production functions would be more problematic given the limited new fertilizer trial data expected to become available every year.

This static nature of the model does not allow for the appropriate treatment of several important variables that are time-dependent. These include crop rotations, fertilizer carry-over effects, seasonal distribution of rainfall, fertilizer and crop inventories, and so forth. Future modifications of the model should also address possible farmers' reactions to any changes in the system. The use of a dynamic programming model would allow for the incorporation of some of these variables, which would greatly enhance the accuracy and usefulness of the fertilizer allocation model.

4. A related issue is the treatment of risk and uncertainty in the model. The present model incorporates risk considerations in an indirect way by enabling to find solutions to the fertilizer allocation

problem under different rainfall scenarios. Also, assumptions were made about the risk-averse behavior of farmers with respect to barley fertilization. These very simplistic assumptions were made given the limited empirical information on farmers' risk management strategies with respect to fertilizer rates used, timing of fertilizer applications, and the number of applications. Future research should focus more on understanding farmers' behavior under uncertainty and identifying their risk strategies. This would allow the formulation of more realistic fertilizer recommendations and would provide the basic information needed for a more systematic treatment of risk in the fertilizer allocation model.

5. The present fertilizer allocation model does not explicitly incorporate farmer's constraints and their potential impact on the farmer's decision on how to allocate the limited quantities of fertilizer among various crops and fruit trees. In order to include such considerations in future modifications of the allocation model, detailed estimates of whole-farm budgets would be needed. These estimates would allow the construction of several model farm budgets, or farm modules, representing the main farming systems in Syria. As a first step, the model would solve for the fertilizer allocation problem at the farm level, for each farm type. This would be followed by the aggregation of all farm modules into a national model that would provide a solution to the allocation problem, given the constraints on fertilizer supplies at the national level.

6. Finally, an important weakness in the present allocation model is the lack of accurate information on the percentage of total cropped areas that are actually fertilized. As discussed in chapter 5, assumptions were made for each crop (in each zone) about the percentage of total area actually fertilized. These assumptions were based on very rough estimates provided by agronomists from the Soils Directorate. More accurate estimates could be obtained from a survey of a representative sample of farmers in the main agricultural regions in Syria. Such a survey could be repeated every few years to get a clearer idea about potential trends in fertilizer use. Based on these trends, specific growth rates for each crop (in each agro-climatic region) could be estimated and incorporated into the procedure for estimating total fertilizer requirements. This would replace the arbitrary 20% annual growth rate in fertilizer consumption for all crops, which is currently used in estimating national fertilizer requirements.

APPENDICES

APPENDIX A

LAND USE AND CROP MIX

Table A.1: EVOLUTION OF TOTAL CULTIVATED AREAS IN SYRIA, 1984/85 to 1989/90 (ha).

Year	Type of Culture	Irrigated	Rainfed, by Agricultural Stability Zones: Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	GRAND TOTAL
1984/85	Crops	684,926	788,455	916,638	427,256	480,376	216,668	2,829,393	3,514,319
	Fruit Trees	82,770	376,664	101,147	18,630	6,468	696	503,605	586,375
	Total	767,696	1,165,119	1,017,785	445,886	486,844	217,364	3,332,998	4,100,694
1985/86	Crops	657,532	754,192	895,712	382,321	505,346	240,585	2,778,156	3,435,688
	Fruit Trees	85,413	389,789	112,642	18,974	6,611	1,329	529,345	614,758
	Total	742,945	1,143,981	1,008,354	401,295	511,957	241,914	3,307,501	4,050,446
1986/87	Crops	671,925	751,977	1,029,005	428,368	505,969	230,414	2,945,733	3,617,658
	Fruit Trees	95,123	402,976	124,729	20,696	7,499	2,376	558,276	653,399
	Total	767,084	1,154,953	1,153,734	449,064	513,468	232,790	3,504,009	4,271,057
1987/88	Crops	695,904	769,778	1,030,294	487,552	474,060	294,646	3,056,330	3,752,234
	Fruit Trees	103,895	429,839	128,483	21,877	8,012	2,598	590,809	694,704
	Total	799,799	1,199,617	1,158,777	509,429	482,072	297,244	3,647,139	4,446,938
1988/89	Crops	728,027	759,559	1,068,544	476,724	508,770	363,076	3,176,673	3,904,700
	Fruit Trees	118,559	425,443	148,835	23,077	8,019	2,947	608,321	726,880
	Total	846,586	1,185,002	1,217,379	499,801	516,789	366,023	3,784,994	4,631,580
1989/90[1]	Crops	767,860	753,723	1,455,988	747,636	879,492	429,912	4,266,751	5,034,611
	Fruit Trees	118,559	440,529	160,430	25,026	8,509	2,947	637,471	756,032
	Total	886,419	1,194,252	1,616,418	772,662	888,001	432,859	4,904,222	5,790,641

1/ Planned, based on the 1989/90 Agricultural Plan.
Source: Annual Agricultural Statistical Abstracts, various years.

Table A.2: PLANNED CROPPING PROGRAM: Syria, 1989/90 season (ha).

		Rainfed, by Agricultural Stability Zones						
Crop	Irrigated	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	GRAND TOTAL
HYV Wheat	245,402	289,353	180,533	--	--	--	469,886	715,288
Local Wheat	22,421	123,647	454,707	148,000	12,000	29,760	768,114	790,535
Barley	4,624	42,778	646,833	580,146	876,231	400,152	2,537,140	2,541,764
Yellow Maize	69,617	15	--	--	--	--	15	69,632
Sorghum	500	9,985	--	--	--	--	9,985	10,485
Total Cereals	342,564	465,778	1,282,073	728,146	879,231	429,912	3,785,140	4,127,704
Lentils	975	118,171	28,522	3,307	--	--	150,000	150,975
Chickpeas	100	36,816	46,506	678	--	--	84,000	84,100
Dry Broad Beans	6,501	3,700	300	--	--	--	4,000	10,501
Dry Peas	300	--	--	--	--	--	--	300
Dry Haricot Beans	4,200	--	--	--	--	--	--	4,200
Total Food Dry Legumes	12,076	158,687	75,328	3,985	--	--	238,000	250,076
Flowering Sern	3,007	11,629	3,323	--	--	--	14,952	17,959
Rambling Vetch	60	6,003	9,707	1,988	--	--	17,700	17,760
Bitter Vetch	--	1,972	5,277	4,284	--	--	11,533	11,533
Total Feed Dry Legumes	3,067	19,604	18,309	6,272	--	--	44,185	47,252
Grazing Vetch	9,850	16,040	6,901	--	--	--	22,941	32,791
Grazing Barley	34,738	1,760	26,569	3,733	261	--	32,323	67,061
Grazing Clover	650	--	--	--	--	--	--	650
Grazing Maize	3,480	1,175	--	--	--	--	1,175	4,655
Total Forage Crops	12,076	158,687	75,328	3,985	--	--	238,000	250,076

(Continued)

Table A.2 (cont'd.).

Crop	Irrigated	Rainfed, by Agricultural Stability Zones						GRAND TOTAL
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	
Cotton	174,000	--	--	--	--	--	--	174,000
Sugar Beet	30,000	--	--	--	--	--	--	30,000
Tobacco	4,150	11,350	--	--	--	--	11,350	15,500
Total Industrial Crops	208,150	11,350	--	--	--	--	11,350	219,500
Soybean	23,414	--	--	--	--	--	--	23,414
Oil Sunflower	4,000	--	--	--	--	--	--	4,000
Regular Sunflower	2,000	5,000	1,000	--	--	--	6,000	8,000
Peanuts	11,070	--	--	--	--	--	--	11,070
Sesame	7,030	7,296	14,276	4,000	--	--	25,572	32,602
Total Oil Crops	47,514	12,296	15,276	4,000	--	--	31,572	79,086
Potato	23,768	1,800	--	--	--	--	1,800	25,568
Tomato	21,385	5,611	800	--	--	--	6,411	27,796
Watermelon & Muskmelon	3,005	37,261	19,394	--	--	--	56,655	59,660
Dry Garlic	1,100	155	--	--	--	--	155	1,255
Misc. Vegetables	49,565	16,794	9,098	--	--	--	25,892	75,457
Total Vegetables	104,623	61,849	29,292	--	--	--	91,141	195,764
Misc. Crops	1,148	5,184	2,240	1,500	--	--	8,924	10,072
Total Annual Crops'	767,860	753,723	1,455,988	747,636	879,492	429,912	4,266,751	5,034,611

(Continued)

Table A.2 (cont'd.).

Crop	Irrigated	Rainfed, by Agricultural Stability Zones						GRAND TOTAL
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	
Olive	11,745	*	*	*	*	*	379,824	391,569
Grape	12,349	*	*	*	*	*	95,205	107,554
Stone Fruits	31,024	*	*	*	*	*	21,465	52,489
Pome Fruits	20,706	*	*	*	*	*	36,775	57,481
Citrus	21,573	*	*	*	*	*	21	21,594
Nuts	6,711	*	*	*	*	*	88,337	95,048
Misc. Fruit Trees	14,451	*	*	*	*	*	15,844	30,295
Total Fruit Trees	118,559	440,529	160,430	25,026	8,509	2,947	637,471	756,030
GRAND TOTAL	886,419	1,194,252	1,616,418	772,662	888,001	432,859	4,904,222	5,790,641

1/ To which around 6,000 ha of irrigated alfalfa are added in estimating fertilizer requirements.
* The breakdown of areas planted to rainfed fruit trees by zone is not available.

Source: Ministry of Agriculture and Agrarian Reform, The Agricultural Production Plan for the 1989/90 Season, 1989.

APPENDIX B

THE FERTILIZER REQUIREMENT SCHEDULE

1989/1990

Table B.1: FERTILIZER REQUIREMENTS OF WINTER CROPS
Syria, 1989/1990

		RECOMMENDED RATES (KG/HA)			TOTAL REQUIREMENTS (TONS)		
Crops	AREA (HA)	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Irrigated Wheat:	267823	135	65	0	36156	17408	0
Rainfed Wheat HYV Zone 1:	289353	80	40	0	23148	11574	0
Rainfed Wheat HYV Zone 2:	180533	60	35	0	10832	6319	0
Rainfed Wheat LYV Zone 1:	123647	40	35	0	4946	4328	0
Rainfed Wheat LYV Zone 2:	464707	25	20	0	11368	9094	0
Rainfed Wheat LYV Zone 3:	148000	20	15	0	2960	2220	0
TOTAL WHEAT:	1464063				89410	50943	0
Rainfed Barley Zone 1:	42778	75	45	0	3208	1925	0
Rainfed Barley Zone 2:	646833	50	40	0	32342	25873	0
Rainfed Barley Zone 3:	580146	40	35	0	23206	20305	0
TOTAL BARLEY:	1269757				58756	48103	0
Irrigated Fall Sugar Beet:	15370	215	120	100	3305	1844	1537
Irrigated Fall Potatoes:	13000	170	120	120	2210	1560	1560
TOTAL SUGAR BEET and POTATOES:	28370				5515	3404	3097
TOTAL WINTER CROPS INCLUDED IN THE STUDY:	2762190				153680	102451	3097
Irrigated Barley:	4624	80	60	0	370	277	0
Irrigated and Rainfed Food Legumes:	250076	20	46	0	5002	11503	0
Irrigated and Rainfed Food Grain Legumes:	47252	20	46	0	945	2174	0
Irrigated and Rainfed Winter Forage Crops:	99852	20	46	0	1997	4593	0
Irrigated Annual Alfalfa (Berseem):	650	20	60	0	13	39	0
Irrigated Alfalfa:	6000	20	180	0	120	1080	0
Irrigated Dry Garlic:	1100	120	120	120	132	132	132
Rainfed Dry Garlic:	155	60	60	60	9	9	9
Irrig. Winter Vegetables:	25462	120	100	100	3055	2546	2546
Rainfed Winter Vegetables	4404	50	50	0	220	220	0
TOTAL WINTER CROPS NOT INCLUDED IN THE STUDY:	439575				11863	22574	2688
TOTAL WINTER CROPS	3201765				165544	125025	5785

Source: Ministry of Agriculture and Agrarian Reform, Fertilizer Requirement Schedule for the 1989/90 Season

Table B.2: FERTILIZER REQUIREMENTS OF SUMMER CROPS
Syria, 1989/1990

		RECOMMENDED RATES (KG/HA)			TOTAL REQUIREMENTS (TONS)		
Crops	AREA (HA)	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Irrigated Cotton:	174000	225	120	0	39150	20880	0
Summer Sugar Beet:	14630	190	120	80	2780	1756	1170
Irrig. Spring & Summer Potatoes:	10768	155	120	120	1669	1292	1292
Irrigated Yellow Maize:		130	80	0	9050	5569	0
SUMMER CROPS IN THE STUDY:	269015				52649	29497	2463
Rainfed Spring & Summer Potatoes:	1800	80	80	80	144	144	144
Rainfed Yellow Maize:	15	60	40	0	1	1	0
Irrigated Forage Maize:	3480	120	80	0	418	278	0
Rainfed Forage Maize:	1175	60	40	0	71	47	0
Irrigated Tobacco:	4150	230	180	150	955	747	623
Rainfed Tobacco:	11350	50	50	0	568	568	0
Irrigated Soybeans:	23414	40	80	40	937	1873	937
Irrigated Peanuts:	11070	40	80	40	443	886	443
Irrigated Sunflower (oil):	4000	40	80	40	160	320	160
Irrigated Sunflower (regular):	2000	40	80	40	80	160	80
Rainfed Sunflower:	6000	30	40	0	180	240	0
Irrigated Sesame:	7030	40	80	40	281	562	281
Rainfed Sesame:	25572	30	40	0	767	1023	0
Irrigated White Maize:	500	80	60	0	40	30	0
Rainfed White Maize:	9985	50	40	0	499	399	0
Irrigated Tomatoes:	21386	180	120	120	3849	2566	2566
Rainfed Tomatoes:	6411	80	80	80	513	513	513
Irrigated Dry Onions:	5800	120	120	120	696	696	696
Rainfed Dry Onions:	228	80	80	80	18	18	18
Irrigated Vegetables:	24103	150	100	100	3615	2410	2410
Rainfed Vegetables:	21488	80	60	0	1719	1289	0
Irrigated Melons:	3005	120	80	80	361	240	240
Rainfed Melons:	56655	50	50	0	2833	2833	0
Misc. Irrigated Summer Crops:	1148	100	100	0	115	115	0
Misc. Rainfed Summer Crops:	8924	50	50	0	446	446	0
SUMMER CROPS NOT IN THE STUDY	260688				19707	18405	9111
TOTAL SUMMER CROPS	529703				72356	47902	11574

Source: Ministry of Agriculture and Agrarian Reform, Fertilizer Requirement Schedule for the 1989/90 Season

Table B.3: FERTILIZER REQUIREMENTS OF IRRIGATED FRUIT TREES
Syria, 1989/1990

		RECOMMENDED RATES (KG/HA)			TOTAL REQUIREMENTS (TONS)		
Irrigated Fruit Trees	AREA (HA)	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Citrus:	21573	400	100	200	8629	2157	4315
Olives:	11745	200	100	100	2349	1175	1175
Grapes:	12349	200	100	100	2470	1235	1235
Apricots:	12724	150	100	100	1909	1272	1272
Peaches:	8512	150	100	150	1277	851	1277
Plums:	3986	150	100	150	598	399	598
Cherries:	1998	150	100	150	300	200	300
Green Plums (Janarek):	3805	150	100	150	571	381	571
TOTAL STONE FRUITS:	31024				4654	3102	4017
POME FRUITS:	20706	200	120	120	4141	2485	2485
Pistachio:	1843	200	200	200	369	369	369
Almonds:	1275	150	100	100	191	128	128
Walnuts:	3593	150	100	100	539	359	359
TOTAL NUTS:	6711				1099	855	855
Pomegranates:	8259	200	120	120	1652	991	991
Figs:	1131	150	100	100	170	113	113
Mulberry	456	150	100	100	68	46	46
Kaki:	338	150	100	100	51	34	34
Other:	4267	150	100	100	640	427	427
TOTAL MISC. FRUITS:	14461				2581	1610	1610
TOTAL IRRIGATED FRUIT TREES:	118569				25922	12620	15692

Source: Ministry of Agriculture and Agrarian Reform, Fertilizer Requirement Schedule for the 1989/90 Season

Table B.4: FERTILIZER REQUIREMENTS OF RAINFED FRUIT TREES
Syria, 1989/1990

		RECOMMENDED RATES (KG/HA)			TOTAL REQUIREMENTS (TONS)		
Rainfed Fruit Trees	AREA (HA)	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Olives:	379824	100	50	50	37982	18991	18991
Grapes:	95205	100	50	50	9521	4760	4760
Apricots:	2669	100	50	50	267	133	133
Peaches:	2117	100	50	50	212	106	106
Plums:	2198	100	50	50	220	110	110
Cherries:	13959	100	50	100	1396	698	1396
Green Plums (Janarek):	522	100	50	50	52	26	26
TOTAL STONE FRUITS:	21465				2147	1073	1771
POME FRUITS:	36775	120	80	80	4413	2942	2942
Pistachio:	62017	100	100	100	6202	6202	6202
Almonds:	25401	100	50	50	2540	1270	1270
Walnuts:	919	100	50	50	92	46	46
TOTAL NUTS:	88337				8834	7518	7518
Pomegranates:	1597	100	60	60	160	96	96
Figs:	13513	100	50	50	1351	676	676
Mulberry	86	100	50	50	9	4	4
Kaki:	1	100	50	50	0	0	0
Citrus:	21	200	50	100	4	1	2
Other:	647	100	50	50	65	32	32
TOTAL MISC. FRUITS:	15865				1589	809	810
TOTAL RAINFED FRUIT TREES:	637471				64485	36094	36793

Source: Ministry of Agriculture and Agrarian Reform, <u>Fertilizer Requirement Schedule for the 1989/90 Season</u>

Table B.5: AGGREGATE FERTILIZER REQUIREMENTS
Syria, 1989/1990

	AREA (HA)	TOTAL REQUIREMENTS (TONS)		
		N	P_2O_5	K_2O
Winter Crops:	3,201,765	165,544	125,025	5,785
Summer Crops:	529,703	72,356	47,902	11,574
TOTAL CROPS:	3,731,468	237,900	172,927	17,358
Irrigated Fruit Trees:	118,559	25,922	12,620	15,692
Rainfed Fruit Trees:	637,471	64,485	36,094	36,793
TOTAL FRUIT TREES:	756,030	90,407	48,713	52,484
IDEAL TOTAL FERTILIZER REQUIREMENTS:		328,307	221,641	69,843
PLANNED FERTILIZER REQUIREMENTS[1]		305,705	209,462	23,048
PLANNED FERTILIZER REQUIREMENTS OF CROPS IN THE STUDY:				
Winter Crops:	2,762,190	153,680	102,451	3,097
Summer Crops:	269,015	52,649	29,497	2,463
All Crops:	3,031,205	206,329	131,948	5,560

1/ Based on : 100% of N and P_2O_5 requirements for all crops
75% of N and P_2O_5 requirements for all fruit trees
33% of total K_2O requirements

Source: Ministry of Agriculture and Agrarian Reform, Fertilizer Requirement Schedule for the 1989/90 Season

APPENDIX C

COMPUTER INPUT FILE FOR THE FERTILIZER ALLOCATION LINEAR PROGRAMMING MODEL

APPENDIX C

COMPUTER INPUT FILE FOR THE FERTILIZER ALLOCATION LINEAR PROGRAMMING MODEL[1]

```
$OFFSYMLIST OFFSYMXREF
$OFFUPPER
$TITLE  FERTILIZER ALLOCATION IN SYRIA


SETS

    I     crops   / WIRR
                    WHYV1
                    WHYV2
                    WLYV1
                    WLYV2
                    WLYV3
                    BARLEY1
                    BARLEY2
                    BARLEY3
                    COTTON
                    MAIZE
                    FALLBEET
                    SUMBEET
                    FALLPOT
                    SUMPOT    /

    W(I)   winter crops

                  / WIRR
                    WHYV1
                    WHYV2
                    WLYV1
                    WLYV2
                    WLYV3
                    BARLEY1
                    BARLEY2
```

[1] GAMS (General Algebraic Modeling System) is the computer package used to develop the fertilizer allocation model in this study. This appendix represents the ASCII input file, which can be run using any solver compatible with GAMS. Refer to the GAMS User's Guide (Brooke, Kendrick, and Meeraus, 1988) for a detailed discussion of GAMS operating instructions.

```
                  BARLEY3
                  FALLBEET
                  FALLPOT  /

     G(I)   rainfed grain crops  / WHYV1
                                   WHYV2
                                   WLYV1
                                   WLYV2
                                   WLYV3
                                   BARLEY1
                                   BARLEY2
                                   BARLEY3 /

     IR(I)  irrigated crops      / WIRR
                                   COTTON
                                   MAIZE
                                   FALLBEET
                                   SUMBEET
                                   FALLPOT
                                   SUMPOT /


     C(IR)  irrigated cash crops  / WIRR, COTTON/

     WH(W)  wheat

                /  WIRR
                   WHYV1
                   WHYV2
                   WLYV1
                   WLYV2
                   WLYV3  /

     RW(G)  rainfed wheat

                /  WHYV1
                   WHYV2
                   WLYV1
                   WLYV2
                   WLYV3  /

     B(G)   barley

                /  BARLEY1
                   BARLEY2
                   BARLEY3  /

     S(I)   summer crops

                /  COTTON
                   MAIZE
                   SUMBEET
                   SUMPOT  /
```

```


    R(IR)  root crops and maize

                /  MAIZE
                   FALLBEET
                   SUMBEET
                   FALLPOT
                   SUMPOT /


    SG     segments for grain crops / G001 * G100 /

    SC     segments for cash crops / C001 * C143 /

    SR     segments for root crops and maize / R01 * R34 /

    E      rain scenarios /GOOD, NORMAL, DRY, V-DRY/

    F      fertilizers / N, P / ;

PARAMETERS

    XCPRICE(I)   financial crop prices in normal years in SL per kg

*   From Table 4.18
*   Note: prices of sugar beets and potatoes are in SL per ton

                   /WIRR       7.65
                    WHYV1      7.65
                    WHYV2      7.65
                    WLYV1      8.45
                    WLYV2      8.45
                    WLYV3      8.45
                    BARLEY1    5.53
                    BARLEY2    5.53
                    BARLEY3    5.53
                    COTTON    13.53
                    MAIZE      6.51
                    FALLBEET  1030
                    SUMBEET   1030
                    FALLPOT   4860
                    SUMPOT    4860   /

    XFPRICE(F)    fertilizer financial prices in SL per kg

                   / N          12.1
                     P          12.8   /

   CPRICE(I)   crop economic prices in normal years in SL per kg

*   From Table 4.18
*   Note: prices of sugar beets and potatoes are in SL per ton
```

```

                 /WIRR      7.81
                  WHYV1     7.81
                  WHYV2     7.81
                  WLYV1     8.13
                  WLYV2     8.13
                  WLYV3     8.13
                  BARLEY1   6.31
                  BARLEY2   6.31
                  BARLEY3   6.31
                  COTTON    16.21
                  MAIZE     6.34
                  FALLBEET  1320
                  SUMBEET   1320
                  FALLPOT   5850
                  SUMPOT    5850  /

   FPRICE(F)    fertilizer economic prices in SL per kg

                 / N          16.81
                   P          23.96  /


    AREA(I)  total area planted with crop i in millions  ha

*  Actual areas fertilized.  See Table 5.9

                 /WIRR        0.267823
                  WHYV1       0.289353
                  WHYV2       0.180533
                  WLYV1       0.1112823
                  WLYV2       0.3182949
                  WLYV3       0.074000
                  BARLEY1     0.021389
                  BARLEY2     0.2587332
                  BARLEY3     0.1740438
                  COTTON      0.174000
                  MAIZE       0.069632
                  FALLBEET    0.015370
                  SUMBEET     0.014630
                  FALLPOT     0.013000
                  SUMPOT      0.010768  /


    FPER(F)   percentage of total fertilizer needs available

             / N   100
               P   100    /

    WPER(F)   percentage of total winter fertilizer needs available

             / N    100
               P    100   /
```

```
     SPER(F)   percentage of total summer fertilizer needs available

               / N    100
                 P    100  /


     FLIM(F)   N and P availability for all crops in thousand tons

              / N     163.691
                P      96.977   /

     WFLIM(F)   N and P availability for winter crops in thousand tons

              / N     9999111.042
                P      999967.480   /


     SFLIM(F)   N and P availability for summer crops in thousand tons

              / N     999952.649
                P     999929.498   /          ;

TABLE FMAX(I,F)  ideal N and P rates in kg per ha

*  From Table 5.2
                                N          P

                  WIRR        135         65
                  WHYV1        80         40
                  WHYV2        60         35
                  WLYV1        40         35
                  WLYV2        25         20
                  WLYV3        20         15
                  BARLEY1      75         45
                  BARLEY2      50         40
                  BARLEY3      40         35
                  COTTON      225        120
                  MAIZE       130         80
                  FALLBEET    215        120
                  SUMBEET     190        120
                  FALLPOT     170        120
                  SUMPOT      155        120              ;

PARAMETER

     PNRATIO(I)  ratio of maximum P to maximum N ;
     PNRATIO(I) - FMAX(I,"P")/FMAX(I,"N") ;
```

```

TABLE RAIN(I,E)  rain scenarios

*  From Table 3.1

                            GOOD      NORMAL     DRY   V-DRY

                  WHYV1     500        400       350    300
                  WHYV2     350        300       250    200
                  WLYV1     500        400       350    300
                  WLYV2     350        300       250    200
                  WLYV3     300        250       200    150
                  BARLEY1   500        400       350    300
                  BARLEY2   350        300       250    200
                  BARLEY3   300        250       200    150   ;

TABLE PROB(I,E)  probabilities of rain scenarios


                            GOOD      NORMAL     DRY   V-DRY

                  WHYV1     0.29       0.47      0.12  0.12
                  WHYV2     0.32       0.42      0.13  0.13
                  WLYV1     0.29       0.47      0.12  0.12
                  WLYV2     0.32       0.42      0.13  0.13
                  WLYV3     0.35       0.41      0.12  0.12
                  BARLEY1   0.29       0.47      0.12  0.12
                  BARLEY2   0.32       0.42      0.12  0.12
                  BARLEY3   0.35       0.41      0.12  0.12  ;


TABLE FERTG(SG,F)  N-P combinations for grain crops in kg per ha

                      N            P

              G001    00           00
              G002    10           00
              G003    20           00
              G004    30           00
              G005    40           00
              G006    50           00
              G007    60           00
              G008    70           00
              G009    80           00
              G010    90           00
              G011    00           10
              G012    10           10
              G013    20           10
              G014    30           10
              G015    40           10
              G016    50           10
              G017    60           10
              G018    70           10
```

299	G019	80	10
300	G020	90	10
301	G021	00	15
302	G022	10	15
303	G023	20	15
304	G024	30	15
305	G025	40	15
306	G026	50	15
307	G027	60	15
308	G028	70	15
309	G029	80	15
310	G030	90	15
311	G031	00	20
312	G032	10	20
313	G033	20	20
314	G034	30	20
315	G035	40	20
316	G036	50	20
317	G037	60	20
318	G038	70	20
319	G039	80	20
320	G040	90	20
321	G041	00	25
322	G042	10	25
323	G043	20	25
324	G044	30	25
325	G045	40	25
326	G046	50	25
327	G047	60	25
328	G048	70	25
329	G049	80	25
330	G050	90	25
331	G051	00	30
332	G052	10	30
333	G053	20	30
334	G054	30	30
335	G055	40	30
336	G056	50	30
337	G057	60	30
338	G058	70	30
339	G059	80	30
340	G060	90	30
341	G061	00	35
342	G062	10	35
343	G063	20	35
344	G064	30	35
345	G065	40	35
346	G066	50	35
347	G067	60	35
348	G068	70	35
349	G069	80	35
350	G070	90	35
351	G071	00	40

```
                  G072        10          40
                  G073        20          40
                  G074        30          40
                  G075        40          40
                  G076        50          40
                  G077        60          40
                  G078        70          40
                  G079        80          40
                  G080        90          40
                  G081        00          45
                  G082        10          45
                  G083        20          45
                  G084        30          45
                  G085        40          45
                  G086        50          45
                  G087        60          45
                  G088        70          45
                  G089        80          45
                  G090        90          45
                  G091        00          65
                  G092        10          65
                  G093        20          65
                  G094        30          65
                  G095        40          65
                  G096        50          65
                  G097        60          65
                  G098        70          65
                  G099        80          65
                  G100        90          65      ;



TABLE FERTC(SC,F)  N-P combinations for cash crops in kg per ha

                              N            P

                  C001       000          00
                  C002       050          00
                  C003       100          00
                  C004       120          00
                  C005       130          00
                  C006       140          00
                  C007       180          00
                  C008       200          00
                  C009       210          00
                  C010       220          00
                  C011       230          00
                  C012       000          40
                  C013       050          40
                  C014       100          40
                  C015       120          40
                  C016       130          40
                  C017       140          40
```

405	C018	180	40
406	C019	200	40
407	C020	210	40
408	C021	220	40
409	C022	230	40
410	C023	000	50
411	C024	050	50
412	C025	100	50
413	C026	120	50
414	C027	130	50
415	C028	140	50
416	C029	180	50
417	C030	200	50
418	C031	210	50
419	C032	220	50
420	C033	230	50
421	C034	000	55
422	C035	050	55
423	C036	100	55
424	C037	120	55
425	C038	130	55
426	C039	140	55
427	C040	180	55
428	C041	200	55
429	C042	210	55
430	C043	220	55
431	C044	230	55
432	C045	000	60
433	C046	050	60
434	C047	100	60
435	C048	120	60
436	C049	130	60
437	C050	140	60
438	C051	180	60
439	C052	200	60
440	C053	210	60
441	C054	220	60
442	C055	230	60
443	C056	000	65
444	C057	050	65
445	C058	100	65
446	C059	120	65
447	C060	130	65
448	C061	140	65
449	C062	180	65
450	C063	200	65
451	C064	210	65
452	C065	220	65
453	C066	230	65
454	C067	000	70
455	C068	050	70
456	C069	100	70
457	C070	120	70

458	C071	130	70
459	C072	140	70
460	C073	180	70
461	C074	200	70
462	C075	210	70
463	C076	220	70
464	C077	230	70
465	C078	000	80
466	C079	050	80
467	C080	100	80
468	C081	120	80
469	C082	130	80
470	C083	140	80
471	C084	180	80
472	C085	200	80
473	C086	210	80
474	C087	220	80
475	C088	230	80
476	C089	000	90
477	C090	050	90
478	C091	100	90
479	C092	120	90
480	C093	130	90
481	C094	140	90
482	C095	180	90
483	C096	200	90
484	C097	210	90
485	C098	220	90
486	C099	230	90
487	C100	000	100
488	C101	050	100
489	C102	100	100
490	C103	120	100
491	C104	130	100
492	C105	140	100
493	C106	180	100
494	C107	200	100
495	C108	210	100
496	C109	220	100
497	C110	230	100
498	C111	000	110
499	C112	050	110
500	C113	100	110
501	C114	120	110
502	C115	130	110
503	C116	140	110
504	C117	180	110
505	C118	200	110
506	C119	210	110
507	C120	220	110
508	C121	230	110
509	C122	000	120
510	C123	050	120

```
                 C124       100           120
                 C125       120           120
                 C126       130           120
                 C127       140           120
                 C128       180           120
                 C129       200           120
                 C130       210           120
                 C131       220           120
                 C132       230           120
                 C133       000           130
                 C134       050           130
                 C135       100           130
                 C136       120           130
                 C137       130           130
                 C138       140           130
                 C139       180           130
                 C140       200           130
                 C141       210           130
                 C142       220           130
                 C143       230           130  ;



TABLE FERTR(SR,F)  N-P combinations for maize and root crops kg per ha

*  Note:  P is not included in the production functions.  Optimum P
*  levels are therefore assumed and they vary at the same rate as the
*  percent change in optimum N.

                             N             P

                 R01         00            0
                 R02         10            0
                 R03         20            0
                 R04         30            0
                 R05         40            0
                 R06         50            0
                 R07         60            0
                 R08         70            0
                 R09         80            0
                 R10         90            0
                 R11        100            0
                 R12        110            0
                 R13        115            0
                 R14        120            0
                 R15        125            0
                 R16        130            0
                 R17        135            0
                 R18        140            0
                 R19        145            0
                 R20        150            0
                 R21        155            0
                 R22        160            0
```

```
                R23         165            0
                R24         170            0
                R25         175            0
                R26         180            0
                R27         185            0
                R28         190            0
                R29         195            0
                R30         200            0
                R31         205            0
                R32         210            0
                R33         215            0
                R34         220            0  ;



PARAMETER

*Production Function Parameters A1 to A11 (from Table 5.1):

    A1(I)    slope of R in the production function for crop i

                  / WHYV1       18.71
                    WHYV2       18.71
                    WLYV1        5.0628
                    WLYV2        5.0628
                    WLYV3        5.0628
                    BARLEY1     24.9455
                    BARLEY2     24.9455
                    BARLEY3     24.9455  /


    A2(I)    slope of RR in the production function for crop i

                   /WHYV1       -0.0152
                    WHYV2       -0.0152
                    WLYV1        0
                    WLYV2        0
                    WLYV3        0
                    BARLEY1     -0.031
                    BARLEY2     -0.031
                    BARLEY3     -0.031  /


    A3(I)    slope of N in the production function for crop i

                   /WIRR        16.3174
                    WHYV1        2.5517
                    WHYV2        2.5517
                    WLYV1        0
                    WLYV2        0
                    WLYV3        0
                    BARLEY1      0.2908
                    BARLEY2      0.2908
```

```
                BARLEY3     0.2908
                COTTON      9.6854
                MAIZE      23.4785
                FALLBEET    0.1424
                SUMBEET     0.1506
                FALLPOT     0.0439
                SUMPOT      0.0437 /

A4(I)   slope of RN in the production function for crop i

              / WHYV1       0.0221
                WHYV2       0.0221
                WLYV1       0.0428
                WLYV2       0.0428
                WLYV3       0.0428
                BARLEY1     0.0506
                BARLEY2     0.0506
                BARLEY3     0.0506  /


A5(I)   slope of P in the production function for crop i

               /WIRR        13.826
                WHYV1        8.1082
                WHYV2        8.1082
                WLYV1        0
                WLYV2        0
                WLYV3        0
                BARLEY1      6.0465
                BARLEY2      6.0465
                BARLEY3      6.0465
                COTTON       5.6493
                MAIZE        0
                FALLBEET     0
                SUMBEET      0
                FALLPOT      0
                SUMPOT       0          /

A6(I)   slope of RP in the production function for crop i

              / WHYV1        0.0066
                WHYV2        0.0066
                WLYV1        0.0222
                WLYV2        0.0222
                WLYV3        0.0222
                BARLEY1      -0.00127
                BARLEY2      -0.00127
                BARLEY3      -0.00127   /

A7(I)   slope of NN in the production function for crop i

               /WIRR        -0.0562
                WHYV1       -0.0559
```

```
                 WHYV2        -0.0559
                 WLYV1        -0.2288
                 WLYV2        -0.2288
                 WLYV3        -0.2288
                 BARLEY1      -0.1117
                 BARLEY2      -0.1117
                 BARLEY3      -0.1117
                 COTTON       -0.0217
                 MAIZE        -0.0804
                 FALLBEET     -0.0003
                 SUMBEET      -0.00036
                 FALLPOT      -0.00012
                 SUMPOT       -0.00013  /

A8(I)    slope of PP in the production function for crop i

                /WIRR         -0.1013
                 WHYV1        -0.1003
                 WHYV2        -0.1003
                 WLYV1        -0.14
                 WLYV2        -0.14
                 WLYV3        -0.14
                 BARLEY1      -0.0408
                 BARLEY2      -0.0408
                 BARLEY3      -0.0408
                 COTTON       -0.027
                 MAIZE         0
                 FALLBEET      0
                 SUMBEET       0
                 FALLPOT       0        /

A9(I)    slope of NP in the production function for crop i

                /WIRR          0.0171
                 WHYV1        -0.0017
                 WHYV2        -0.0017
                 WLYV1         0
                 WLYV2         0
                 WLYV3         0
                 BARLEY1       0.0263
                 BARLEY2       0.0263
                 BARLEY3       0.0263
                 COTTON        0.0097
                 MAIZE         0
                 FALLBEET      0
                 SUMBEET       0
                 FALLPOT       0
                 SUMPOT        0             /

A10(I)    slope of RNP in the production function for crop i

               / WLYV1         0.00025
                 WLYV2         0.00025
```

```
                   WLYV3        0.00025     /      ;


PARAMETER

    YG(G,E,SG)  yield increase segments for rainfed grains ;
    YG(G,E,SG) = A3(G)*FERTG(SG,"N")+A4(G)*RAIN(G,E)*FERTG(SG,"N")
              +A5(G)*FERTG(SG,"P")+A6(G)*RAIN(G,E)*FERTG(SG,"P")
              +A7(G)*FERTG(SG,"N")*FERTG(SG,"N")
              +A8(G)*FERTG(SG,"P")*FERTG(SG,"P")
              +A9(G)*FERTG(SG,"N")*FERTG(SG,"P")
              +A10(G)*RAIN(G,E)*FERTG(SG,"N")*FERTG(SG,"P")   ;


PARAMETER

    YC(C,SC)  yield increase segments for irrigated cash crops ;
    YC(C,SC) = A3(C)*FERTC(SC,"N")+A5(C)*FERTC(SC,"P")
              +A7(C)*FERTC(SC,"N")*FERTC(SC,"N")
              +A8(C)*FERTC(SC,"P")*FERTC(SC,"P")
              +A9(C)*FERTC(SC,"N")*FERTC(SC,"P")  ;

PARAMETER

    YR(R,SR)  yield increase segments for maize and root crops ;
    YR(R,SR) = A3(R)*FERTR(SR,"N")+A7(R)*FERTR(SR,"N")*FERTR(SR,"N") ;


VARIABLES

     GSEG(G,SG) production function segments for rainfed crops
     CSEG(C,SC) production function segments for cash crops
     RSEG(R,SR) production function segments for maize and root crops
     TYG(G,E)   increase in output of rainfed crops in thousand tons
     TYIR(IR)   increase in output of irrigated crops in thousand tons
     OPTF(I,F)  opt. N and P rates in kg per ha
     TFU(F)     total N and P used in 1000 tons
     WTFU(F)    total N and P used in winter in 1000 tons
     STFU(F)    total N and P used in summer in 1000 tons
     RETURNS(E) returns Winter and Summer in million SL
     WRETURNS(E) returns Winter in million SL
     SRETURNS   returns Summer in million SL

     Z  net returns in millions of SL        ;


POSITIVE VARIABLES
GSEG(G,SG),CSEG(C,SC),RSEG(R,SR),TYG(G,E),TYIR(IR),
OPTF(I,F),TFU(F),WTFU(F),STFU(F),RETURNS(E), WRETURNS(E), SRETURNS  ;

EQUATIONS

  OBJ          defines objective function
```

```
  GSEPROW(G)   separable row for rainfed grain crops
  CSEPROW(C)   separable row for cash crops
  RSEPROW(R)   separable row for maize and root crops
  OPTFG(G,F)   determines optimum N and P rates for rainfed grains
  OPTFC(C,F)   determines optimum N and P rates for cash crops
  OPTFR(R,F)   determines opt N and P rates for maize and root crops
  MAX(I,F)     satisfies maximum limit on optimum N and P rates
  TOTYG(G,E)   determines net increase in total output for grain crops
  TOTYC(C)     determines net increase in total output for cash crops
  TOTYR(R)     determines net incr in total output for maize and roots
  WTOTN        aggregates N  use over all winter crops
  WTOTP        aggregates P use over all winter crops
  STOTN        aggregates N P use over all summer crops
  STOTP        aggregates P use over all summer crops
  TOTF(F)      aggregates N and P use over all winter and summer crops
  WLIMF(F)     satisfies limits on N and P available for winter crops
  SLIMF(F)     satisfies limits on N and P available for summer crops
  LIMF(F)      satisfies limits on N and P availability for all crops
  NR(E)        calculates net returns for winter and summer seasons
  WNR(E)       calculates net returns for winter season
  SNR          calculates net returns for summer season   ;


OBJ          ..    SUM(RW, CPRICE(RW)*TYG(RW,"NORMAL"))
                  +SUM(B, CPRICE(B)*TYG(B,"DRY"))
                  +SUM(IR, CPRICE(IR)*TYIR(IR))
                  -SUM(F, FPRICE(F)*TFU(F))  -E- Z  ;

GSEPROW(G)     .. SUM(SG, GSEG(G,SG)) -E- 1 ;
CSEPROW(C)     .. SUM(SC, CSEG(C,SC)) -E- 1 ;
RSEPROW(R)     .. SUM(SR, RSEG(R,SR)) -E- 1 ;
OPTFG(G,F)     .. SUM(SG, GSEG(G,SG)*FERTG(SG,F)) -E- OPTF(G,F) ;
OPTFC(C,F)     .. SUM(SC, CSEG(C,SC)*FERTC(SC,F)) -E- OPTF(C,F) ;
OPTFR(R,F)     .. SUM(SR, RSEG(R,SR)*FERTR(SR,F)) -E- OPTF(R,F) ;
MAX(I,F)       .. OPTF(I,F) -L- FMAX(I,F) ;
TOTYG(G,E)     .. SUM(SG, GSEG(G,SG)*YG(G,E,SG)) -E- TYG(G,E)/AREA(G) ;
TOTYC(C)       .. SUM(SC, CSEG(C,SC)*YC(C,SC)) -E- TYIR(C)/AREA(C) ;
TOTYR(R)       .. SUM(SR, RSEG(R,SR)*YR(R,SR)) -E- TYIR(R)/AREA(R) ;
WTOTN          .. SUM(W, AREA(W)*OPTF(W,"N")) -E- WTFU("N") ;
WTOTP      .. SUM(W, AREA(W)*OPTF(W,"P"))
             +PNRATIO("FALLBEET")*OPTF("FALLBEET","N")*AREA("FALLBEET")
             +PNRATIO("FALLPOT")*OPTF("FALLPOT","N")*AREA("FALLPOT")
             -E- WTFU("P") ;
STOTN          .. SUM(S, AREA(S)*OPTF(S,"N")) -E- STFU("N") ;
STOTP          .. SUM(S, AREA(S)*OPTF(S,"P"))
                 +PNRATIO("SUMBEET")*OPTF("SUMBEET","N")*AREA("SUMBEET")
                  +PNRATIO("SUMPOT")*OPTF("SUMPOT","N")*AREA("SUMPOT")
                  +PNRATIO("MAIZE")*OPTF("MAIZE","N")*AREA("MAIZE")
                   -E- STFU("P") ;
TOTF(F)        .. WTFU(F)+STFU(F) -E- TFU(F) ;
WLIMF(F)       .. WTFU(F) -L- 0.01*WPER(F)*WFLIM(F) ;
SLIMF(F)       .. STFU(F) -L- 0.01*SPER(F)*SFLIM(F) ;
LIMF(F)        .. TFU(F) -L- 0.01*FPER(F)*FLIM(F) ;
```

```
NR(E)         .. SUM(G, CPRICE(G)*TYG(G,E))
                 +SUM(IR,CPRICE(IR)*TYIR(IR))
                 -SUM(F, FPRICE(F)*TFU(F))  =E= RETURNS(E) ;
WNR(E)        .. SUM(G, CPRICE(G)*TYG(G,E))
                 +CPRICE("WIRR")*TYIR("WIRR")
                 +CPRICE("FALLBEET")*TYIR("FALLBEET")
                 +CPRICE("FALLPOT")*TYIR("FALLPOT")
                 -SUM(F, FPRICE(F)*WTFU(F))  =E= WRETURNS(E) ;
SNR           .. SUM(IR, CPRICE(IR)*TYIR(IR))
                 -CPRICE("WIRR")*TYIR("WIRR")
                 -CPRICE("FALLBEET")*TYIR("FALLBEET")
                 -CPRICE("FALLPOT")*TYIR("FALLPOT")
                 -SUM(F, FPRICE(F)*STFU(F))  =E= SRETURNS ;


MODEL SYRIA  /ALL/ ;

SOLVE SYRIA USING LP MAXIMIZING Z ;

PARAMETER

   PR(R)  OPTIMUM P FOR MAIZE AND ROOT CROPS;
   PR(R) = PNRATIO(R)*OPTF.L(R,"N");

DISPLAY TFU.L, OPTF.L, PR, RETURNS.L ;


^Z
```

BIBLIOGRAPHY

BIBLIOGRAPHY

Adams, R.M., S.A. Hamilton and B.A. McCarl. "The Benefits of Pollution Control: The Case of Ozone and U.S. Agriculture". American Journal of Agricultural Economics. 68(1986):886-895.

Agricultural Cooperative Bank. Unpublished internal documents (Arabic). Ministry of Agriculture and Agrarian Reform. Damascus, Syria, various years.

Akinola, A.A. "An Alternative Procedure for Granting Farm Input Subsidies in Africa". Food Policy. 12(1987):77-81

Al-Akhrass, A.M. "The Syrian Economy Since the 8th of March Revolution: Evolution of Key Macroeconomic Indicators" (Arabic). The Syrian Economic Journal. 314(1990): 3-11.

Anderson, R.L. and L.A. Nelson. "A Family of Models Involving Intersecting Straight Lines and Concomitant Experimental Designs Useful in Evaluating Response to Fertilizer Nutrients". Biometrics. 31(1975): 303-318.

Anderson, J.R., J.L. Dillon and B. Hardaker. Agricultural Decision Analysis. Ames: Iowa State University Press, 1977.

Antle, J.M. "Incorporating Risk in Production Analysis", American Journal of Agricultural Economics. 65(1983):1099-1106.

"Syria: Poor Harvest Follows a Year of Record Crop". Arab Agriculture. 1990, p. 70.

Baum, E.L., E.O. Heady and J. Blackmore (ed.). Methodological Procedures in the Economic Analysis of Fertilizer Use Data. Ames: The Iowa State College Press, 1956.

Baum, E.L., E.O. Heady, J.T. Pesek and C.G. Hildreth (ed.). Economic and Technical Analysis of Fertilizer Innovations and Resource Use. Ames: The Iowa State College Press, 1957.

Boisvert, R.N. and B. McCarl. Agricultural Risk Modeling Using Mathematical Programming. A. E. Res. 90-9, Department of Agricultural Economics, Cornell University Agricultural Experiment Station. Ithaca, N.Y., July 1990.

Bouzo, H. "The General State Budget: Basis, Objectives, and Results" (Arabic). The Syrian Economic Journal. 316(1990): 44-50.

Bronson, R. Theory and Problems of Operations Research. Schaum's Outline Series in Engineering. New York: McGraw-Hill Book Company, 1982.

Brook, A., D. Kendrick and A. Meeraus. GAMS, a User's Guide. Redwood City: The Scientific Press, 1988.

CIMMYT. From Agronomic Data to Farmer Recommendations: An Economic Training Manual. Completely Revised Edition. Mexico, D.F., 1988.

Cate, R.B. Jr. and L.A. Nelson. "A Simple Procedure for Partioning Soil Test Correlation Data into Two Classes". Soil Science Society of America Proceedings. 35(1971): 658-660.

Cowitt, P.P. 1988-1989 World Currency Yearbook. Brooklyn, NY: International Currency Analysis Inc., 1991.

da Cruz, E.R. and V.H. da Fonseca Porto. "Simplified Risk Analysis in Agricultural Extension". Agricultural Economics. 1(1988): 381-390.

Dillon, J.L. The Analysis of Response in Crop and Livestock Production. 2nd Edition. Oxford: Pergamon Press, 1977.

Doll, J.P. and F. Orazem. Production Economics, Theory with Applications. 2nd Edition. New York: John Wiley & Sons, 1984.

Dumenil, L. and L.B. Nelson. "Nutrient Balance and Interaction in Fertilizer Experiments". Proceedings of the Soil Science Society of America. 13(1948): 335-342.

El-Hajj, K. Crop Rotations and Fertilization in Rainfed Farming (Arabic). Soils Directorate, Ministry of Agriculture and Agrarian Reform. Damascus, Syria, 1985a.

————. Fertilizer Uses in Syria: Present Situation and Possible Future Trends (Arabic). Soils Directorate, Ministry of Agriculture and Agrarian Reform. Damascus, Syria, 1985b.

————. "Economics of fertilizer Use on Irrigated and Rainfed Wheat" (Arabic). Agriculture 2000, 1(1986): 15-18.

El-Sherbini, A. and R. Sinha. "Arab Agriculture: Prospects for Self-Sufficiency". Food Policy. 3(1978): 84-94.

"Evolution of Syria's Fertilizer Industry". Fertilizer International. No. 220, February 13, 1986, PP. 13-17.

Food and Agriculture Organization of the United Nations. Fertilizer Use Manual. Food and Agriculture Organization of the United Nations (FAO), Rome, 1966.

————. Syrian Arab Republic, Soils and Fertilizers. Food and Agriculture Organization (FAO), ESR:SF/SYR 14, Technical Report 1. Rome, 1970.

————. Crop Production Levels and Fertilizer Use". FAO Fertilizer and Plant Nutrition Bulletin, No. 2. Fertilizer and Plant Nutrition Service, Land and Water Development Division. Rome, 1981.

————. "Fertilizer and Plant Nutrition Guide". FAO Fertilizer and Plant Nutrition Bulletin, No. 9. Fertilizer and Plant Nutrition Service, Land and Water Development Division. Rome, 1984.

————. "Agricultural Price Policies in the Near East: Lessons of Experience". FAO Economic and Social Development Paper, No. 82. Rome, 1989.

————. FAO Production Yearbook. Rome, various years.

Fuss, M., D. McFadden and Y. Mundlak. "A Survey of Functional Forms in the Economic Analysis of Production". In Production Economics: A Dual Approach to Theory and Applications, ed. M. Fuss and D. McFadden, pp. 219-268. Amsterdam: North-Holland Publishing Co., 1978.

General Establishment for Sugar Refining. 1989 Annual Report on Agricultural and Technical Production of Sugar Beet (Arabic). Ministry of Industry, Homs, Syria, 1989.

Gittinger, J.P. Economic Analysis of Agricultural Projects. 2nd Edition. Baltimore: The Johns Hopkins University Press, 1982.

Griffin, R.C., J.M. Montgomery and M.E. Rister. "Selecting Functional Form in Production Function Analysis". Western Journal of Agricultural Economics. 12(1987): 216-227.

Griliches, Z. "The Demand for Fertilizer: An Economic Interpretation of Technical Change". Journal of Farm Economics. 40(1958): 591-606.

Hayami, Y. "Demand for Fertilizer in the Course of Japanese Agricultural Development". Journal of Farm Economics. 46(1964): 766-779.

Hazell, P.B.R. and R.D. Norton. Mathematical Programming for Economic Analysis in Agriculture. New York: Macmillan Publishing Company, 1986.

Heady, E.O. "Choice of Functions in Estimating Input-Output Relationships". Proceedings of 51st Annual Meeting of the Agricultural Economics and Rural Sociology Section of the Association of Southern Agricultural Workers, 1954.

Heady, E.O. and J.L. Dillon. Agricultural Production Functions. 3rd printing. Ames: Iowa State University Press, 1961.

Heady, E.O. and M.H. Yeh. "National and Regional Demand Function for Fertilizer". Journal of Farm Economics. 40(1959): 1407-1415.

Heady, E.O., J.T. Pesek and W.G. Brown. Crop Response Surfaces and Economic Optima in Fertilizer Use. Iowa Agricultural Experiment Station Bulletin 424, 1955.

Henderson, J.M. and R.E. Quandt. Microeconomic Theory: A Mathematical Approach. 2nd Edition. New York: McGraw-Hill, Inc., 1972.

Hoshmand, A.R. Statistical Methods for Agricultural Sciences. Portland, Oregon: Timber Press, 1988.

Hsu, R.C. "The Demand for Fertilizer in a Developing Country: The Case of Taiwan, 1950-1966". Economic Development and Cultural Change. 20(1972): 299-309.

Hutton, R.F. An Appraisal of Research on the Economics of Fertilizer Use. Report No. T 55-1, Tennessee Valley Authority, Division of Agricultural Relations, Agricultural Economics Branch, 1955.

Hutton, R.F. and J.D. Elderkin. "Use of a Particular Function in Investment Income Studies". Proceedings of 51st Annual Meeting of the Agricultural Economics and Rural Sociology Section of the Association of Southern Agricultural Workers, 1954.

ICARDA/FRMP. Farm Resource Management Program Annual Report for 1987. International Center for Agricultural Research in the Dry Areas. Aleppo, Syria, 1988.

ICARDA/FSR. An Introduction to Agriculture within the Syrian Economy. International Center for Agricultural Research in the Dry Areas, Farming Systems Research Program, Research Project No. 1. Aleppo, Syria, December 1979.

ISNAR. Organization and Structure of Arab National Agricultural Research Systems (NARS). International Service for National Agricultural Research (ISNAR), Working Paper No. 31. The Hague, The Netherlands, 1990.

International Financial Statistics, Vol. 44, No. 4, April 1991.

Jaber, R. "Syria: Striving to Resume Normal Production". Cotton International, 1989, p. 192

Johnson, P.R. "Alternative Functions for Analyzing a Fertilizer-Yield Relationship". Journal of Farm Economics. 35(1953): 519-529.

Josephson, R.M. and D.M. Zbeetnoff. "The Value of Probability Distribution Information for Fertilizer Application Decisions". Canadian Journal of Agricultural Economics. 36(1988): 837-844.

Kanbar, M.R., and K. El-Hajj. Report on the Fertilization of Local and Mexican Wheat under Rainfed and Irrigated Cultivation (1969/70, 1970/71, and 1971/72) (Arabic). Ministry of Agriculture and Agrarian Reform, Soils Directorate, Soil Fertility Division. Damascus, Syria, June 1973.

———. Report on the Fertilization of Cotton (1970, 1971, and 1972) (Arabic). Ministry of Agriculture and Agrarian Reform, Soils Directorate, Soil Fertility Division. Damascus, Syria, January, 1974.

———. Report on the Fertilization of Local and Mexican Wheat under Rainfed and Irrigated Cultivation (1972/73 and 1973/74) (Arabic). Ministry of Agriculture and Agrarian Reform, Soils Directorate, Soil Fertility Division. Damascus, Syria, December 1975a.

———. Report on the Fertilization of Cotton (1973 and 1974) (Arabic). Ministry of Agriculture and Agrarian Reform, Soils Directorate, Soil Fertility Division. Damascus, Syria, June 1975b.

———. Report on the Fertilization of Sugar Beet (1980/81, 1981/82, 1982/83 and 1983/84) (Arabic). Ministry of Agriculture and Agrarian Reform, Soils Directorate, Soil Fertility Division. Damascus, Syria, January 1986.

Kennedy, J.O.S. "Rules for Optimal Fertilizer Carryover: An Alternative Explanation". Review of Marketing and Agricultural Economics. 54(1986): 3-10.

Kennedy, J.O.S. "Principles of Dynamic Optimization in Resource Management". Agricultural Economics. 2(1988): 57-72.

Kennedy, J.O.S., I.F. Whan, R. Jackson and J.L. Dillon. "Optimal Fertilizer Carryover and Crop Recycling Policies for a Tropical Grain Crop". Australian Journal of Agricultural Economics. 17(1973): 104-113.

Khazmah, M., S. Abdul-Karim, A.R. Al-Hassan, M. Mudawar and I. Hammudah. Report of the Syrian Arab Republic to the Workshop on Structural Adjustments in Agricultural Policies in the Arab Countries (Arabic). Damascus, October 29 to November 10, 1988.

Kilmer, R.L. "Optimality and Separable Linear Programming: An Additional Reminder". Western Journal of Agricultural Economics. 3(1978): 81-84.

Lanzer, E.A., Q. Paris and W.A. Williams. A Nonsubstitution Dynamic Model for Optimal Fertilizer Recommendations. Giannini Foundation Monograph Number 41, May 1987.

Lanzer, E.A. and Q. Paris. "A New Analytical Framework for the Fertilization Problem". American Journal of Agricultural Economics. 63(1981): 93-103.

Lele, U., R.E. Christiansen and K. Kadiresan. Fertilizer Policy in Africa: Lessons from Development Programs and Adjustment Lending, 1970-87. MADIA Discussion Paper 5. The World Bank, Washington, D.C., 1989.

Loizides, P. Report of the Technical Officer, Soil Management and Fertilizer. UNDP/SF FAO Damascus Agricultural Research Station Project (SYR 14). United Nations Special Fund and the Food and Agriculture Organization of the United Nations, Damascus, November 1968.

McInerney, J.P. "'Maximin Programming' -- An Approach to Farm Planning under Uncertainty". Journal of Agricultural Economics. 18(1967): 279-289.

Mason, D.D. "Functional Models and Experimental Designs for Characterizing Response Curves and Surfaces". In Methodological Procedures in the Economic Analysis of Fertilizer Use Data, edited by E.L. Baum, E.O. Heady and J. Blackmore, pp. 76-98. Ames: The Iowa State College Press, 1956.

Mills, G. Optimization in Economic Analysis. London: George Allen & Unwin Publishers Ltd, 1984.

MAAR (Ministry of Agriculture and Agrarian Reform). Annual Agricultural Statistical Abstracts. Department of Planning and Statistics, Division of Agricultural Statistics. Damascus, Syria, various years.

———. Annual Report on Winter Crops and Vegetables (Arabic). Department of Planning and Statistics, Division of Agricultural Statistics. Damascus, Syria, various years.

———. Accomplishments of the Ministry of Agriculture and Agrarian Reform in 1979 (Arabic). Agricultural Extension Directorate, Division of Information, Damascus, Syria, 1980.

———. Accomplishments of the Ministry of Agriculture and Agrarian Reform in 1980 (Arabic). Agricultural Extension Directorate, Division of Information, Damascus, Syria, 1981.

———. Accomplishments of the Ministry of Agriculture and Agrarian Reform in 1981 (Arabic). Agricultural Extension Directorate, Division of Information, Damascus, Syria, 1982.

———. Accomplishments of the Ministry of Agriculture and Agrarian Reform in 1982 (Arabic). Agricultural Extension Directorate, Division of Information, Damascus, Syria, 1983.

———. Accomplishments of the Ministry of Agriculture and Agrarian Reform in 1986 (Arabic). Agricultural Extension Directorate, Division of Information, Damascus, Syria, 1987.

———. Decision 50/T, October 1, 1981 (Arabic). Damascus, Syria, 1981.

———. The Agricultural Production Plan for the 1989/1990 Season (Arabic). Department of Planning and Statistics. Damascus, Syria, 1989.

Nixon, C.J. "An Assessment of the Marketing of Physical Inputs in the Syrian Agricultural Sector". In Syrian Agricultural Sector Assessment, Vol. V., Texas Agricultural Experiment Station, Departmental Information Report, Staff Paper Series No. DIR 79-1, SP-14, 1979.

Nordblom, T.L. and M. Al-Ashram. An Economic Framework for Centralized Fertilizer Allocations to Crops in Contrasting Production Zones. International Center for Agricultural Research in the Dry Areas (ICARDA). Aleppo, Syria, January 1989.

Nordblom, T.L. and E.F. Thomson. A Whole-Farm Model Based on Experimental Flocks and Crop Rotations in Northwest Syria. International Center for Agricultural Research in the Dry Areas (ICARDA). Aleppo, Syria, January 1987.

Parikh, A.K. "Demand for Nitrogenous Fertilizers: An Econometric Study". Indian Journal of Agricultural Economics. 20(1965): 13-20.

Perrin, R.K. "The Value of Information and the Value of Theoretical Models in Crop Response Research". American Journal of Agricultural Economics. 58(1976): 54-61.

Peterson, W.A. "Agricultural Research in the Syrian Arab Republic". Working Paper No. 9, Human Resources for Rural Development in the Syrian Arab Republic, University of Wisconsin, Madison, 1980.

Saade, M.E., K. El-Hajj and L. Meda. An Economic Analysis of Fertilizer Allocation Strategies in the Syrian Arab Republic. Ministry of Agriculture and Agrarian Reform and the International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria, forthcoming.

Savoie, P. and M. Kabay. "Choosing Optimum Application Rates in Developing Countries". American Journal of Agricultural Economics. 62(1980): 734-736.

Schrijver, A. Theory of Linear and Integer Programming. Chichester: John Wiley & Sons, 1986.

Segara, E., D.E. Ethridge, C.R. Deussen, and A.B. Onken. "Nitrogen Carry-over Impacts in Irrigated Cotton Production, Southern High Plains of Texas". Western Journal of Agricultural Economics. 14(1989): 300-309.

Shields, J.T. "Estimating Fertilizer Demand". Food Policy. 1(1976): 333-341.

Smith, J. and G. Umali. "Fertilizer Recommendations Based on Soil Nitrogen Levels: A Total Nutrient Model". Journal of Agricultural Economics. 35(1984): 231-241.

Soils Directorate. Unpublished internal documents (Arabic). Ministry of Agriculture and Agrarian Reform. Damascus, Syria, various years.

Soils Directorate/ICARDA. Collaborative Research Project on Fertilizer Use on Wheat in Northern Syria (1986-1988). International Center for Agricultural Research in the Dry Areas (ICARDA). Aleppo, Syria, 1989.

———. Collaborative Research Project on Fertilizer Use on Barley in Northern Syria (1984-1988), Part I. International Center for Agricultural Research in the Dry Areas (ICARDA). Aleppo, Syria, January 1990.

Stauber, M.S., O.R. Burt, and F. Linse. "An Economic Evaluation of Nitrogen Fertilization of Grasses When Carry-over is Significant". American Journal of Agricultural Economics. 57(1975): 463-471.

Sung, B.Y., D.C. Dahl and Y.K. Shim. "Projection of the Demand for Fertilizer Time Series Data Analysis". Journal of Agricultural Economics. 15(1973).

Taha, H.A. Operations Research, An Introduction. 4th Edition. New York: Macmillan Publishing Company, 1987.

Taylor, C.R. "Certainty Equivalence for Determination of Optimal Fertilizer Application Rates with Carry-over". Western Journal of Agricultural Economics. 8(1983): 64-67.

Timmer, C.P. "The Demand for Fertilizer in Developing Countries". Food Research Institute Studies. 13(1974):197-224.

———. "Fertilizer and Food Policy in LDCs". Food Policy. 1(1976): 143-154.

von Neumann, J. and O. Moregenstern. Theory of Games and Economic Behavior. Princeton, N.J.: Princeton University Press, 1947.

Whitaker, M. Nitrogen Fertilizer Strategies for Rainfed Wheat in Northern Syria. Unpublished PhD Dissertation, Food Research Institute, Stanford University, 1990.

World Bank. World Development Report, 1987. New York: Oxford University Press, 1987.

Zahlan, A.B. (ed.) Agricultural Bibliography of Syria, to 1983. London: Ithaca Press, 1984.