OPTIMAL LAND AND WATER USE AND PRODUCTION RESPONSE UNDER ALTERNATIVE TECHNOLOGIES IN BANGLADESH
- A PROGRAMMING APPROACH -

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ABSTRACT

OPTIMAL LAND AND WATER USE AND PRODUCTION
RESPONSE UNDER ALTERNATIVE TECHNOLOGIES
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By

Mohammad Faisal

The agriculture sector of Bangladesh consists of complex interactions related to regional production possibilities, and comparative advantage in crop alternatives. Consequently, an improved allocation of productive resources in agriculture requires continuous analysis of new regional possibilities and interregional relationships. The aim of this research was to investigate the efficient allocation of productive resources and to determine the optimal land use and production pattern in each region of Bangladesh under two technological levels, existing agricultural technology and technology projected for 1985.

Specifically, the objectives were:

1) to evaluate and compare the effects of alternative technological adjustments on net national farm income, employment, and resource use;

2) to determine improved land use and production patterns for the four regions of Bangladesh with particular attention to food grains and commercial crops (e.g., jute and sugarcane);

3) to examine the effects of alternative government price and input distribution and policies on land use, farm income, and employment; and lastly,

4) to estimate the supply response for rice under two technological levels.

The analysis was carried out on two technological levels, within four regions, which were defined as (i) Transitional agriculture (Technology level-I) -- a level which uses relatively small amounts of improved inputs and modern technology, approximately the present technology level. (ii) Improved agriculture (Technology-II) -- this level of technology was defined by input-output coefficients which were changed significantly from their present values and include substantial increased use of HYV Aman and increased amounts of chemical fertilizers. The two technological levels represent two plan periods used in the analysis - viz the Technology-I as Plan I (1976) and Technology-II as Plan II (1985).

The research finding that the farmers' profitability increases significantly, as a result of the introduction of HYV Aman, reinforces the possibility of success of a government policy to encourage expansion of areas under this crop. As the existing policies with respect to supply in inputs (e.g., fertilizer, water, etc.) are mainly geared to the Boro season, a similar sort of provision for HYV Aman will necessitate the reorientation of these policies.

All the programming results under alternative government policies and technological constraints retained rice production at a very high level. Therefore, high profitability in rice production indicates a substantial scope for reduction of input subsidies involved in irrigation water, fertilizers, and pesticides with little significant adverse effects on farmers' incentives. The existing support price appears high relative to the prices of other competitive crops. Currently rice support prices appear fixed at a level where supply response of rice is inelastic. On the other hand, these high levels have severe detrimental impacts on production incentives for jute, sugarcane, and wheat. The finding of this research indicates that the existing support price for rice could probably be reduced by one third without appreciable adverse effects on rice production.

The breakthrough in seed technology for HYV Aus rice has increased considerably the competitive strength of Aus rice relative to jute. With high yield potential of HYV Aus rice, the jute acreage will likely be further adversely affected, unless the relative price of jute is adjusted proportionately to the price of rice to maintain its competitive position.

OPTIMAL LAND AND WATER USE AND PRODUCTION RESPONSE UNDER ALTERNATIVE TECHNOLOGIES IN BANGLADESH - A PROGRAMMING APPROACH -

By

Mohammad Faisal

A DISSERTATION

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Dedicated to my

grandfather (Mr. Mohammad Ansar Khan)

and mother (Mst. Zabun Nessa Khanum)

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INTRODUCTION

Precise objectives of development planning differ from country to country and over time. In a general sense, however, all seek to promote human welfare through economic growth. Planning attempts to connect ends and means. In economic terms the efforts at development are designed to optimize use of existing resources among alternative means to achieve maximum production over a specified time period. In LDC's the knowledge of strategic parameters (e.g. relations between production inputs, soil, and output, etc.) associated with transformation of the existing production structure need to be delineated clearly so as to achieve optimum resource utilization and enhancement of farm and national income.

Reliable economic analysis of agricultural sector in LDC's is confounded by the complexities due to the existence of: (i) old technological structure; (ii) inadequate supply of higher yielding inputs (e.g. seeds, fertilizer, water, etc.); (iii) inflexibility of the production structure; (iv) high risk and uncertainty surrounding farmers' decision environment; and (v) lack of emphasis on scientific investigation and economic research.

Problem Situation

Over the last two decades total food consumption has doubled in Bangladesh. This has been due to an unprecedented population upsurge at the rate of 3.1 percent per annum. Food production, however, has failed to keep pace with population growth. Rice production increased from 9.52 million tons in 1960-61 to 10.96 in 1970-71, an annual growth rate of 1.2 percent (44) and declined to 10.4 million ton during 1970-75 (5 years average). As a result of the widening gap between supply and demand, the food prices soared up to an average of Rs. 3264 per ton in 1970-75 as against Rs. 880 per ton in 1965, an increase of 271 percent due partly to inflation.

To meet increasing demand, the government of Bangladesh has laid tremendous emphasis on enhancing food production. Government policies have consisted of:

(a) Input subsidies -- To accelerate the use of a substantial quantum of required production inputs by farmers, the government used high subsidy rates -- ranged from 40 percent and 60 percent for fertilizers and water respectively, and100 percent for pesticides. High production incentives were sought particularly for high yielding varieties.

(b) Support price -- Provision for dual procurement prices for food grains was made so that a higher price could be paid for the high yielding varieties than for local varieties.

(c) Supervised credit -- Increased flows of credit have been provided through co-ops. An appropriate supervision and guidance was attempted to assure its proper utilization.

(d) Research and extension -- Crop Research Institutes and agricultural extension services have been strengthened. In addition, large amounts of high yielding seeds were made available to farmers.

Though this intensive production effort has continued over the last decade and produced certain achievements, it has posed certain serious problems to decision makers:

(i) In spite of large input subsidies and high procurement prices, food production has lagged continuously behind population growth. As a result, the per capita availability of food grains has declined over the years (Table 1.1).

(ii) Secondly, the relative increases in food grain prices in comparison to other competing crop prices has resulted in continuous transfer of lands to rice crops, thereby leaving a smaller percentage of total land

Table 1.1. Per Capita Availability of Food Grains (in million tons)

Years	Net domestic production	Total Imports	Net availability for consumption	Population (in million)	Per capita availability ounce/person/day	
					with import	without import
1	2	3	4	5	6	7
1964-65	9.290	.360	10.120	61.3	16.2	14.9
1965-66	9.510	.870	10.410	64.7	15.8	14.4
1966-67	8.720	1.200	9.880	66.7	14.5	12.8
1967-68	9.290	1.070	10.050	68.6	14.4	13.3
1968-69	9.630	1.250	10.860	70.7	15.1	13.4
1969-70	10.570	1.640	12.110	72.4	16.4	14.3
1970-71	9.650	1.340	10.990	73.37	14.7	13.1
1971-72	9.013	2.398	11.411	73.38	15.0	12.1
1972-73	9.512	2.378	11.890	75.11	15.3	12.4

for the other food and cash crops. Rice prices show an increase of 196 percent from 1964 to 1970, whereas price increases of other crops only ranged from 5 to 20 percent (Table 1.2). In the case of potatoes, the price has declined by 60 percent during the period under comparison. Due to low prices of other crops relative to rice at the farm level, the acreages of sugarcane and tobacco have declined from 0.42 million acres in 1965-70 and .131 million acres in 1950-55 (5 years average) to 0.36 million acres and .110 million acreage in 1970-75 respectively; whereas the areas under rice crop have increased by 3 million acreage (a 15 percent increase) during the same period.

(iii) Thirdly, the great increase of food grain prices has caused farmers to become less careful about topographic and hydrological characteristics of land with respect to its suitability for food grain production vis-a-vis other alternative crops. This has two dampening and vulnerable effects on production:

(a) As lands are being transferred to food grains, only marginal lands which are inferior in quality are being left for other crop production. Consequently, the Marginal Physical Product (MPP) of these crops have shown a continuous declining trend. For example, Table 1.3 indicates that the

Table 1.2. The Wholesale Prices of Different Agricultural Commodities[1]

Rupees/md

	Rice[2] (Course)	Potato	Jute[3]	Tobacco	Sugar
1964	26.38	31.51	22.52	107.92	74.77
1965	32.05	29.52	31.47	119.38	85.32
1966	41.10	23.13	27.39	99.17	69.87
1967	42.20	25.32	31.0	103.42	67.14
1968	47.66	23.09	26.0	158.77	84.42
1969	67.64	24.15	26.0	174.59	90.00
1970	78.10	18.50	27.0	110.50	90.00
Percentage inc.(+) or dec.(-) over 1964	196	-41.3	19.8	2.4	20.4
1975*[3]	120.0	45.0	100	N.A.	154.5 (72-73)

*The price series from 1971 to 1974 are omitted as the data of these years do not represent a meaningful indicator for economic analysis. The reasons for not incorporating the data for these years are: (i) War during 1971-72; (ii) unstable political situation; (iii) existence of rampant inflation, etc. According to experts of World Bank and USAID, etc., economy appears to have stabilized during later part of 1974 and beginning of 1975. For this reason, price data for 1975 is included.

Source: [1]Directorate of Agricultural Marketing. Ministry of Agriculture.

[2]Wholesale prices of rice in E. Pakistan - Quarterly Eco. Indicator for E. Pak., p. 4, Bangladesh Bureau of Ag. Statistics.

[3]Bangladesh Agriculture Statistics, Ministry of Agriculture, Bangladesh.

Table 1.3. Comparative Statement of 5 Years Average Acreage Production and Per Acre Yield of Different Agricultural Commodities

Year	SUGARCANE[3]			TOBACCO		
	Acres (million)	Production (million tons)	Per acre yield(tons)	Acre (million)	Production million lbs	Per acre yield/lbs
1950-55 (5 years ave)	N.A.	N.A.	N.A.	.131	93.7	811
1965-70	0.42	7.525	18	.110	80.3	691
1970-75	0.36	6.316	17.4	.110	86.2	770
	JUTE[2]			RICE[3]		
	Acres (million)	Production bales (million)	Per acre yield acre/bales	Acres (million)	Production million tons	Yield per acre/maund
1950-55 (5 years ave)	1.521	5.487	3.6	20.88	7.50	9.8
1965-70	2.280	6.574	2.9	23.90	10.74	12.2
1970-75	1.952	5.875	2.7	23.97	10.70	12.2

Source: [1]Food Agr'l. Section & Plan. Com. Gov't. of Pakistan and Statistical Digest of Gov't. of E. Pakistan.

[2]Ag. Statistics, Ministry of Ag. and Works, Gov't. of Pakistan (Jute Board)

[3]Bureau of Ag. Statistics, Gov't. of Bangladesh.

N.A. = Not available.

per acre yield of jute has decreased from 3.6 bales/acre in 1950-55 to 2.9 bales/acre in 1965-70 and to 2.7 bales/acre in 1970-75. Similarly, the tobacco yield declined from 811 lbs/acre in 1950-55 to 770 lbs/acre in 1970-75. The per acre yield of sugarcane has declined from 18 tons in 1965-69 to 17.4 in 1970-75.

(b) Due to the increased use of land, a significant portion of land (nearly 10% of rice land) which is at present being used for food grain production is located in low areas subject to recurring floods every year. It is estimated that since 1964-65, on an average, about 0.8 to 1.0 million tons (10) of rice as against the actual average imported requirement of 1.5 million tons, have been destroyed by floods annually.

(iv) Fourthly, in spite of increasing emphasis on rice production and large transfer payments to farmers in the form of input subsidies, it was found that real per capita rural income declined from Rs. 275 in the early 1950's to Rs. 268 in the 1960's. Over the same period, the urban income rose from Rs. 619 to Rs. 677 per annum(3). The problems of Bangladesh agriculture as seen by the Annual Plan for 1974-75 were:

(i) How to increase production of cereals (e.g., rice and wheat) to the maximum extent from the minimum acreage of land;

(ii) How to enhance production of noncereals and important cash crops like jute, tobacco, pulses, sugarcane;

(iii) How to release land from rice to other cash and food crops production so as to enable the country to earn foreign exchange needed for economic development and bridge the nutritional gap of the population;

(iv) How to improve the allocative efficiency and optimum use of economic inputs, e.g., fertilizer, water, pesticides, and land; and above all,

(v) How to increase farm profit in order to provide sufficient production incentives to farmers.

Objectives of the Study

The general purpose of this study is to develop an empirical base for analyzing alternative agricultural policies for Bangladesh. The investigation centers on four specific objectives. They are:

(i) To evaluate the effects of alternative levels of agricultural technology on net national farm income, employment, and resource use;

(ii) To determine optimal land use and production patterns for the four regions of Bangladesh with particular attention to food grains and commercial crops (e.g., jute and sugarcane);

(iii) To examine the effects of alternative government price and input distribution policies on land use, farm income, and employment; and lastly,

(iv) To estimate the supply response for rice under two levels of agricultural technology.

It is important to clarify some terminology and concepts used here, which might confuse the reader in understanding this analysis.

(a) Net National Farm Income (NNFI): is defined as the gross revenue received from the production of eleven commodities in the nation minus the variable cost incurred from the production of these commodities.

(b) Employment: is related to the total farm labor force (both family labor and hired labor) that is absorbed in the production of eleven crop activities studied.

(c) Resource use: includes both fixed and variable inputs which are limited in supply and act as constraints on production activities. The constraining resources considered in the study were: agricultural land, family labor, hired labor, bullock power, irrigation water, fertilizer and credit.

(d) The optimum allocation of land: this condition has been defined as one, that with given physical and technical resource constraints , indicates which crop activities would be undertaken and how much land would be allocated to each crop activity so that net national farm returns are maximized in an annual cycle.

(e) Procurement price: refers to the government fixed prices for rice, wheat and sugarcane whereas farm gate prices are used for potato and jute.

Scope of the Study

The entire area of Bangladesh is included in this investigation. The analysis concentrates on two technological levels of farming within the four regions of Bangladesh identified by the soil reconnaissance survey project. The regions are: (i) central; (ii) eastern; (iii) northwest; and (iv) southwest. The two levels of agricultural technology used in this study are defined as follows:

(i) Transitional Agriculture -- Technology Level-I

The level which uses small amounts of improved inputs and modern technology. The existing transitional system of operation is regarded as technological level-1. This level of technology is included in Plan I.

(ii) Improved Agriculture -- Technological Level-II

The second level of technology is defined by input-output coefficients which have changed significantly from their existing values and include use of larger quantities of high yielding (HYV) Aman seeds and increased use of chemical fertilizers as projected for 1985 (Plan II).

Theoretical Background of the Research

The agricultural sector consists of a series of complex interactions relating to regional production possibilities, comparative advantage, competitive crop alternatives and a marketing system that is both uncertain and complex. The importance of this sector stems largely from its contribution to: (i) the domestic food supply; (ii) the supply of domestic savings needed for investment; and (iii) the supply of foreign exchange required for importation of capital goods. The failure of Bangladesh agriculture to produce adequate requirements of food grains for the entire population, and to generate increasing rates of savings and foreign exchange earning capacity may result from: (i) underallocation of resources to the agriculture sector; (ii) inhibition of free play of market forces due to regulation and administrative action or other constraints; and (iii) misallocation of resources associated with inadequate technical information required for optimal use of resources.

In agriculture production typically takes place on multi-product farms where several activities compete for common resources. This suggests that it is not possible to regard supply response to prices, costs and other variables of one crop as being independent of the response to other crops grown on the same farm. Besides, regional characteristics influence the predominant size of the production units, the methods of production that can be used and crops or livestock alternatives that can be considered. The regional characteristics are controlled by such factors as the existing climate, topography and hydrological condition available to the farm or region. Specialization resulting from regional comparative advantage is a function of relative yield as affected by soils and climate, regional resource supplies and the relative profitability of different crop and livestock enterprises for the individual farmer. Due to the presence of these technical relationships, it is found that a crop suitable for a particular region or farm may be less productive in other areas. Allocation of production inputs by government agencies which disregard these regional technical characteristics are likely to cause inefficient use of resources, which, in turn, results in less production and increased costs.

In the past, very little technical information has been available to the agricultural policy decision makers of Bangladesh. Consequently, the growing of a particular crop in a region as well as distribution of production inputs among alternative crops through governmental channels was primarily a function of administrative and political choices. As a result, it is hypothesized that agriculture has not been able to produce its greatest potential results in spite of vigorous government efforts in continuously augmenting the supply of production inputs. The availability of improved scientific information about technical relationships between crop physiology, topographic and hydrological characteristics of particular regions or soil strata can result in improved allocation of production inputs, optimum cropping patterns and increased production. The "Soil Reconnaissance Project" of Bangladesh/FAO/UNDP, which has completed a survey of 80 percent of agricultural land during the last ten years was a step in that direction. The survey provides an improved estimate of technical production relationship in different regions in Bangladesh. The extent to which Bangladesh agriculture can satisfy internal food needs and is able to compete in the international market depends to a large extent on the utilization of her productive resources where these can produce highest returns and the extent to which crop and livestock production is distributed among regions according to their comparative advantage.

Technological Change and the Theory of Farm Level Adjustment in Bangladesh

This theoretical framework shows that farm level adjustment processes are a result of changes in the production and cost functions under alternative technologies considered in this study. Over the years, the term "technological change" has been given a wide range of meanings and interpretations. In the field of agriculture in LDC's, development strategy often looks to the "seed-fertilizer revolution" as the primary source of technical change which includes three key elements: (i) agricultural research leading to the development of high yielding varieties (HYV) which have the capacity to respond to high levels of soil fertility; (ii) greatly increased application of chemical fertilizers; and (iii) activities which promote both the widespread use of new varieties and the associated changes in the farm practices which are needed if these varieties are to realize their high yield potential (29). Recently, the FAO/UNDP soil reconnaissance survey has indicated that about 22 million acres (11) of land can be brought under improved HYV rice varieties of Irri-aman and Irri-Aus/boro in Bangladesh. This new potential means that technical change resulting from the introduction of HYV leads to a production function shift which will enable the agricultural sector to increase output associated with greater use of inputs, particularly fertilizers. Consequently, in this study the introduction of HYV seeds accompanied with increased use of chemical fertilizers is regarded as a prime-determinant of technical change in agriculture in Bangladesh.

Separate production functions are, therefore, specified with and without technological change based on HYV seeds and chemical fertilizer. In a production function the fixed factors are always specified as representing not only a specific quantity but also a specific quality as well. Hence, whenever either of these two aspects change for one or more of the fixed factors, the production function will shift upward/downward depending on the nature of the change. However, a change in the quantity of variable factor is reflected in movements along the production function (4,6). In Bangladesh, under transitional technological conditions, the output will be a function of land, labor, bullock-power, water, fertilizer, seed and pesticides, etc. Under an improved technological situation resulting from introduction of HYV seeds, the production function shift upwards enabling greater output to be produced with increased use of other variable inputs. However, in order to avoid data constraints for the purpose of this study, it is assumed that the use of only one variable factor, i.e., fertilizer, would change under the two technological adjustments. The production function with HYV and local seed varieties is specified as follows:

$$Y = f(X_1/X_2, X_3, X_4, X_5, X_6, X_7)$$

where Y = output

X_1 = variable quantities of fertilizer,

X_2 = land,

X_3 = labor,

X_4 = bullock power,

X_5 = seed, traditional or HYV

X_6 = water,

X_7 = pesticides.

In addition to the specification of the production function, the following assumptions are necessary for the purpose of theoretical analysis. First, the levels of inputs per acre other than fertilizer are known for each crop activity; second, prices of inputs and output per unit remain constant; third, the farm operators are profit maximizers and will, therefore, produce at that output level where the marginal factor cost (MFC) of fertilizer equals the marginal value product (MVP) of fertilizer.

With the production function under HYV seeds and assumptions as specified above, it is possible to present a theoretical exposition of the farm adjustment process under the technological alternatives considered in this study. Figure 1 illustrates an upward shift in the production function from TVP_0 to TVP_1 due to introduction of HYV seeds. The total value product curve is obtained by multiplying total physical product (TPP, i.e., output of crops) by the prices of the product. The two marginal value product (MVP) curves representing two technological situations were obtained from TVP curves ($MVP_F = \frac{\partial TP}{\partial F} \cdot P_0$). The marginal factor cost (MFC) of fertilizer is assumed to be constant. First, notice the impact of a shift in the production function has on the MVP of F in the production of Y. With the old technology, a price of F at F_x, the ideal level of factor use was F_0 units of fertilizer input with a corresponding output of Y_0. With technological change due to the introduction of HYV seeds, at F_0 unit of fertilizer, the $MVP_1 > F_x$. So, the rational entrepreneur would increase use of F from F_0 to F_1. This would result in total output Y_1 instead of Y_0^1, that would otherwise result if the entrepreneur did not increase the use of F. The TVP curve originates from N and N^1 because ON and ON^1 amounts of value products are assumed to result from natural fertilizer for local and HYV seeds respectively.

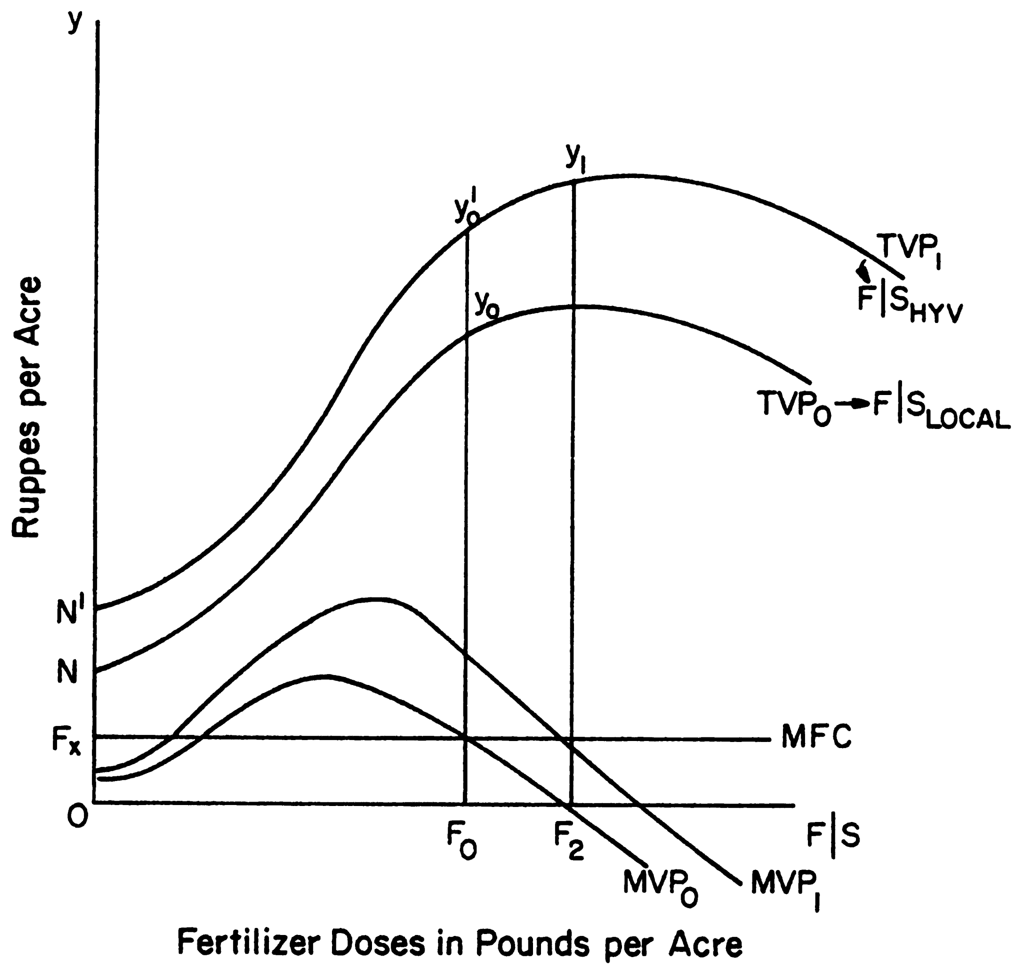

Figure I. Production Function of Fertilizer With and Without Technological Change

Figure II shows that in the case of a farm-adjustment process, a change in fertilizer price will shift the TVC curve upwards/downwards as well as the quantum of fertilizer to be used increase/decrease depending on the nature of the change.

Figure II shows the impact of a change in fertilizer price on the farm adjustment process. As the fertilizer price increases from Fx_0 to Fx_1, the quantum of fertilizer used will decline from F_0 to F_1. The optimum output will change from Y_0 to Y_1.

The Analytical Framework of Enterprise Combination Between Farm-Firm and Regions

This analytical framework includes the conceptualization of procedures to determine the most profitable resource allocation when two and more products are being produced on a farm. In the latter part of this section, this theoretical idea is extended beyond micro-production economics to demonstrate the theoretical rules of enterprise combination between regions. This is particularly relevant when the national planning objective is to ensure regional specialization in order to derive maximum output from a limited amount of resources.

The search for optimum enterprise combinations is necessary to determine the best combination of products to obtain maximum use for a given outlay of resources or the

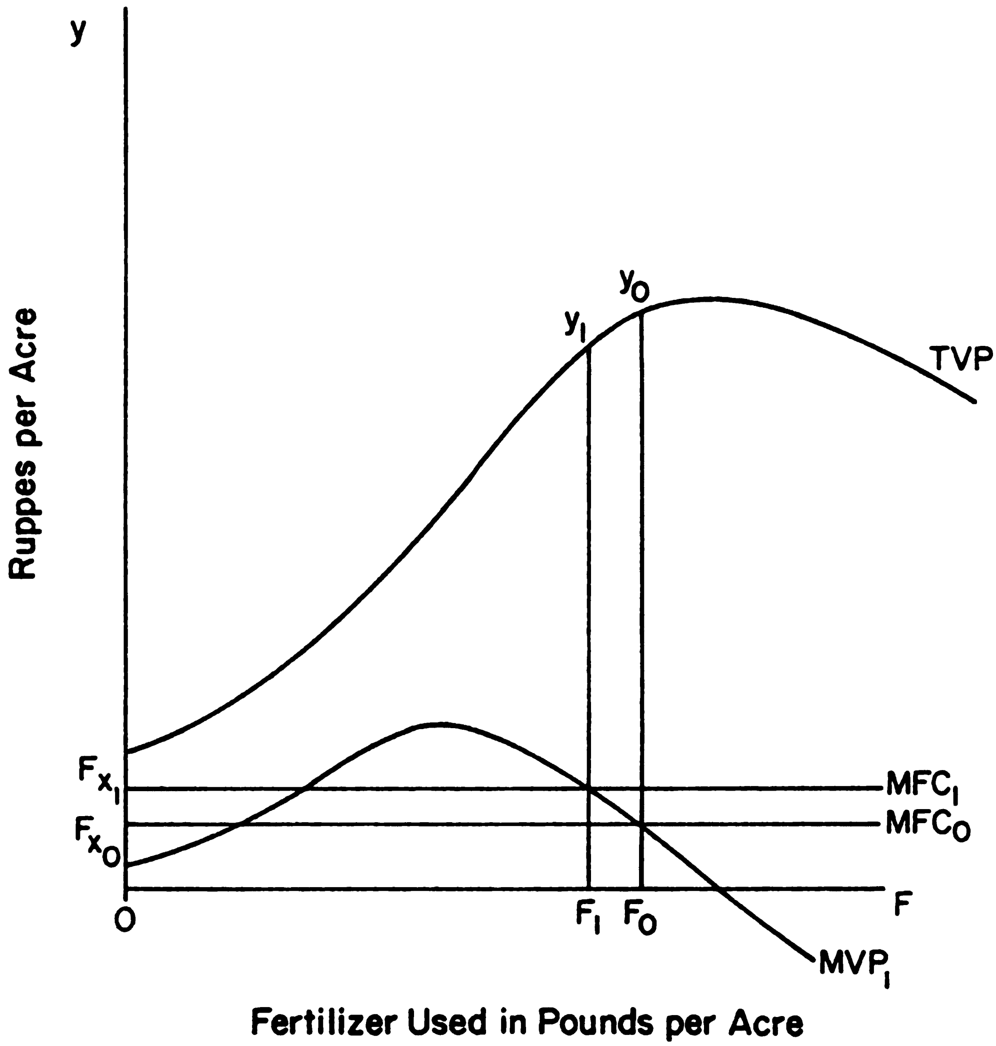

Figure II. Optimum Value Product and Costs With Changed Fertilizer Prices best use of resources for a given combination of products within or in between farms or regions. Assume that a farm or region in Bangladesh produces two crops, rice (Y_1) and jute (Y_2), with their production functions specified as follows:

$$Y_1 = (x_1 \ldots x_d / x_{d+1}, \ldots x_g // x_{g+1} \ldots x_n)$$

$$Y_2 = (x_1 \ldots x_d / x_{d+1}, \ldots x_g // x_{r+1} \ldots x_t)$$

where:

$x_1 \ldots x_d$ = inputs which variable for the farm as a whole as well as each enterprise such as fertilizer, etc.

$x_{d+1} \ldots x_g$ = resources fixed to the firm but allocable between Y_1 and Y_2 such as land, plough and family labor.

$x_{g+1} \ldots x_n$ = inputs fixed in the production of rice

$x_{r+1} \ldots x_t$ = inputs fixed in the production of jute.

These hypothetically specified production functions for rice and jute are shown in graphical form in Figures 3(a) and 3(b). Assume that the farm has a given amount of resources allotted to variable inputs $x_1 \ldots x_d$ which would enable the farm to produce: (a) only rice; (b) only jute or (c) some combination of both. If the entire budget were forced into jute production the farm would be producing at "a" (Figure 2(b)) and no rice. By reducing expenditure on jute to "b" (Figure 2(b)), the farm would be producing F

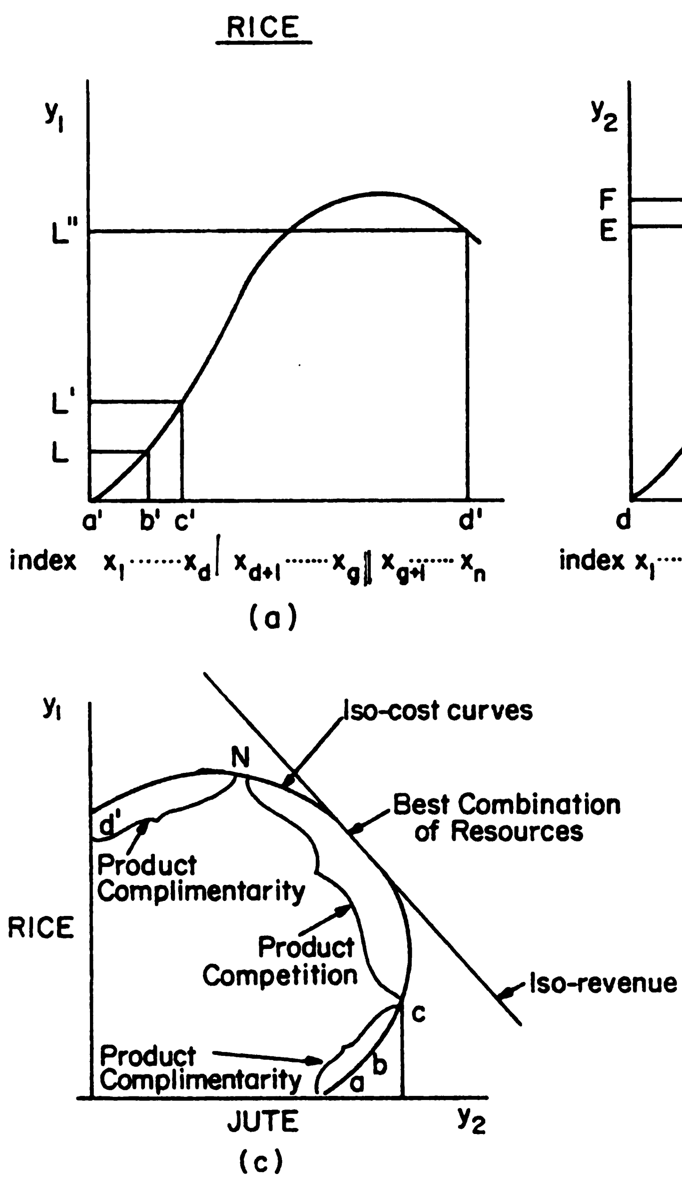
RICE
JUTE
y_1
L"
L'
L
a' b' c' d'
index x_1 ······ x_d | x_{d+1} ······ x_g || x_{g+1} ······ x_n
(a)
y_2
F
E
d c b a
index x_1 ··· x_d | x_{d+1} ······ x_g | x_{r+1} ······ x_t
(b)
y_1
Iso-cost curves
N
Best Combination of Resources
d'
Product Complimentarity
RICE
Product Competition
Iso-revenue
c
Product Complimentarity
b
a
JUTE
y_2
(c)

Figure III

quantity of jute and L quantity of rice. Similarly, if the entire resources are spent (d^1 in Figure 3(a)) on rice, the farm would be producing a^1L^{11} quantity of rice and no jute. By continuing the above process it is possible to construct a production possibility or iso-cost curve representing the possible combination of Y_1 and Y_2 which could be produced for given resource level (shown in Figure 3(c)). On the production possibility curve (PPC), below the point C and to the right of N, the production function would be in stage III, and thereby represent an irrational boundary of production choice. By combining iso-cost and iso-revenue line determines the profitable enterprise combination. For the best enterprise combination the variable resources should be used such that:

$$\frac{MVP_{xi}(Y_1)}{P_{xi}} = \frac{MVP_{xi}(Y_2)}{P_{xi}}$$

and for best level of production with the optimum enterprise combination, the variable resources should be used such that:

$$\frac{MVP_{xi}(Y_1)}{P_{xi}} = \frac{MMP_{xi}(Y_2)}{P_{xi}} = 1$$

The above mentioned idea of micro-production economics can be used to obtain enterprise combination in between regions. Assuming the production functions pertaining to the production of the two commodities in each region is known, it is possible to derive regional production possibility curves for the two regions. From these production possibility curves best combination of products Y_1 and Y_2 are determined where the price ratio is tangent to the PPC (shown in figure 4a). Determination of the combination of production which would yield the maximum total output from the two regions combined is demonstrated in figure 4b. In this diagram the production curve for region I has been inverted and plotted tangent to the production possibility curve or region II. The point of tangency indicates the combination of production which would be the maximum of both Y_1 and Y_2.[1]

Analytical Tools for Regional Analysis

The whole spectrum of Bangladesh agriculture, its present problems and full potential under alternative regional resource constraints, technological change resulting from "HYV seed-fertilizer revolution" and its capacity of meeting internal demand for food, etc., needs to be evaluated for formulation of appropriate policy guidelines for future development. Answers to these wide range of problems require an analytical tool that generates both sufficient empirical results at both regional as well as national levels. Detail by region is needed

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[1] For details see G. L. Johnson, Enterprise Combination -- Economics and Management in Agriculture, edited by W. H. Vincent, pp. 82-114.

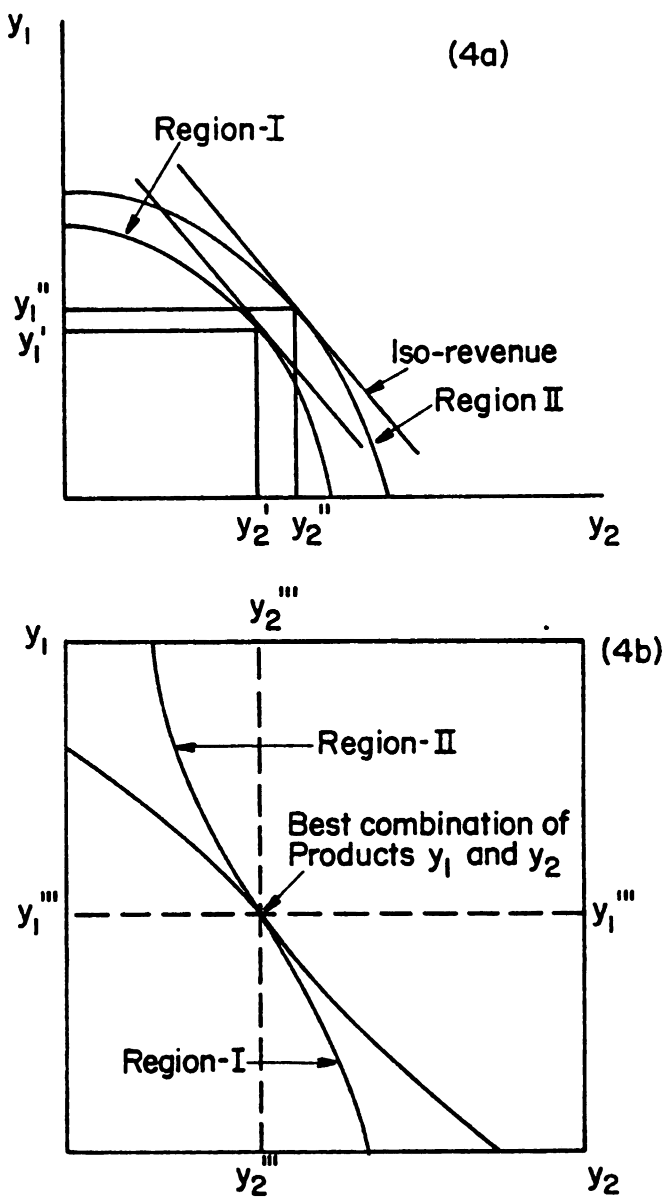

Figure IV. Optimum Resource Utilization and Product Combination in-between Regions so that the flexibilities of or restraints on production and resources can be measured and impact can be expressed at the local level. National detail is required so that market impacts on prices can be measured and interdependence among regions in terms of their comparative advantage can be established. Thus, if either resource and production potentials under various technologies, resource or production policies are to be evaluated, an analytical tool is needed that allows measures and generates results at the level of both individual regions and the nation as a whole. This type of detail can be provided by a linear programming model incorporating relevant production possibilities and various regional constraints under alternative technological adjustments.

L.P. is a method of combining resources, whereby it is assumed that the production process can be broken down into a series of straight line relationships. A unique solution is obtained to a set of simultaneous linear equations which represent the productive relationships of the various resources. It is a method of finding the most profitable combination of alternative production processes within a given set of restrictions. Linear optimization models in the agriculture sector are expected to attain a double aim: (i) to help agricultural planning by indicating optimal distribution of the available resources between and within geographic regions (branches) and (ii) to make calculations in order to estimate for agriculture the national economic resources it can fruitfully utilize. Regional resource availabilities can be altered by policies affecting land use, water availabilities or transfer and the availability of other endogenously allocated inputs such as fertilizer, pesticides, etc. These policy alternatives will be evaluated in this framework by (i) incorporating new restraints necessitated by a new policy; (ii) changing the values in "c" vector to reflect changes in the relative activity costs resulting from a different policy or assumptions; (iii) changing the coefficient in the "A" matrix to reflect a changed level of interaction between an activity and any of the relevant markets.

Limitations of the Programming Model

Programming techniques represent a useful and versatile method of evaluating agricultural policies. But L.P. has its limitations that restrict the scope of its use and the interpretation of results. Its limitations are inherent in its assumptions which are: (i) additivity and linearity; (ii) divisibility; (iii) finiteness; (iv) single-value expectations; and (v) nonnegative output.

Methods to Deal with Aggregation
Bias in Regional Model

Aggregation error is said to exist when the weighted sum of production of representative farms does not equal to the total production of the region. The sufficient condition for zero aggregation bias are:

(i) B_1, ... B_2, ... B_n = B. Condition (1) states that all firms must have identical matrices of input-output coefficients.

(ii) $Z_g = Y_g Z$, where Y_g is a scalor greater than zero for all j. The vector of net returns for every farm has to be proportional to the vector of the aggregate;

(iii) $C_g = \lambda_g C$ where λ_g is a scalor greater than zero and less than one for all g. Vectors of resources of every farm must be proportional to corresponding vector (i.e., proportional variation in constraint vector).

The term proportional variation means that if farms differ in one resource, say labor, by a certain ratio, then they must differ in all resources by that ratio. Miller[2], on the other hand, in his qualitative homogeneous output vector (QHN) approach indicated that in order to have a bias free aggregation the following conditions need

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[2] Miller, T. A. "Sufficient Conditions for Exact Aggregation in Linear Programming Models", Agricultural Economic Research. ERS/USDA, 18: 52-57, April 1, 1966.

to be met: (a) all farms must have an identical coefficient matrix and (b) all farms must have the same activities included in the solution.

Conventional procedures have invariably used "farm size" as the selection criterion for bias free aggregation. The weakness of this procedure is that it takes into account only one factor of production, namely, land, and ignores all other resources of the farm-firm. In this study both land and labor have been considered as strategic factors for aggregation. The master survey of agriculture (7th edition, 67) indicated that nearly 71 percent of farmers hold, on an average, 3.1 acres of land and only 3 percent hold more than 12 acres. Recent estimates show that nearly 85 percent of the farm families hold about 3.1 acres of land. With respect to labor, the "Farm Mechanization Survey Report" indicated that 98 percent of the farm families had on an average, about 2.1 adults working population. Judging from these two resource points of view,since 85 percent to 98 percent of farm families possess uniform land and labor resource endowments, it is assumed that their a_{ij}'s would not be significantly different from each other.

CHAPTER II

SALIENT FEATURES OF AGRICULTURE AND ITS POTENTIAL FOR FUTURE DEVELOPMENT IN BANGLADESH

The combination of soils, climate and hydrology greatly influence the crop production environment in Bangladesh. The first part of this chapter focuses on the important existing elements of regional diversity in respect to topography, soils, climate and hydrology and its impact on land use patterns and cropping intensity, etc. The second part of this chapter deals with the potential for increased crop production with the innovation of new "seed-fertilizer" technology and the availability of detailed technical information regarding soil strata, topography and hydrology in respect of each region through Soil Reconnaissance Survey. This discussion will help in providing a basis as to what extent modern technology under given information would enable Bangladesh agriculture to surmount the natural as well as physical constraints to crop production that it is encountering today and usher a new hope and aspiration in the future.

Bangladesh is traditionally and predominantly an agricultural country stretching over 55,000 square miles with a population density of 525 per square mile. It is situated on the confluence of three big rivers of the world -- the Ganges, Brahamputra and Megna.

A. Topography and Soils

The characteristics of topography and soils in Bangladesh have influenced the evolution of the cropping pattern and are important in determining irrigation and other agricultural development possibilities. The alluvial plains of Bangladesh rise with very low gradients of .03'-.06' per mile, with few parts of the country being more than 50 feet above sea level. The only significant elevation, the Sythet hills in the northeast and the chittagong hills in the southeast. The terrain is crossed by 15,000 square miles of waterways including major rivers. The overall picture disguises considerable variations in local relief. Complex local differences in elevation are important in planning irrigation and drainage especially as they are associated with important differences in soil permeability and associated crop suitability.

Bangladesh soils have, in general, a high potential for increased crop production. This is particularly due to high natural fertility, as evidenced by the extensive agronomic trials which show that virtually all soils respond well to fertilizers. The Soil Reconnaissance Survey (SRS) has identified the main soil tracts in each region including their physiography and important characteristics which are:

(I) CENTRAL REGION

(a) Northern Piedmont Plains -- are mainly loamy sediments subject to shallow and intermittent flooding and these are adjoined by clay plains or basins subject to deeper flooding.

(b) The Old Brahamputra Flood Plain -- the sediments are mainly silty on the ridges and clay in the basins but there are important sandy areas in the west of mymensing and northeast of Dacca. The highest ridges and basin in the west and in Dacca are shallowly flooded in the monsoon area.

(c) The Madhupur Tract -- is a heavy slicken sided clay, but gives rise to both loamy and clay soils. They are few valleys which have a general pattern of relatively well drained soils or have the higher edges and of poorly drained or seasonably shallowly flooded soils on slightly lower terrace interiors.

(d) The Jamuna Flood Plain -- comprises a typical meander flood plain pattern of broad ridges and river channels. This unit also includes the temporary alluvial formations (chars) within and adjoining the main river channels.

(II) EASTERN REGION

(a) Northern Piedmont Plain -- consisting of mainly loamy sediments subject to shallow or intermittent flooding and clay basins subject to deeper flooding.

(b) Sythet Basin -- consists mainly of heavy deposits of clay soils.

(c) Young, Middle and Old Megna Estuarine -- mainly alluvial land. The sediments are predominantly highly silty and finely stratified with clays in some basins. Flooding varies from shallow to deep.

(d) Chittagong Coastal Plain -- consists of loamy alluvial from adjoining the hills and level clay plains adjoining the three rivers.

(III) NORTHWEST REGION

(a) The Old Himalayan Plain -- is a complex pattern of broad sandy or loamy ridges intermixed with numerous shallow channels with mainly loamy soils.

(b) Tista Alluvial Flood Plain -- consists of silty sediments and heavy clays.

(c) The Barind Tract -- is mainly level with slowly permeable soils overlying little-weathered madhupur clay.

(d) The Ganges River Flood Plain -- where clay soils predominate in basins and on the greater part of most ridges, but silts and occasionally sands occupy higher ridge crests.

(IV) SOUTHWEST REGION

(a) Ganges River Flood Plain -- as a whole, comprises a typical meander flood plain landscape of ridges, basins and old channels. The Ganges channel itself is constantly changing, eroding and depositing large areas of new alluvium which is calcareous. Clay soils predominate in basins and on the greater part of most ridges, but silts and occasionally sands occupy higher ridge crests.

(b) Gopalganj-Khulna Peat Basins -- occupy perennially west basins and are covered by clay.

(c) The Ganges Tidal Flood Plain -- the sediments are mainly noncalcareous clays, but they become more silty in the east and usually have a buried peat layer in the West.

The above mentioned physiological characteristics of land, soils and hydrology and its influence on existing cropping patterns is shown in Table 2.1.

A.1. Climate and Rainfall

Bangladesh has a tropical climate with mean monthly temperatures of 60°F and hence permit the growth of a wide range of tropical and sub-tropical crops such as rice, sugarcane, jute, potatoes and tea, etc., throughout the year. Rainfall ranges from 50 inches in the west to over 200 inches in the northeast and the southeast. The monthly distribution of rainfall follows the monsoon pattern of

Table 2.1. Present Adaptation of Cropping Pattern to Land and Soil

Land Type	Land Elevation	Soil permeability	State of flood During monsoon season	Present Cropping Pattern		
				Spring	Summer & fall	Winter
1	High	High	Free	Aus or Millet fallow	Fallow or Kharif vegetables	Rabi or Fallow
2	High (Flood plain)	Low	Free	Aus or Jute	Fallow	Rabi or Fallow
3	High (Barind tract)	Low	Water poundable by bunding	Fallow or Aus	T. Aman	Fallow
4.	Medium	High	Water poundable by bunding	Aus or Jute	T. Aman	Rabi or Fallow
5.	Medium	Low	Very shallowly flooded	Aus or Jute	T. Aman	Rabi or Fallow
6.	Medium	Low	Flooded up to 3 feet.	Aus or Jute	T. Aman	Rabi or Fallow
7.	Medium	Low	With flood hazard	Aus	Tall T. Aman	Fallow
8.	Low	High or low	Deep, but not hazardous	Mixed Aus & B. Aman, Jute	B. Aman (continue) Fallow	Fallow Fallow
9.	Low	High or low	Deep and hazardous	B. Aman Fallow	B. Aman (continue) Fallow	Fallow Boro
10.	Low, char land	High or low	Flood hazard	Fallor or Jute or Aus, or millet or B. Aman	Fallow Fallow or B. Aman(cont)	Fallow
11	Low, char land	High or low	Flood hazard	Fallow or Jute, B. Aman	Fallow B. Aman (cont)	Fallow Fallow
12	Low, flood plain ridges outside of embankment	High or low	Flood hazard	Aus or Jute or Millet	Fallow	Rabi or Fallow
13	Low, Flood plain depressions outside of embankment	High or low	Flood hazard	Mixed Aus and B. Aman Jute	B. Aman (cont) Fallow	Fallow Fallow

Source: Report compiled from data extracted from (1) East Pakistan Soil Survey Reports, Bogra District and (2) Report on the Potential for Rainfed HYV Rice Cultivation in Bangladesh, by H. Brammer, 1974.

South Asia, with heavy rains starting in June and ending in October. From November through March, there is virtually no rain. April through May are transitional.

The abundant monsoon rainfall, with the resulting widespread water logging and flooding, give a comparative advantage to wetland crops, rice and jute over dry land crops. However, wherever drainage conditions are good, there is a great diversity of cropping opportunities during the monsoon season.

A.2. Farm Structure and Tenure

The average farm size, as found in the 1960 census, is 3.50 acres; out of which about 3.1 acres are cultivable land (13). Distribution of the number of farms under various size groups indicates that 83 percent of the farms are of the size of 3 acres and below and that 0-48 percnnt are of the size of 25 acres and above (14). In addition to small size, farms in Bangladesh are highly fragmented. About 90 percent of the farms are fragmented of which 29 percent of them having more than two (10) fragments.

There are three types of tenure groups, namely: (a) owner-cultivator; (b) owner-cum-tenant cultivator; and (c) tenant-cultivator. Farm classification on the basis of tenure indicates that 61 percent of the farms, accounting for 52 percent of the total cultivable area are owned by owner-cultivators. The owner-cum-tenant and

tenant-cultivator poses about 37 percent and 2 percent of farms comprising 47 percent and 1 percent of cultivable area respectively.

A.3. Land Use and Cropping Intensity

Land is the major constraint to expanding agricultural production in Bangladesh. Topography, soils, climate and depth of flooding determines to a large extent the pattern of land use as well as cropping intensity. Data on land utilization shown in Table 2.2 indicates that increases in cultivated area have come about by a decrease in area classified as cultivable waste from an average 1.95 million acres in 1955-60 to only .67 million acres in 1973-74. Increased cropping of 'cultivated area' has taken place through a decrease in 'current fallows' from 1.32 million acres in 1955-60 to .73 million acres in 1969-70. However, area under current fallow has increased to 1.55 million acres in 1973-74 just after the war of independence as farmers were compelled to keep their land fallow due to lack of production inputs.

More significant than the increase in cultivated area has been the growth of 'cropped area'. It has increased from 25.91 million acres in 1955-60 to 32.84 million acres in 1969-70 (Table 2.2). This was achieved by a dramatic increase in multiple cropping which raised cropping intensity from 120 percent to 146 percent, but

Table 2.2. Bangladesh Land Utilization (millions of acres)

Particulars	5-year average ending 1959-60	5-year average ending 1964-65	1976-68	1969-70	1970-71	1971-72	1973-74
1. Forest	5.46	5.46	5.54	5.54	5.50	5.51	5.51
2. Not available for cultivation	5.59	5.97	6.24	6.50	6.57	6.57	6.57
3. Cultivable waste	1.95	1.82	1.03	0.74	0.74	0.73	0.67
TOTAL	13.00	13.25	12.81	12.78	12.81	12.81	12.75
4. Current fallow	1.32	0.93	0.73	0.73	1.12	2.10	1.55
5. Net cropped area	20.33	20.98	21.75	21.76	21.36	20.37	20.98
TOTAL	21.65	21.91	22.48	22.49	22.48	22.47	22.53
6. Total cropped area	25.91	27.88	31.44	32.84	31.53	29.11	30.68
7. Cropping intensity[a/] percentage	120%	127%	140%	146%	140%	130%	136%
8. Land use intencity[b/]	86%	88%		94%		88%	90%

Source: Bureau of Agricultural Statistics, Ministry of Agriculture, Government of Bangladesh. 1976.

a/ $\frac{\text{Net cropped area}}{\text{Total cropped are}} \times 100$

b/ $\frac{\text{Net cropped area}}{\text{Total cultivable area}} \times 100$
(be-cultivated area plus cultivable waste)

the same has been declined to 136 percent in 1973-74. Similarly, land use intensity has increased from 86 percent in 1955-60 to 94 percent in 1970. Nearly half of the cultivated area is double cropped. The nature of the double crop system is defined by relief or depth of flooding shown in Chart I.

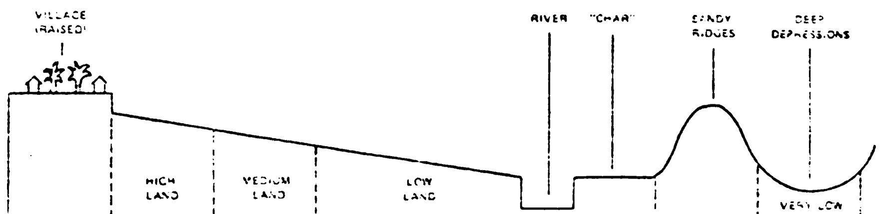
On medium and highland, cropping intensity is usually above 140 percent (shown in Table 2.3), where aus or jute precede T. Aman, which precede dry season fallow or rabi crops. On lowland (flooding 3-6 feet), the cropping intensity average about 120-130 percent.

A.4. Cropping pattern and relative Importance of Crops

Chart 2 indicates graphically the existing cropping pattern and how the cultivated area in Bangladesh is used throughout the year. Rice dominates the chart and the agriculture of Bangladesh. About 90 percent of the cultivated area is devoted to rice (Table 2.4). It is grown in three seasons -- aus, aman and Boro. Aman rice is predominantly rainfed and accounts for 56-58 percent of rice acreage and production. Aus is the second largest rice crop, predominantly rainfed and occupied about 32 percent of rice acreage during 1974-75. Boro, however, is entirely dependent on irrigation and is grown in winter season. There has been a gradual increase of boro acreage over the years from 5 percent of the total rice acreage in

Chart I

DIAGRAMMATIC ILLUSTRATION OF CROPPING SYSTEM



DEPTH OF FLOODING	0	0-1'	1-3'	3-6'	3-6'	3'	OVER 6'
CROPPING							
1ST KHARIF	FRUIT & VEG	AUS, SOME JUTE NEAR VILLAGES	AUS SOME JUTE, FALLOW	MIXED AUS AND BROADCAST AMAN	AUS, OR JUTE, OR BROADCAST AMAN	AUS OR FALLOW	—
2ND KHARIF	FRUIT & VEG	FALLOW, OR TRANS-PLANTED AMAN	TRANSPLANTED AMAN	FALLOW OR BROAD-CAST AMAN (CONT.)	FALLOW OR BROADCAST AMAN (CONT.)	FALLOW	—
RABI	FRUIT & VEG	RABI, OR FALLOW	FALLOW	FALLOW	RABI, OR FALLOW	RABI OR FALLOW	BORO

Table 2.3. Land Use (average 1969-1973) of Bangladesh

Land elevation	Crop	Area acr.'000	Area %	Cropping Intensity %
High and medium	Jute	2,140	7	
	Aus (single)*	5,730	19	
	T. Aman*	9,280	30	
	Boro*	500	1	
	Rabi*	1,500	5	
	Sugarcane, fruit & other	2,530	8	
	Sub-total 1/	21,680	70	143
Low and very low	B. Aman*	4,900	16	
	Aus 3/*	2,000	6	
	Boro*	1,750	6	
	Rabi*	640	2	
	Sub-total 2/	9,290	30	127
Total cropped		30,970	100	140
Total cultivated		22,460	-	-

Source: Bureau of Agricultural Statistics, MA. (Report No. 455a-BD)

*Divison approximate

1/ Approximately 15.2 M ac.

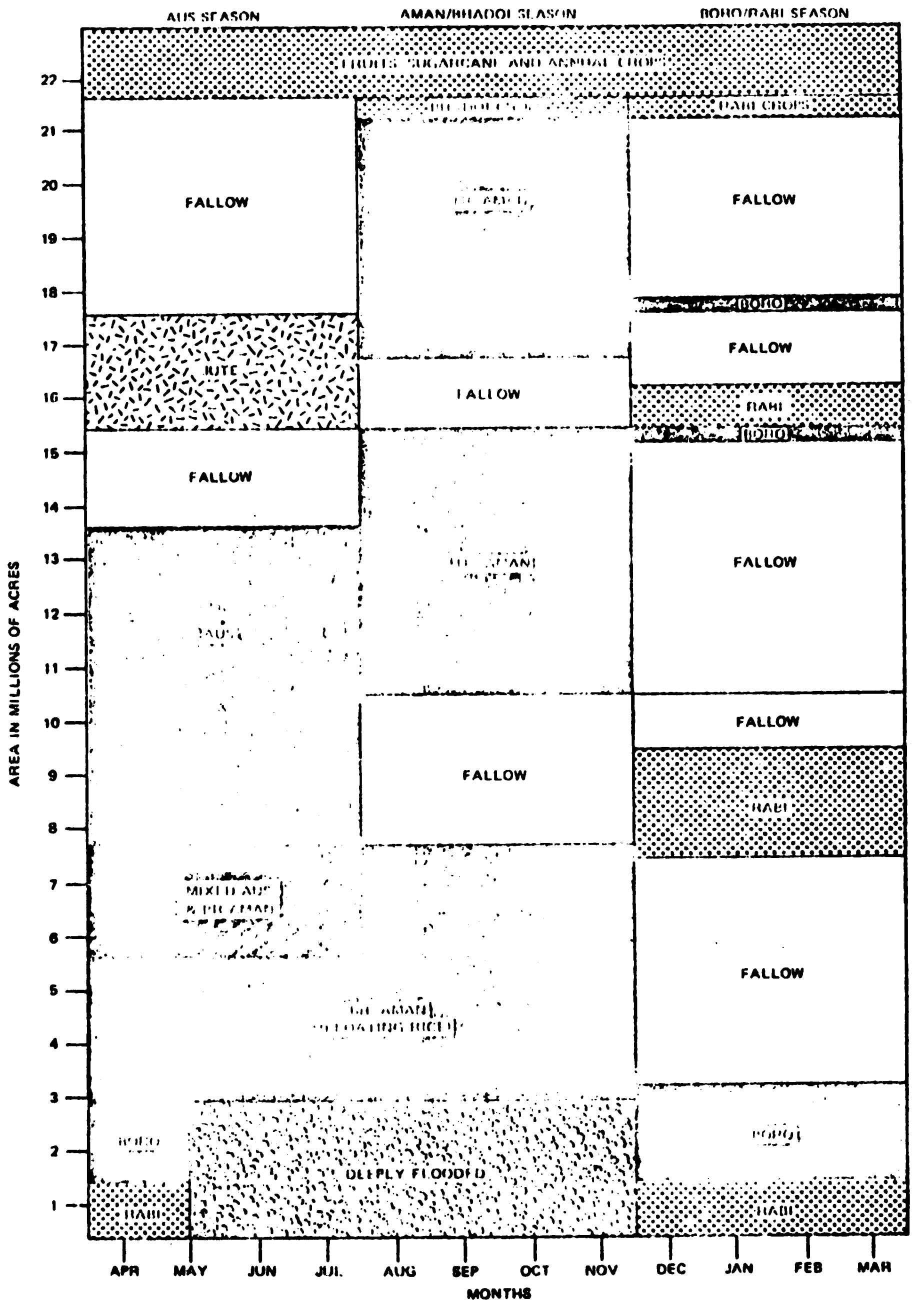
2/ Approximately 7.3 M ac.

3/ Sown together with B. Aman as a mixed crop.

Chart II

BANGLADESH

USE OF CULTIVATED AREA (1969 - 73) (AVERAGE)



Note:

The cropping seasons have been simplified in this chart. Sowing and harvesting actually take place with greater overlap than shown here.

1960-65 to 9 percent in 1969-70 and over 12 percent in 1974-75. Table 2.4 shows that the total rice area has increased from 22.2 million acreage in 1960-65 to 24.2 in 1974-75, an increase of 9 percent. Most of the increase in rice area was gained through expansion of Boro and Aus rice. Jute is the second largest crop and occupies about 2.2 to 2.4 million acres of total cultivated land.

In terms of regional distribution of crops, whereas rice is grown in all parts of the country, Jute is mainly concentrated in the districts of Mymensing, Dacca, Faridpur, Rangpur and Comilla. About 72 percent of the total area under Jute is located within these five districts. The sugarcane area is mainly concentrated in the Northwest region and a part of Kushtia, Kishoreganj and Mymensing districts. Potato is mainly grown in the Northwest region followed closely by central and eastern regions. The Southwest region hardly accounts for 5 percent of the total potato area.

B. Potential for Agricultural Development

This section deals with the existing states of art and technology in the realm of agricultural crops, particularly with reference to rice, and assesses its production potential with the advent of new 'seed fertilizer' technology and the results of soil reconnaissance surveys.

Table 2.4. Area Under Main Crops in Bangladesh (million acres)

Crops	Average 1960-61/ 1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
1. Rice											
(a) Aus	6.64	7.32	5.96	8.22	7.65	8.46	7.86	7.42	7.24	7.68	7.55
(b) Aman	14.52	14.67	14.05	14.68	14.40	14.34	14.15	13.37	14.12	14.13	13.47
(c) Boro	1.04	1.14	1.39	1.53	2.01	2.18	2.42	2.19	2.43	2.60	2.87
Total	(22.20)	(23.13)	(22.41)	(24.43)	(24.77)	(25.48)	(25.48)	(22.98)	(23.79)	(24.41)	(24.20)
2. Wheat	0.15	0.14	0.18	0.19	0.29	0.30	0.31	0.31	0.30	0.30	0.31
3. Other Cereals	0.22	0.20	0.24	0.26	0.29	0.28	0.30	0.25	0.23	0.24	0.24
4. Pulses	0.93	0.83	0.90	0.89	0.92	0.91	0.92	0.89	0.78	0.70	0.76
5. Oilseeds											
(a) Rape and Mustard	0.54	0.47	0.49	0.53	0.55	0.54	0.53	0.47	0.47	0.44	0.48
(b) Til and Linseed	0.15	0.18	0.17	0.16	0.17	0.16	0.15	0.15	0.15	0.14	0.15
(c) Groundnut	0.02	0.02	0.04	0.06	0.08	0.08	0.06	0.07	0.06	0.05	0.05
Total	(0.74)	(0.67)	(0.70)	(0.75)	(0.80)	(0.78)	(0.76)	(0.69)	(0.68)	(0.63)	(0.69)
6. Spices	0.41	0.36	0.39	0.42	0.41	0.42	0.40	0.39	0.38	0.35	0.38
7. Sugarcane	0.32	0.38	0.41	0.42	0.41	0.40	0.40	0.35	0.32	0.36	0.33
8. Potato	0.14	0.15	0.17	0.19	0.21	0.21	0.21	0.19	0.19	0.20	0.22
9. Sweet Potato	0.10	0.11	0.15	0.16	0.17	0.18	0.18	0.17	0.16	0.15	0.17
10. Fruits and Vegetables	0.52	0.53	0.58	0.60	0.63	0.64	0.63	0.58	0.58	0.59	0.61
11. Jute	1.73	2.20	2.17	2.34	2.17	2.46	2.20	1.68	2.11	2.22	1.42 1/
12. Cotton	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.03	0.04	0.02	0.02
13. Tea	0.08	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11
14. Tobacco	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
15. Others	0.10	0.55	0.49	0.54	0.51	0.53	0.50	0.39	0.49	0.51	[illegible]
Total All Crops	27.83	29.54	29.04	31.44	31.13	32.54	31.53	29.11	30.24	30.50	30.12
Net Cropped Area Including Current Fallow	21.91	22.33	22.43	22.48	22.41	22.49	22.48	22.47	22.47	22.48	22.48
Cropping Intensity	127%	132%	129%	140%	139%	146%	140%	130%	135%	136%	134%

1/ Provisional.

Source: Bureau of Agricultural Statistics, Ministry of Agriculture.

B.1. Traditional Technology

Bangladesh rice production technology has long been dominated by varieties with limited capacity to utilize fertilizer efficiently. Traditional varieties, like in most other areas of Asia are relatively tall, weak stemmed plants and not receptive to chemical fertilizers. For this reason, farmers use a very negligible quantum of fertilizer. The end result has been that cultivation technology used on traditional varieties remained largely unchanged for decades. It is observed that though the area under rice has increased by over 3 million acres from 1960-65 to 1975, production has increased by only 1.1 percent during the same period. Thus, the increased rice output in Bangladesh remained dependent on major modification in the crop environment through increased cropping intensities or a shift from broadcasting to transplanting techniques.

B.2. New Technology -- "Seed-Fertilizer Revolution"

The major breakthrough in rice production technology was achieved with the introduction of IR-8 varieties during Boro season. On the average a yield of 1.5 tons of rice was obtained in the Boro HYV crop with proper fertilization and pest control. The area under the crop has increased from an annual average of 0.83 million acres in 1955-60 to 2.87 million acres in 1974-75. In spite of its tremendous success Boro constitutes only 12 percent of the total rice area and its further expansion has been extremely difficult due to the following reasons: it is (a) largely dependent on irrigation water which is very difficult to meet; (b) very susceptible to disease and pest attacks, and (c) requires a longer growing season than the traditional Boro variety, thus interfering with Aus crop.

The overriding constraints to the expansion of Boro crops led to the innovation of HYV varieties for Aman season which constitutes nearly 60 percent of the total rice acreage. The experimental findings suggest that these new varieties are (a) better adjusted to the rainy season than traditional Aman; (b)matures in 120-135 days as compared to 150 days or more required for traditional varieties; (c) highly resistant to bacterial leaf blight, tungro virus, and partly resistant to leak streak and stem borers; (d) has a production potential of 3 tons or more, and above all, (e) requires much less water than 112-8. Similarly, the innovation of varieties like 122-72-4-1-2, etc., for Aus season offered similar prospects. This recent dramatic breakthrough achieved in the production technology of rice ushered in an enormous prospect and potential for a large increase in rice production, thereby, for solution of food shortage problem.

B.3. Regional Land Suitable to New "Seed Fertilizer" Technology as Determined by Soil Reconnaissance Survey

With a view to devising a better national agricultural development strategy to increase agricultural production, the government in 1964-65 undertook a soil survey project assisted by FAO/UNDP. The major purpose of land capability evaluation is to facilitate the identification of suitable areas for agricultural intensification. Since land and water resources determine the potential for future agricultural development (i.e., where production of existing crops can be increased or replaced; where new high yielding varieties can be introduced with or without irrigation, etc.), it is anticipated that a comprehensive soil reconnaissance survey would provide a sound basis for allocation or land among its alternative agricultural and nonagricultural uses.

By the end of 1969-70, the soil survey had completed a detailed reconnaissance survey for 70 percent of Bangladesh. In addition, sufficient information has been obtained for the remainder of the country through aerial photo interpretation and exploratory surveys to extrapolate the results of the survey to the entire area of Bangladesh. The survey provides information not only on soil conditions but also on present land use and on physical factors limiting agricultural development, such as depth of natural flooding, surface relief, erosion hazard. This information has been interpreted to determine the suitability of individual soils for production of particular crops, with and without irrigation.

The survey recognized five classes of land, ranging in terms of quality from very good to very poor. The survey divided the country into four regions, namely, (1) Northwest (NW); (2) Central (C); (3) East (E); and (4) Southwest (SW), primarily on hydrological and topographic (soil strata) considerations. The study indicates the considerable scope for increased rice production possible from the introduction of IRRI rice varieties in all regions of Bangladesh. In addition, soil, land capability and hydrological information reveals that there is ample suitable land available that could be irrigated where necessary for cultivation of strategic crops such us jute, sugarcane, potato.

The most important finding is that some 11 million acres out of 22.5 million acres of agricultural land are suited for agricultural intensification with an input package consisting of improved crop varieties (especially IRRI rice), fertilizers, and pesticides without major investments in drainage or flood protection works (see Table 2.5). About 6.2 million acres would be suitable for the existing IR-20 Aman variety following either IRRI-Aus, or jute. On a further 1.7 million acres in the dry western portion of the country, where currently only a

Table 2.5 LAND CAPABILITY AND IMPROVED VARIETIES [1/]

		Alternatives offered by Land Capabilities and Improved Varieties	
		Without Irrigation and Drainage/Flood Control Works ('000 Acres)	Additional with Irrigation only (m Acres)
Rice			
Boro/Transplanted Aus:			
a) Traditional Varieties	1.5	1.4	-
b) IRRI Varieties	0.6	-	15.6
Total	2.1	1.4	15.6
Broadcast Aus:			
a) Traditional Varieties	8.5	1.0	-
b) IRRI Varieties (IR-176 (Chandina), IR-442)	-	7.5	-
Total	8.5	8.5	
Transplanted Aman:			
a) Traditional varieties	9.3	-	-
b) IRRI Varieties:			
i) IR-20	0.2	6.2*	1.7
ii) IR-20, IR-442 IR-176 (Chandina) and non-photosensitive varieties in research pipeline	-	1.7*	-
iii) IR-442, its improvements	-	3.1*	-
Sub-total	9.5	11.0	-
Broadcast Aman	5.5	4.0	-
Total	15.0	15.0	
Rice - Total	25.6	-	-
Crops Other Than Rice			
Jute	2.5	4.5*	0.5
Wheat	0.3	-	5.4**
Brassicas (Mustard and related crops)	0.5	12.0*	-
Groundnuts:	0.1	-	-
a) Rabi Season	n.a.	-	9.8
b) Kharif Season	n.a.	3.1	-
Total	0.1	-	-
Sugarcane	0.4	3.9	3.9

* Yields will be improved if supplementary irrigation is available.
** Assuming that wheat is confined to areas N of lattitude 25°N
1/ Source: Soil Survey by Soil Survey of Bangladesh, UNDP/FAO.

single local rice crop is grown, a HYV rice either IR-20 or IR442 would be able to replace the traditional variety. In addition, 3.1 million acres of deeply flooded broadcast Aman could be substituted by IR442. Moreover, of the 8.5 million acres of B Aus, some 7.5 million acres could be replaced by HYV varieties. Besides rice, substantial acres of about 4 and 5 million acres were found to be suitable for sugarcane and wheat, respectively.

The development potential for further intensification of crop production in different regions as revealed in the study is enumerated briefly below:

(i) The Northwest Region (NR)

The NR has higher potential for rapid agricultural development than any other region. This is mainly because of the great extent of highland and shallowly flooded land suitable for conversion to IRRI Aman varieties without irrigation. Much of this land, except on the Briand tract, could also produce a broadcast IRRI-Aus crop without irrigation to replace the local varieties. With irrigation, Boro or T. Aus could be grown on all except the permeable ridge soil covering much of the Dinaipur and on the highest flood plain land elsewhere. This permeable land is also suitable for different Rabi crops and sugarcane.

(ii) The Central Region (CR)

In CR IRRI varieties could be substituted for local Aus and T. Aman varieties throughout the region. Irrigation would make possible a vast extension in Boro cultivation, replacing deep water Aman on basin land subject to flood hazard and B. Aus in higher land where drought is the main hazard. Irrigation would be particularly beneficial on the Madupur tract, especially for sugarcane, dryland cereals and vegetables.

(iii) The Southwest Region

Irrigation in this area, as within the existing G.K. project area, could be used to enhance both rice and dryland crop production: sugarcane, tobacco, and vegetables, B Aus and T. Aman together with jute and rabi crops on lower ridges. Irrigation also would make it possible to follow a T. Aman crop (which may not need irrigation) with IRRI Bora.

(iv) The Eastern Region

The highest potential exists on the old Meghnan flood plain, especially in the higher east where IRRI-Aus and T. Aman could be substituted for existing varieties without the need to provide supplementary irrigation. Irrigation in this area would permit Boro to be substituted for B. Aus; alternatively it could be used to provide high yielding dryland rabi crops.

The areas suitable for different crop production activities in each region as identified by land survey is shown in Table 2.6.

Table 2.6. Summary Estimates of Acreages Suitable for Specified Crops By Region[a]

Region	Total area of region (000 acres)	Crop (000 acres)			
		IRRI Transplanted Aman	IRRI Boro Transplanted Aus	Wheat[b][c]	Sugarcane
NW	8047	2150	4548	2752 (2628)	1469
CN	5254	1326	2978	2082 (1720)	1091
EST	10917	1996	4069	2456 (662)	438
SW	9304	2450	3992	1814 (400)	870
TOTAL	33522[d]	7922	15587	9104 (5410)	3868

[a] Acreage of crops are gross, exclusive of settlement and water. The estimates relate solely to the suitability of soils and land for crop production with irrigation (except for Kharif groundnuts, and for most of the IRRI Aman acreage). They do not take into account availability of water for irrigation. Drainage is not assumed.

[b] The estimates relate to the crops individually, not as components of crop rotations, e.g., on most soils, dry land rabi crops cannot be grown if the land is also used for IRRI Aman.

[c] There are indications that high wheat yields may not be obtainable south of about latitude 24°N, but agronomic trials are needed to check this. If confirmed, the acreage suitable would be reduced to the figure given in parentheses.

[d] Gross area of Bangladesh is 35,280,640 acres, including water in the major rivers and estuaries.

Source: Soil Survey by Soil Survey of Bangladesh, and UNDP/FAO.

CHAPTER III

FRAMEWORK AND STRUCTURE OF MACRO MODEL

Chapter I has provided a conceptual framework for these studies. In this Chapter a detailed programming model is described to operationalize that conceptual framework. Linear programming is used as the basic tool to investigate the likely impact of alternative technological adjustments at the regional level on the allocation of resources and on the estimation of production response of different crops. Profit maximization is selected as the objective function over cost minimization because it seems more realistic that farmers in Bangladesh are generally concerned with increasing their profits. There is ample literature which purports to test the economic rationality of agricultural producers (10,33,54,55). Such studies generally concluded that producers, even in the most backward areas, act as a profit maximizer within their technological and institutional constraints. Even Dillion and Anderson in an article generally critical of the methodology employed in this area concluded that using a probability technique does not change this conclusion. The important reasons for choosing profit maximization in the objective function are: (i) in the past, empirical studies explicitly employing the profit maximization hypotheses (e.g., in linear programming studies of individual farm) have generally provided results consistent with observed and plausible behaviour (47,52) of farmers in Bangladesh; (ii) product prices and technology, the most risky components of a production function, are mostly controlled and determined by the government. The modern inputs such as HYV seeds, sophisticated machineries for irrigation, fertilizer and pesticides, etc., are all procured and distributed to farmers through government supply and service agencies. The procurement price for important agricultural crops is determined by the ministry of agriculture in consultation with other ministries; (iii) previous studies (16) found that farmers in LDC's do respond to price incentives though the magnitude of such response varies from one environment to another. However, the present study has not altogether omitted the risk-factor. But, to a certain extent, the risk factor has been implicitly considered in the model by incorporating the minimum consumption constraints which have to be produced by the farmers.

The whole nation consists of four regions which is used as the unit of optimization. A region is considered homogenous with regard to climate, topology, farm size and resource distribution. For such a homogenous region, it is possible to view a regional model with the following three elements: (1) the objective function; (2) the activity set; and (3) the constraint structure. The mathematical LP model can be expressed in the following form:

$$\text{maximize } \Pi = C'X$$

subject to restrictions

$$A\ X \leq B$$

$$X \geq 0$$

where A is an MXN matrix of technical coefficient

C is an nX1 vector of prices

X is an nX1 vector of activities

B is an mX1 vector of resources and other constraints

$C'X = \Pi$ in the objective function.

Objective Function

The model maximizes the following objective function:

$$\text{Max } \Pi_{(t)} = \sum_{i=1}^{n} [P_{it}\ S_{it} + Z_{it}\ C_{it} - D_{it}]$$

$\Pi_{(t)}$ is the objective value.

P_{it} is the harvest price for the final output in year t.

S_{it} is the actual level of i^{th} sales activity in year t (in pounds).

Z_{it} is the price of crop output consumed at farm level

C_{it} is the actual level of i^{th} consumption activity in year t in pounds.

D_{it} is the actual amount of cost incurred for purchasing different variable production inputs like seeds, fertilizer, hired labor, etc., in year t.

This objective function assumes that each farmer (i) expects the same output prices; (ii) incurs the same amount per unit production and marketing costs; (iii) possesses initial endowments of land, labor, and money capital in the same proportion, and (iv) responds the same way to price and income changes in making production and consumption decisions. The above linear programming model can be used to represent the sum of the decisions for all the farm-firms in a particular homogenous region.

The objective function maximizes the short run net national farm income (NNFI) on fixed factors. The variable inputs to the agricultural production process are expressed in terms of seeds, fertilizer, pesticides and hired labor and accounted for by assigning unit cost per acre to each of these items. The interest cost is also included in the variable cost. The cost associated with the fixed factors of production such as land, family labor, bullock power, and fixed irrigation rental were excluded.

Output is expressed in terms of crop yields. A farm household generally uses its output in two ways -- part of it is consumed at the farm level and the residual is sold in the market. Consequently, the output price is determined in the model by the manner in which it is utilized. The marketable surplus (sales) is accounted for at the minimum procurement price fixed by the government for each commodity whereas the quantity which is consumed at the farm is accounted for at the buying price. (For details see Chapter IV, Product and Factor Prices.)

The Activity Set

A typical farm household in Bangladesh is expected to be engaged in certain activities like (i) production activities; (ii) labor hiring activities; (iii) subsistence consumption activities; (iv) sales activities; (v) buying activities, and (vi) financial activities. The activity set used in the model is denoted by

$$|\tilde{P}_1 --- \tilde{P}_g,\ H_1 --- H_L,\ \tilde{C}_1 --- \tilde{C}_g,\ \tilde{S}_1 --- \tilde{S}_g,\ \tilde{V}_1 --- \tilde{V}_q,\ \tilde{M}_f|$$

where

$\tilde{P}_1 --- \tilde{P}_g$ are production activities measured in crop acreage sown to 1---g crops in the region.

$H_1 --- H_L$ are activities associated with the purchase of outside labor to the extent family labor could not fulfill the labor input requirement for various crops.

$\tilde{C}_1 --- \tilde{C}_g$ are the consumption activities of 1---g crops. The household consumption requirement is retained from total farm output.

$\tilde{S}_1 --- \tilde{S}_g$ are sales activiiies of final output for cash.

$\tilde{V}_1 --- \tilde{V}_q$ activities involving the purchase of v outputs for domestic consumption.

$\tilde{M}_f$ associated with farmers borrowing activity.

The following assumptions were deemed essential for the model: (i) input-output coefficients considered are consistent with the farmers' cultural practices; (ii) prices are held constant at current prices; (iii) the input subsidy policy of the government would continue in the same form and rate in 1975 except for fertilizers.

The matrices for technology I is presented in Table 3.1. The basic structures are the same for another technological stage. Consequently, they have not been duplicated here. Each of the model activity as mentioned above is discussed in detail below.

(1) Crop Production Activities: Eleven (11) crop production activities are considered in the model, which consists of seven different varieties of rice and four other food and cash crops: wheat, potato, jute, and

Table 3.1. Schematic Representation of LP Tableau of the Model

Constraints (rows) / Activities (columns)		Region I P_1 … P_{11}	Region II P_{12} … P_{22}	Region III P_{23} … P_{33}	Region IV P_{34} … P_{44}	Hired Labor JANHLAB$_{45}$	Hired Labor … DECHLAB	Consumption CAUSLC$_{65}$	Consumption … CADIAT$_{74}$	Sell SLAUSLC$_{75}$	Sell … SWHTE$_{85}$	Buying BYAUSLC$_{86}$	Buying … BYPUTAT$_{95}$	Borrow 96	RHS
Obj. fn. Coeff. (c_j)	Max	$-P_1$			P_9	$-W_1$	$-W_{12}$	C_1	C_9	S_1	S_9	$-V_1$	$-V_4$	$-(1+i)$	
Req AI SUMLND	B_1														$\le L(t)$
Land (in acres)		A_{11}	A_{12}	A_{13}	A_{14}										
Req. IV WNTLND	B_8														$\le L(t)$
MARFLAB	B_9														$\le B_1(t)$
Family labor (man-days)		A_{21}	A_{22}	A_{23}	A_{24}	$-A_{25}$									
DECFLAB	B_{20}														$\le B_{12}(t)$
JANHLAB	B_{21}														$\le H_1(t)$
Hired labor (man-days)						A_{35}									
DECHLAB	B_{32}														$\le H_{12}(t)$
BULCPWR	B_{33}														$\le B_1(t)$
Bullock power (man days)		A_{41}	A_{42}	A_{43}	A_{44}										
BULCPWR	B_{36}														$\le B_4(t)$
FERTSUP	B_{37}														$\le F_1(t)$
Fertilizer (Ac/mds)		A_{51}	A_{52}	A_{53}	A_{54}										
FERTSUP	B_{40}														$\le F_4(t)$
SUMIRGT	B_{41}														$\le W_1(t)$
Irrigation (Ac/ft of water)		A_{61}	A_{62}	A_{63}	A_{64}										
WINIRGT	B_{48}														$\le W_8(t)$
CONRICE	B_{49}														$\ge C_1$
Consumption (in lbs.)								A_{77}							
CONPOT	B_{52}														$\ge C_4$
PAUSLC	B_{53}														$= 0$
Balance equation		$-A_{81}$	$-A_{82}$	$-A_{83}$	$-A_{84}$			A_{87}		A_{88}		$-A_{89}$			
PPOTAT	B_{64}														$= 0$
MARCPTL Financial constraints (in Tk.)	B_{65}	A_{91}	A_{92}	A_{93}	A_{94}									-1	≤ 0
DECCPTL	B_{66}													$+1$	$\le M_f$
AAUSLC Acreage Constraints Regions	B_{67}	+1 +1 +1 +1 +1													$\le t_1$
															$\le t_{11}$
AAUSHT Region II			+1 +1 +1 +1 +1												$\le t_{12}$
															$\le t_{22}$
Region III				+1 +1 +1 +1 +1											$\le t_{23}$
															$\le t_{33}$
Region IV					+1 +1 +1 +1 +1										$\le t_{34}$
AWHTL	B_{100}														$\le t_{44}$

sugarcane. These crops entered into the model in two time periods viz summer and winter seasons. The net price shown in the C_j row for crop growing and harvesting activities is negative. The latter functions, when considered separately, subtract from income. The income from different crop activities derives from its sale whose coefficient in C row is positive. Thus, the C_j row entry for each crop activity (P_1--- to P_{44}) is negative by the amount of allocable costs, other than land and labor, entailed in crop growing and harvesting.

(2) Labor Hiring Activities: There are two main sources of agricultural labor -- family labor and hired labor. Farmers hire labor only when the household is not adequate to perform all the agricultural operations in any particular month of the year. In all, there are twelve labor hiring activities, i.e., one for each month. Consequently, labor hiring activities deal with labor from outside the families at the prevailing wage rate and are included in the model through transfer activities. The total amount of hired labor depends on the level of production activities and the amount of family labor available from the households. Since the hiring activities add to the supply of family labor rows, their coefficients are negative. However, the labor hiring activities in their row column (JHRLBR21 to JHRLBR32) have positive coefficients, indicating that each man-day of

labor hired reduces the B column value by one man-day. Net prices for labor hiring activities are negative because the labor hiring activities themselves substract from the value of the program.

(3) Consumption Activities: Subsistence consumption activities describe the consumption of farm commodities by the farm household. Farmers grow food crops mainly to satisfy their household consumption requirements. In this model the minimum household consumption requirements for each farm commodity are determined exogenously from the farm household budget studies conducted jointly by USAID and University of Dacca. In the consumption activities in the row column for rice (CONRICE 49) no specific distinction has been made in between different qualities of rice. In other words, all different qualities/varieties of rice will hold uniform taste in the preference list of farm households. The C_j value of consumption of different crops are positive (CONRICE 65 --- CONPOT 74) as the price of crops has not been taken into account in the objective value of each crop production.

(4) Selling Activities: The marketable surplus of various farm commodities is determined as a residual of production and planned consumption decisions taken by farm households. As the consumption of different farm commodities is determined outside the model, the marketable surplus function of farm household can be obtained.

$S_{j(t)} = [Q_{j(t)} - \tilde{C}_{g(t)}]$ and since $Q_{j(t)} \geq \tilde{C}_{g(t)} = \tilde{S}_{j(t)} \geq 0$

where $S_{j(t)}$ is the marketable surplus, $Q_{j(t)}$ is the total production of a particular crop and $\tilde{C}_{g(t)}$ is the consumption requirement of each member of the farm family. The surplus of farm commodities is sold in a nearby market which is assumed to be perfectly competitive. The magnitude of the sale value is the expected price of rice per maund minus the cost incurred in marketing. The income derives from the sale through SELAUSLC75 to SELJUTE88 whose coefficient in the C_j row is positive because selling adds to the value of the program. The row coefficient of the selling activity (PAUSLC53 to PPOTAT63) carries a positive sign because selling of a crop takes away from the supply in the transfer row.

(5) Buying Activities: Food buying activities arise due to two reasons: (i) firstly, immediately after harvest large numbers of farmers are obliged to sell a certain portion of their produce to repay the borrowed capital as well as to purchase essential consumer goods, e.g., clothing, oil, etc.; (ii) secondly, for those farmers whose production capacity is not at all adequate to meet their consumption requirements. The C_j row entry for buying activities (BYAUSLC86 --- to BYPOTAT95) is negative because these activities by themselves would not add to the value of the program, but constitute a cost not

accounted for elsewhere in the model. Likewise, the farm commodities purchasing activity coefficients in their row column (PAUSLC53 to PJUTE63) carry a negative sign indicating that one unit of purchasing activity will add to the corresponding row supply by one unit.

(6) Financial Activities: Farmers borrow when their cash incomes is not enough to meet the cash production expenditures. For the purpose of this study two assumptions have been made: (i) only short-term borrowing is considered; (ii) expenditures which are fixed and quasi-fixed in nature are deemed to be available to the farmer. The C_j row of borrowing activity (C-96) carried a negative sign and reflects the interest charge for that part of the year for which money is borrowed. The money capital coefficients in money capital row (MONCAPTL64) for each crop activity refers to the amount of capital required, over and above, farmers' own cash for each crop production activity. The MONCAPTL row in the borrowing activity column (C-96) serves as a transfer row for production capital. Its value is 0 in the B column and carries negative sign in column (C-96). Thus, BORCAPTL (R65) in its B column represents an estimate of total credit available aside from dealer accounts.

Production Constraints

Agricultural production on the representative farm-firm in Bangladesh is restricted by a series of constraints of a broad nature: (i) land constraints; (ii) variable inputs constraints; (iii) financial constraints; and (iv) behavioural constraints. The relevant constraints faced by the farmer are discussed in detail below.

(1) Land Constraints: The total land available for cultivation in each region has been divided into two crop seasons: viz (i) Summer land, and (ii) Winter land. The Winter land was estimated from Summer land after deducting the cultivable fallow land which could not be brought under cultivation due to scarcity of irrigation facilities. The total land available for cultivation in each region incorporated in the model was taken from the districtwise arable land estimates provided by the Ministry of Agriculture (36).

(2) Labor Constraints: The nature of this resource supply stems from its interpretation as the labor of the tenant or owner and his family. According to the 1961 census each farm family has, on an average, about 3 acres of land. The total number of farm families was estimated to be 7,254,667[3]. As per Farm Powers Survey

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[3]Total net cropped land = (21,764000/3 acres (per family holding) = 7254667.

Report (37), a farm family is comprised of 4.0 adults, of which 2.1 are male members. Considering the social structure of Bangladesh whereby only male members of the society work in the field, it is estimated that about (7,254,667 x 2.1) = 15,234,801 adult family laborers are available in the agriculture sector. Assuming a farm laborer works, on an average, about 26 days per month (15,234,801 x 26) = 396.104 million man-days of farm labor is available every month.

However, a serious controversy exists over the extent of surplus labor available for hiring during crop seasons. W. C. Robinson (48) found that Bangladesh has all the characteristics of the classic labor surplus economy, whereas Gunnar Myrdal (18) argued that there is very little redundant labor. It appears from Habibullah's case study of Sobilpur that about 20 percent of the farm labor force could be released for the full year (19). Consequently, assuming 20 percent of the farm population is landless, the maximum hired labor supply was estimated to be 85.31 million man-days per month. The family and hired labor supply for Plan II was estimated from the current population growth rate of 3 percent. It is assumed that the growth would decline to 2.8 percent by 1985.

Bullock Power Constraints

With regard to bullock power constraints, no major changes in the present system of cultivation is envisaged. This means no allowance is being made for a large scale introduction of better tillage implements that would reduce the time taken for land preparation, nor is a significant degree of mechanization contemplated. Bullock power resources are presumed to be mobile within the region but immobile in-between regions. The supply of draft power in each region has been estimated on the basis that each farm family possesses a pair of cultivable bullock and it works for 26 days per month. However, the maximum bullock power supply during the peak season was obtained from the corresponding ploughing period of each crop activity as shown below:

Crops	Ploughing Period (months)
Boro local, Boro Irri, Aus Irri, wheat, potato and sugarcane	December-January
Local Aus, jute, B. Aman	March-April
T. Aman local, Aman Irri	June-July

The ploughing period indicates that the critical time span when the farmer needs his draft power for the ploughing of 11 crop activities lies during six months of the year. Consequently, the supply of bullock power during six months was estimated as actual constraints of the model.

Fertilizer Constraints

The supply of fertilizers grew rapidly from 11,000 tons in 1955-56 to 66,000 tons in 1960-61 to an average 425,000 tons in 1972-75. At present, fertilizers are being produced, procured and distributed through public agencies. The fertilizer constraints were estimated in two technological stages under the following considerations:

(i) TECH I (PLAN I): Last three years mean allocation of fertilizers to each region considered for solution in Plan I.

(ii) TECH II (PLAN II): The trend of average supply of fertilizer from 1960-65 to 1965-70 increased from 82 to 195 thousand tons, an increase of 58 percent. Similarly, from 1965-70 to 1971-75, the average supply registered an increase of 44 percent. Considering the declining trend, it is assumed that fertilizer supply by 1985 would not exceed more than 30 percent above the last five year average. The reduction of fertilizer supply is assumed, as it is expected that fertilizer import would decline relatively during the coming decades due to (a) scarcity of fertilizer in the international market; (b) high imported price of fertilizer resulting from scarcity, and lastly, (c) prevalence of intense competition for the purchase of fertilizers in the international market. The region fertilizer constraints under

Table 3.2. Estimated Regionwise[1/] Fertilizer Availability During Phases I and II (1975 actual and 1980-85 projected) (000 tons)

	1975	1980[2/]		1985	
	(actual)	With import	Without import	With import	Without import
Central	111	325	216	406	270
Eastern	171	507	336	634	421
Northwest	75	247	164	309	205
Southwest	68	221	147	276	183
TOTAL	425	1,300	863	1,625	1,079

[1/]The regionwise location of fertilizers during 1980 and 1985 were made on the basis of last 5 years (1970-75) average actual fertilizer supply in each region.

[2/]Fertilizer availability in 1980 has been estimated on the basis of USAID Survey Report (see Table 2).

two phases of development are shown in Table 3.2.

Water Constraints

In Bangladesh, any future plan for increased agricultural production is crucially linked up with the feasibility of expanding irrigation facilities. At present, irrigation facilities are being provided through (1) low lift pumps; (2) shallow tube-well; (3) tube-wells; and (4) indigenous methods. These different modes of irrigation provides about 4.88 million acre feet of water and irrigate about 1.43[4] million acres of land. Irrigation potential is, however, constrained by the availability of surface water as well as the intrusion and occurrence of saline groundwater in the south. These problems have been aggravated further due to diversion of considerable quantities of water from the Ganges during the winter season through the construction of Farraka barrage by India. The plan indicates that the major rivers carry about 50 million (46) cusecs of water. This water is more than adequate to irrigate summer crops including high yielding varieties like Irri-Aman. On the other hand, during the long dry months of November through April, the rainfall hardly accounts for more than 4 inches.

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[4]Source: Compiled from Bangladesh Agril. in Statistics, Ministry of Agriculture, Bangladesh, Nov., 1973. pp. 57-61.

Consequently, it is in the winter season that the need for irrigation is deemed very essential.

The flows of water in all the major as well as minor rivers add up to only 22,500 cusecs of water during the winter season, which could possibly utilize a maximum number of 45,000 single stage low lift pumps[5] in the winter season. The past trend of using low lift pumps indicates that the number of pumps has increased from 2,024 in 1962-63 to 35,427 in 1974-75. However, coverage per cusce pump has decreased from 38.5 acres in 1962-63 to 20.0 acres in 1972-73. This is partly due to the fact that pumps are being provided without careful survey of surface water availability and partly due to the lack of government institutional and organizational abilities in organizing farmer groups large enough to make maximum potential use of the pumps' capacity. These are basic inherent bottlenecks in any organization and require a considerable gestation period to manage. Understanding these situations, it is expected that a total of 45,000 low lift pumps of full capacity would be fielded by 1980. However, by 1985 no enhancement of fielding of low lift pumps is envisaged due to a paucity of available surface water. The maximum potential use of the estimated

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[5] *Ibid.*, p. 144.

existing surface water of 225,000 cusces would be utilized only by expanding the coverage of each pump by 1985.

Groundwater represents another potential source of irrigation where surface water is not available. The comprehensive ground water supply has identified about 9.5 million[6] acres for prospective tube-well development. From recharge considerations alone, it is estimated that about 47,000 (2 cusces) tube-wells can be accommodated in the area. However, there are serious limiting factors on which development of groundwater depends: (i) safe yield; (ii) economies of pumping; (iii) diminution effect of surface water on ground recharge capacity and saline water intrusion due to diversion of water through Farraka barrage, and (iv) institutional and organizational capacity of government. These factors tend to have a tremendous impact on the possibilities of expanding the tube-well program. A hypothetical long range water development program, as estimated by Harvard University, indicates that a total of about 8.2 million acres would be brought under alternative modes of irrigation (shown in Table 3.3) as compared to the planned target of 19,000 tube-wells and 15,000 frictional pumps covering 1.369 million[7] acres. In addition to the above mentioned projection and programs, the following factors

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[6] _Ibid._, p. 144

[7] _Ibid._, p. 144-146.

Table 3.3. Hypothetical Long-Range Water Development by Region

Region	Low lift pumps	Tube-wells	Polders	Total
Northwest	0.13	2.21	0.13	2.47
Central	0.25	1.15	0.25	1.65
East	0.40	0.27	0.98	1.65
Southwest	1.02	0.39	1.00[1/]	2.41
TOTAL	1.80	4.02	2.36	8.18

[1/] Includes 500,000 acres Coastal Embankment Project and 300,000 acres Genges - Kobadak Project.

have been considered in estimating tube-well projection for this study: (i) last 5 years average growth rate of tube-wells; and (ii) groundwater availability. Considering these factors, it is estimated that about 10,000 tube-wells and 10,000 frictional pumps are likely to be sunk by 1980, which would increase to 20,000 tube-wells, and 20,000 frictional pumps by 1985. The detailed estimates of irrigation possibilities under alternative set of assumptions and technological adjustments are given in Table 3.4.

Credit Constraints

The credit supply is extremely inadequate and often available at an interest rate as high as 30 percent to 40 percent in the noninstitutional market. The supply of credit from institutional sources accounted for only 14 percent while 86 percent is available from noninstitutional sources like the well-to-do rural people and friends, etc. The total credit constraint can be specified as

$$L_{ij} \leq A_{ij} \cdot R_{ij} \qquad i = \text{crops}, \quad j = \text{regions}$$

where L_{ij} = potential credit available to farmers for use in the i^{th} crop in j^{th} region from both institutional and noninstitutional sources;

A_{ij} = area under i^{th} crop and j^{th} region;

Table 3.4. Projected Irrigation Availability During Three Phases of Development.

1975	Low Lift Pumps Nos	Low Lift Pumps Acre Ft. water 3/	Tube Wells Nos. 2/	Tube Wells Acre Ft water	Shallow Tube Wells 4/ Nos	Shallow Tube Wells Acre ft. Water	Traditional Method 000	Traditional Method Acre ft Water	Total acre feet water
CENTRAL Summer	-	-	1385	208	670	14	240	480	702
CENTRAL Winter	9505	795	1385	208	670	14	765	1530	2547
EASTERN Summer	-	-	275	41	295	6	600	1200	1247
EASTERN Winter	11473	960	275	41	295	6	775	1860	2867
NORTHWEST Summer	-	-	1050	158	1580	33	250	500	691
NORTHWEST Winter	3831	321	1050	158	1580	33	485	970	1482
SOUTHWEST Summer	-	-	190	29	455	10	350	700	739
SOUTHWEST Winter	10191	853	190	29	455	10	467	934	1826
1985									
CENTRAL Summer	-	-	2400	600	2400	50	100	200	850
CENTRAL Winter	10700	1338	2400	600	2400	50	380	760	2748
EASTERN Summer	-	-	400	100	400	8	700	1400	1508
EASTERN Winter	12710	1589	400	100	400	8	765	1865	3557
NORTHWEST Summer	-	-	10200	2550	10200	213	-	-	2763
NORTHWEST Winter	4400	550	10200	2550	10200	213	-	-	3313
SOUTHWEST Summer	-	-	7000	1750	7000	146	100	200	2096
SOUTHWEST Winter	17190	2149	7000	1750	7000	146	100	200	4245

1/ The regionwise powerpumps figures are three years average from 72-75 (source= Bangladesh Agril. in Statistics, Ministry of Agriculture)

2/ The nos of tubewells and shallow tubewells to be sunk in each region in 1985 were not available. The total national figure estimates are 20,000. The regionwise figures were approximated from the percentage of most favorable acres exist in each region as outlined in the plan. The total prospective area in each region as mentioned in the plan i.e.:

4000 sq. mls. in NW region = .56 percent X 20,000 total tubewells to be sunk in 1985 = 10,200 nos. of tubewells
2600 sq. mls. in SW region = .36 percent X 20,000 total tubewells to be sunk in 1985 = 7,000 nos. of tubewells
500 sq. mls. in Central region = . 07 percent X 20,000 total tubewells to be sunk in 1985 = 2,400 nos. of tubewells
7100

3/ In total 150 days in the Winter season (December to April) it is observed that a power pumps and tubewells supply about 1004 and 1800 acre inchs of water per season respectively, and runs about 6.7 and 6 hr. each day. Considering the heavy underutilization of these resources and a recent emphasis by the government for increasing capacity utilization of pumps and tubewells, it is inputed that per day utilization would be increased to 8 hr. and 10 hr. during 1980 and 85 respectively, (i.e. supply would be 1200 and 1500 acre inch of water through power pumps and 2400 and 3000 through tubewells.)

4/ One of pump operate about 502 hr. per season and supply about equivalent amount of water. So, if ½ pump operate about 502 hr. would supply about 250 acre inch of water in one season per shallow tubewells.

5/ A total about 1400 thousand acres of land irrigated through traditional methods. Survey in Commilla shows that about 74% of land irrigated through traditional methods. Which comes about 6 to 7 thousand acres of land.

Source: Winter Crop Survey in Comilla Kotwali Thana B. M. Soloiman, BARD, Aug., 1970, p. 10

6/ Since the Eastern region is not suitable for tube-well irrigation, it is assumed that the traditional method of irrigation would continue in Plan II at the same rate as in Plan I.

R_{ij} = average per crop credit supply under i^{th} crop and j^{th} region. The average supply of credit per crop acre for both local and irri-varieties are obtained from the Survey Reports undertaken by the Cooperative directorate and BIDE (75,2). According to these surveys, a farm family on an average, is able to secure a per acre loan of Rs. 200 for local varieties and Rs. 400 for HYV from both institutional and noninstitutional sources.

Thus, the total potential credit availability for the entire country is arrived at by adding the estimates of credit supply of different regions and over different crops. That is:

$$TNSC = \sum_{i=1}^{n} \sum_{j=1}^{m} L_{ij} ;$$

where TNSC = total national credit supply.

On the basis of these equations, the estimated credit constraints for Plan I comes to about Rs. 6830 million. For Plan II TNSC is assumed to be 30 percent higher than Plan I. The per acre credit availability for other cash crop is also assumed to be equivalent to the credit supply of local varieties.

Behavioural Constraints, Consumption Constraints

The food consumption levels of the model were exogenously determined. The household food consumption and nutrition survey conducted jointly by USAID and the University of Dacca serves as the basis for estimating total rural consumption constraints. (Table 3.5.)

Nonnegative Constraints

None of the activities discussed above can be operated at negative levels.

Acreage Constraints

Estimates of acreage for different varieties of rice and other crops included in the model were made separately for two levels of technology.

(i) TECH I: For Plan I solution, the acreage of each crop activity has been constructed by taking a mean of last three years' actual harvested acreage statistics received from the Bureau of Agricultural Statistics.

(ii) TECH II (Plan II): The only meaningful way the total production can be increased is through transfer of land from local to HYV varieties as well as by increasing the cropping intensity. The FAO/UNDP Soil Survey Scheme has identified suitable areas for

Table 3.5. Estimated Subsistence Consumption Requirement of Farm Population During 1975, 1980 and 1985[1/]

Crops/ Commodities	Per Capita[2/] Consumption per day (in ounce)	1975 (in million tons)	1980 (in million tons)	1985 (in million tons)
Rice	.9375	7.7570	8.9916	10.3221
Wheat	.0625	0.0517	0.0599	0.0668
Potato	.09375	0.7757	0.8992	1.0322
Sugar	.0625	0.0517	0.0599	0.0668

[1/]Farm population for 1980 and 1985 were projected on the basis of 3 percent and 2.8 percent growth rate, respectively. Current farm population was estimated from total number of farms[(2,176,400/3 acres) = 7,254,667 number of farms x 7 members each farm holding = 50.78 (million)]. So for 1980 and 1985 it comes about 58.86 and 67.57 million, respectively.

[2/]Household consumption survey conducted by USAID and Dacca University. Source: A. Jalimian - Consumption Requirement for a Balanced Diet in Bangladesh 1975-80. Ministry of Agriculture, Government of Bangladesh.

agricultural intensification (see Chapter II for details). Consequently, the areas delineated as suitable for different crops serve the basis for acreage constraints in Plan II.

CHAPTER IV

GENERATION OF INPUT-OUTPUT COEFFICIENTS

In Chapter III a linear programming model was set forth to determine the optimal land use pattern which would serve as a guide to profitable crop adjustments in four regions of Bangladesh. In this Chapter the input-output coefficients and prices of inputs and outputs used in the model are estimated. The first part of this Chapter discusses the problems associated with the estimation of input-output coefficients and procedures used by different researchers to alleviate these problems. The sources of data used in this study are also mentioned in this section. The second part of this Chapter describes the estimation procedures of input-output coefficients for all crop activities incorporated in this model. The main inputs to the agricultural production process are expressed in terms of land, human labor, draft animal power, fertilizers, water, seeds, and pesticides and accounted for by assigning unit costs to each of these items. Output is expressed in terms of crop yields and accounted for at the minimum-procurement price fixed by the government for each commodity.

The application of LP involves the accurate estimate of input-output coefficients and prices of inputs and outputs. However, the extensive and detailed enterprise budgeting information needed for constructing input-output coefficients were difficult to obtain. The problems often become complicated when the data is needed for macro model, because the input-output coefficients of a particular crop is usually affected by climate, soil differences, and resource availabilities. In addition, the principal cropped areas among regions exhibit considerable dissimilarities in terms of absorption of inputs and production of outputs. The degree of information required to take into account all these differences is hardly possible by available means. Thus, budgets and technical coefficients underlying the L.P. model were either (1) assembled and synthesized from information gained at meetings with personnel from the applied and technical agricultural services or (2) obtained from research publications. For macro models the data are best suited if they are collected in terms of 'typical or representative' farm-firms. Heady (21) has mentioned that where the solution is to provide for 'typical or representative' farm-firm the best sources of data are likely to be census data, farm record surveys and technical studies of production relations, information from extension personnel and conference with interested farmers. Considering the relative advantage of this approach over others, for the purpose of this study the input-output coefficients are estimated in terms of average 'typical or representative farm' in Bangladesh. Brief details about the representative farm approach including the sources of data are described below.

The Representative Farm

The input-output coefficients generated for the model were in terms of average representative farms in the four regions of Bangladesh. The development of a "representative" farm involves the estimates of input-output relationships, prices of inputs and outputs, net returns obtained from different crop enterprises, and the level of available resources relevant for this type of farm. The "Synthetic Firm Technique" is used to make these estimates. This technique allows the development of average representative (or hypothetical) farms by using estimates based on data the researcher judges to be most relevant under the specified conditions. The synthetic farms developed here are designed to be "representative" under the physical and economic environment it operates. This is "representative" in the sense that it displays identical internal and external characteristics with respect to resource endowments, production facilities, production constraints encountered, input-output relationships, and input and product market situations.

The estimates were made by examining data from a number of sources and making judgements based on these data. The data were obtained from many sources: published and unpublished reports and studies from: (i) government ministries; (ii) semi-government agencies like ADC and WAPDA, and (iii) educational and research institutes, e.g., Rice Research Institutes (BRRI), Mymensing Agricultural University, Academy for Rural Development (Comilla), and Institute for Development Studies (BIDS), etc. However, certain input coefficient requirements which are of strategic significance with respect to output determination, such as use of fertilizer, were estimated from the data obtained from fertilizer experimental stations.

The required input coefficients for all crop activities incorporated in the model are discussed below:

(i) Land

The resulting coefficients(Table 3.1,Chapter III) are simply a description of the period (i.e., Summer and Winter) during which a particular crop occupies the land.

(ii) Fertilizer input and yield

The input coefficient of fertilizers for each crop activity is contingent upon a wide range of variables such as crop varieties grown, the availability of irrigation water, regional climatic differences, and the availability of auxiliary inputs such as credit and extension programs. The following procedures were followed to generate fertilizer yield coefficients for use in the programming analysis at two alternative levels of technology -- TECH I (BENCHMARK), and TECH II (1985).

(a) TECH I (BENCHMARK)

Data on existing farmer's fertilizer application rate for different crop activities were not available but were imputed by relating monthly fertilizer sales to cropping patterns.[8] The yield rate for all crops were estimated by taking averages of the last three years' yield received by the farmers during 1972-75.

(b) TECH II

The fertilizer input-output coefficients and yields of different crops were estimated from the secondary data of crop-fertilizer trials received from the Soil Fertility Institute and Comilla Academy.*

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[8] The per-acre use fertilizer for different crops is imputed from BADC's monthly fertilizer sales to cropping pattern during 1972-73.

*The experiment was conducted through 200 fieldmen based on 200 thanas (out of a total of 417) throughout the country. Each fieldman is attached to 5 plots. The design is laid out in randomized block design. One advantageous feature of the randomized block is that experiemntal units are first sorted into homogenous groups called blocks. Such grouping of the experimental units tends to minimize experimental error within each block. Two variables were used where nitrogen was in the form of urea and $K_2O(P)$ in the form of TSP. There were nine treatments and there were three observations on yield for each treatment. The selected treatments were then allocated at random anong experimental units. In most of the experimens the surface region of interest was bounded by $0 \leq N \leq 200$ and $0 \leq P \leq 200$.

Various research studies indicate that by using statistical estimating procedures one can obtain reliable estimates of the relevant portions of the fertilizer-crop yield production surface to be able to predict input-output relationships at any relevant point on the surface. Fertilizer use depends on cultivators demand for it. Demand is an outcome of two decisions: whether to use fertilizer and how much to use. These decisions are governed by cultivator returns. The cultivator return depends on: (1) fertilizer production functions; (2) prices of crops, and (3) cost of fertilizer. Understanding these three factors, the farmer will demand the optimum amount of fertilizer. In Bangladesh, the Rice Research Institute and FAO Soil Fertility Investigation Project conducted a series of fertilizer experiments on different varieties of rice and other crops in four regions. The fertilizer experiments were done both in experimental and farmers' plots and on representative soils which had the widest possible relevance to established soil conditions.

In the experiments, all resources or inputs except fertilizer, were held constant. The crop was grown under controlled irrigation. In all, there were (2x9x3) = 54 plots, each of which was the size 1/40 of an acre. For grain yield determination, $10m^2$ per plot was harvested from the center of each plot. Yields were calculated and expressed in terms of a per maund per acre basis. The average yield of the experiment was made available to the author from where the fertilizer coefficients and yields for different crops were estimated.

The average results of these trials were used to obtain the various optimal combination of plant nutrients. The yield of the fertilizer trials obtained in the experimental stations were deflated by 30 percent to make it realistic vis-a-vis farmers' plot. The yield was deflated because research results based on experiment data often overestimate yield forthcoming on a farmer's plot where nontreatment variables are not controllable to the same degree as in the experiment plot. In Bangladesh no such experiment has been conducted thus far, so as to provide an indicative figure regarding the difference in yield between the experimental and representative plots (farmers' plot). Similar sorts of experiments have, however, been conducted in the Philippines where it has been observed that in the dry season the yield from representative plots would average 17 percent lower than the maximum attainable from experimental plots (25). Consequently, for the purpose of this study yield figures received from the experimental stations were deflated by 30 percent. The functional forms used to determine the optimum doses of fertilizers for different crops were as follows:

$$Y = X + B_1N + B_2N^{\nu} \ldots. \quad (1)$$

$$Y = X + B_1N + B_2P + B_3N^{\nu} + B_4P^{\nu} + B_5N\,P \ldots. \quad (2)$$

where Y = yield

N and P = two plant nutrients -- nitrogen and phosphate

NP = interaction term.

Taking the partial derivatives of the two nutrients N and P in the equation (2) with respect to Y gives

$$\frac{\partial Y}{\partial N} = b_1 + 2b_3N + b_5P \quad .... \qquad (3)$$

$$\frac{\partial Y}{\partial P} = b_2 + 2b_4P + b_5N \quad .... \qquad (4)$$

to obtain economic optima in the case of two inputs, profits would be maximized where the value of the marginal product ($MPP_x \cdot P_y = VmP_n$) of each input is equal to the price (P_N) of that input. This occurs where:

$$\frac{\partial Y}{\partial N} P_y = P_N \quad .... \qquad (5)$$

$$Vmp_N = P_N \quad .... \qquad (6)$$

Dividing (5) by P_y gives

$$\frac{\partial Y}{\partial N} = \frac{P_N}{P_y} \quad .... \qquad (7)$$

Utilizing the partial derivatives of the previous equation (3) ad (4) gives:

$$b_1 + 2b_3N + b_5P = \frac{P_N}{P_y} \quad .... \qquad (8)$$

$$b_2 + 2b_4P + b_5N = \frac{P_p}{P_y} \quad .... \qquad (9)$$

Solving by use of simultaneous equations which is in matrix notation Ax = b, where A is an n_2 by n_2 matrix of coefficients, X = col., (X_1, X_2) is a column vector of n_2 variables and b = col., (b_1, b_2) is a column vector of the given constants in the n_2 equations. On pre-multiplication by A^{-1} we obtain

$$A^{-1}Ax = A^{-1}b$$

since $A^{-1}A = I$ and since $Ix = x$,

$$X = A^{-1}b.$$

Using Cramer's rule gives the optima combination of plant nutrients for a given set of product and factor prices.

The regression equations obtained by fitting the two different functional forms were given in Table 4.1. The Table shows that the equation (2) in respect to all crops provide higher R^{ν} than equation (1). Consequently, equation (2) was used to obtain the optimal input-output coefficients for each crop activity. In case of certain crops like T. Aman, where equation (2) could not provide satisfactory results due to high multi-collinearity between N and P only equation (1) was used omitting variable P. The optimum profit points were analyzed with common price levels of Py = Rs · 120.00 per maund (see factor and product price of this Chapter), Pn = Rs · 0.51 and Pp = Rs · 1.38. The cost of nitrogen and phosphate

Table 4.1. Estimated Regression Coefficients for Fertilizer

Crops		R^2	Sig.*
1. Boro (local)	(a) Y = 17.1044 + .1927N - .00096N^2	.51	.009
	(2.2042 (.0668) (.0005)		
	(b) Y = 17.0242 + .1250N + .0661P - .0010N^2 - .007P^2 + .0008NP	.55	.10
	(2.5443) (.1229) (.1284) (.0009) (.0009) (.00012)		
2. IRRI Boro	Y = 24.994 + .1555N - .0003N^2	.60	.015
	(3.6823) (.1249) (.0008)		
	Y = 24.0610 + .1491N + .0085P - .0011N^2 - .0007P^2 + .0015NP	.90	.006
	(2.3777) (.1203) (.1185) (.0008) (.0002) (.0005)		
3. T. Aman	Y = 14.9544 + .2282N - .0018N^2	.69	.001
	(1.3210) (.0711) (.0009)		
	Y = 14.8000 + ,0159N + .1292P - .00032N^2 - .0004P^2 + .00005NP	.83	.003
4. Aman (HYV)	Y = 15.1689 + .2131N - .0009N^2	.52	.006
	(2.6718) (.0831) (.0006)		
	Y = 14.9502 + .1647N + .0634P - .0014N^2 - .0008P^2 + .0014NP	.62	.03
	(2.7734) (.1012) (.1060) (.0010) (.0007) (.0013)		
5. Jute	Y = 7.9966 + .1456N - .00018N^2	.89	.0005
	(1.0045) (.0544) (.003)		
	Y = 7.8384 + .1634N + .0137P - .0013N^2 - .0008P^2 + .00025NP	.94	.0005
	(.9996) (.0443) (.0663) (.0004) (.002) (.00015)		
6. Wheat	Y = 7.0971 + .1523N - .00057N^2	.79	.0005
	(1.1272) (.0419) (.00027)		
	Y = 8.1757 + .0907N + .0732P - .0007N^2 + .0012P^2 + .0015NP	.97	.0005
	(.7388) (.0315) (.0558) (.00016) (.0008) (.0005)		

considered for optimum profit points were the actual procurement and distribution costs incurred by the government. All the equations (in Table 4.1) were significant at 10 percent or less for coefficients of N, P, N^2, and NP. The equation for local Boro and HYV Aman yielded slightly higher doses of N and P than the current imputed doses computed from fertilizer sales to cropping pattern. The optimum doses, however, were below the recommended doses of 1:50:50 (i.e., 1 maund of nitrogen, 1/2 maund of phosphate and 1/2 maund potash) and 2:2:1 for local Boro and HYV Aman respectively. The estimated fertilizer doses for other crops are quite reasonable as well as consistent. The fertilizer input-output coefficients for each crop activity under alternative technological adjustments are shown in Table 4.2 and 4.3.

In the L.P. model (Table 3.1, Chapter III), the P_1 to P_{44} coefficients for fertilizer (R_{37} to R_{40}) reflect the fertilizer input required to produce one acre of each crop in four regions of Bangladesh. The yield of each crop, expressed as production from one acre of crop harvesting activity (P_1 to P_{44}), which is entered in the balance equation (R_{53} to R_{64}) as the output transfer row.

(iii) Labor Input Requirement

One of the crucial problems in budgeting crop production is the estimation of labor input requirements. The significance of reliable estimates of labor use for

Table 4.2. Estimated Fertilizers Input - Requirement for Different Crops in Alternative Stage of Development

Crops	1974-75[1/]	1980	1985
	Fertilizer use Lb/acre	Fertilizer use Lb/acre	Fertilizer use Lb/acre
Rice			
Aus (local)	10	12	15
Aus (HYV)	100	170	253
Aman B	-	-	-
Aman T	29	26	24
Aman (HYV)	120	150	190
Boro (local)	35	50	80
Boro (HYV)	150	170	253
Wheat	10	25	40
Jute	22	45	73
Potato	5	20	50
Sugarcane	73	80	110

[1/] The per acre use of fertilizers for different crops is imputed from ADC's monthly fertilizer sales to cropping patterns. It is actually the figure of 1972-73 as the monthly sales of later years are not available which is obviously higher.

Table 4.3. Estimated Yield Projection for Alternative Phases of Development

(in acre/maund)

	1970-75[1/] (5 yrs. ave.)	1980	1985[2/] Estimated
Aus (local)	8.6	8.6	8.6
Aus (HYV)	30.3	34	40
Aman B	9.2	9.2	9.2
Aman T	12.5	13.5	15.0
Aman (HYV)	25.5	26.0	29.0
Boro (local)	15.0	18.0	22.0
Boro (HYV)	33.5	35	42.0
Wheat	9.2	10	11.0
Jute	13.78	13	13.0
Potato	105.0	111.30	117
Sugarcane[3/]	473.0	473	500

[1/]Source: Bangladesh Agriculture in Statistics, Ministry of Agriculture, Gov't. of Bangladesh.

[2/]Estimated from the data obtained from Fertilizer Experimental Stations and Comilla Academy.

[3/]The 1970-75 yield data for sugarcane and jute appears to be highly inflated. Consequently, has not given much weight in estimating yield figures for 1970-75.

each crop activity can hardly be overemphasized due to the fact that it accounts for significant portion of the total production cost. In spite of such importance, dependable data on this particular aspect are scarce. Most of the farm management studies reveal that employment on HYV farms is about 1 1/2 times that of traditional rice farms (all on a per acre basis) (26). For the purpose of this study almost all of the crop production surveys[9] so far undertaken in different parts of Bangladesh were consulted and realistic estimates were made on the basis of these reports and my personal experience in the area. The labor input requirements were calculated per acre by crop for each month of the growing season. The monthwise labor requirement for each crop activity is shown in Table 4.4.

(iv) Bullock Power Requirement

Bullock power is the traditional source of cultivation in Bnagladesh. Mechanization has hardly been used; neither is its introduction on a significant scale contemplated in the future. Most of the farm management studies conducted thus far have been consulted and bullock power requirements for each crop activity have been worked out. Table 4.5 shows the bullock power requirement for each crop activity.

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[9](i) Gumail Bill Survey report; (ii) Mymensing area Survey; (iii) Comilla data; (iv) Rural Development Project I Survey Data.

Table 4.4. Estimate Monthly Labor Requirements for Various Crops (in Man-days)

	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov.	Dec	Total
Boro (local	16	22	4	4	14							6	66
Boro (HYV)	15	36	10	16	28							5	110
Aman-B						4	22	8	2	16	4		56
Aman-T							3	27	12	2	20	6	70
Aman-T (HYV)							4	38	15	2	21	10	90
Aus (local)				2	28	7	1	12	10				60
Aus (HYV)		5	40	10	14	25	16						110
Wheat	16	9	2	25	11								63
Jute				12	16	18	38	18					102
Potato	35	8	28	26									97
Sugarcane	1	22	17	1	1	1	1	1	1	15	20		81

Table 4.5. Estimated Bullock Power Requirements for Different Crop Activities in Bangladesh

Crops	Bullock Power Requirement (in Bullock pair-days)
Aus local	20
Aus HYV	26
B. Aman	20
T. Aman (local)	21
Aman HYV	24
Boro local	22
Boro HYV	26
Wheat	19
Sugarcane	25
Potato	23
Jute	17

(v) Water Input Coefficients

The climatic and weather conditions of different regions of Bangladesh vary considerably from each other. For this reason, the use of country-wide average water requirement coefficients for all regions would likely provide an erroneous policy conclusion regarding the availability as well as requirement of total quantum of water for various crops. Considering this fact, the irrigation water requirement for major crops estimated by Trafdar[10] on the basis of the Penman approach was used for this analysis. The irrigation water requirements for crops were computed as:

$$\sum_{i=1}^{n} I_{r_i} = \sum_{i=1} E_{t_i} + P_{d_i} + L_{s_i} - M_{b_i} - R_{e_i}$$

where:

I_{r_i} = Irrigation water requirement in the i^{th} period;

E_{t_i} = Evapo-transpiration requirement in the i^{th} period;

P_{d_i} = Deep percolation loss in the i^{th} period;

M_{b_i} = Initial moisture at the beginning of the i^{th} period;

R_{e_i} = Effective rainfall in the i^{th} period.

Monthly data on rainfall and evapo-transpiration have been

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[10]Op.cit., p. 116-120.

used. The reason for using this study is that it recognized the climatic and weather differences between different regions and estimated water requirements for each crop grown in high, medium and low rainfall regions separately (shown in Table 4.6). Indicative figures have been taken from the theoretical estimates and the results used as region-wide averages of the depth of irrigation water required to bring a crop to maturity. The estimates of irrigation water requirements were divided into two time periods: (i) Summer; and (ii) Winter, which correspond to the cropping pattern of the country.

(vi) Credit Requirement

A clear consensus of opinion as to the actual quantum of credit required per acre for each crop activity is not available. A number of studies mentioned a lump sum requirement for each farm family. The Cooperative Survey Studies[11] indicated the required quantum of credit by per family ranging from Rs. 178 to Rs. 475 in the Eastern region, Rs. 185 to Rs. 271 in the Central region and Rs. 278 to Rs. 300 and Rs. 135 to Rs. 221 in the Southwest and Northwest regions, respectively. The study was, however, representative of the requirement for credit only for indigenous crop varieties, as the survey was undertaken at a time when HYV was barely introduced. Understanding this

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[11]Agril. Credit in East Pakistan: A Survey, 1966. Op.Cit., p. 61-70.

Table 4.6. Estimated Irrigation Requirement Per Acre in the Low, Medium, and High Rainfall Regions in Bangladesh[1/]

(Acre feet of water)

	Low rainfall region	Medium rainfall region	High rainfall region
Aus (HYV	2.75	2.6	2.4
Aus (local)	-	-	-
Aman B	-	-	-
Aman T	-	-	-
Aman (HYV)	1.5	1.0	0.167
Boro (HYV)	2.75	2.6	2.4
Boro (local)	-	-	-
Wheat	1.6	1.0	0.9
Sugarcane	-	-	-
Potato	1.5	1.0	0.96
Jute	-	-	-

[1/]Source: Trafdar R. Islam - Low Lift Pump Irrigation in Bangladesh - Ph.D. Thesis in Michigan State University, 1973. p. 105-122.

problem the credit requirement was assumed to be 30 percent of production cost of each crop activity.

Factor and Product Prices and Cost of Production Factor Prices

The concept of cost that is relevant for economic analysis differs considerably from that which is relevant for private profitability analysis. The gap between social and private cost increased or decreased depending on extent to which imperfection and externality existed in the marketing mechanism and inhibited the free play of market forces. In Bangladesh a significant degree of distortion exists in factor market prices due to large transfer payments made to farmers through heavy subsidization of all inputs. Throughout the last decade it has been the practice of the government to provide modern inputs to farmers either free or at heavily subsidized prices. The extent of subsidy allowed to farmers is estimated to range from 56 percent to 65 percent for fertilizers, and between 60 percent to 65 percent and 40 percent to 50 percent for pesticides and irrigation water, respectively.

Recently, the government has emphasized the need for decreasing subsidies toward their gradual elimination. But the rate at which it would be reduced and the time it would take for its elimination were very difficult to predict. Such a proposal has often in the past been deemed economically feasible but regarded as politically vulnerable. Skepticism often shrouded the minds of the decision maker regarding its impact on demand for inputs, performance level of farmers and thereby on production. All these problems pose a serious difficulty in projecting different input prices during alternative phases of development. However, it has been observed that the farmers have recognized the importance of fertilizers for crop production and evidence indicates that they are willing to pay higher prices for it. With these perspectives, for the purpose of this study it is assumed that the present rate of subsidy for pesticides and water will continue whereas fertilizer subsidies would be eliminated during terminal phase of development (i.e., 1985). This would mean that farmers would be charged at Rs. 8.00 per pound of pesticides and Rs. 80.00 per acre feet of irrigation water.

Labor is the single most important input. Production costs fluctuate widely due to variation in wage rates. It has been observed that because of seasonal peak demand, the wage rate increased to Rs. 9.00 in 1975. The data of the Bureau of Statistics indicate that the average wage rate of agricultural labor in seasonal peak demand oscillated around Rs. 8.00 during the last two years (1974-1975). Consequently, the wage rate of Rs. 8.00 per day was considered for the model.

Product Prices

The relevant price that is usually accounted for in determining returns from crop activities is what farmers actually receive for their crops, that is, the farm gate price. But, the farm gate price is not collected in Bangladesh. Only wholesale prices were collected from district markets which are compiled and published in the form of national averages. Estimates for farmers selling prices for outputs in the model were, therefore, based on average wholesale prices.

There are several other difficulties regarding which product prices are to be considered for estimating farmer returns. It has been observed that prices for rice went up from Rs. 37 in 1970 to as high as Rs. 300 in 1974. The prices for other commodities also went up in a similar fashion. The reasons for abnormal increases in prices were (i) scarcity and high prices of production inputs in the international market; (ii) breakdown and suspension of production in local fertilizer factories; (iii) high rates of inflation both at home and abroad; (iv) large smuggling of food grains across the border, etc. The logical consequence of these facts suggests that any price projection will hardly be expected to provide a realistic estimate for economic analysis of the future. However, to alleviate the wide fluctuations in the product market, the government has fixed the price of rice at Rs. 120 in 1975. Recent conversations with officials of Bangladesh's Planning Commission and the World Bank indicate that the present market price for rice is more or less stabilized around the price fixed by the government.

Like rice, the jute price has also undergone similar sorts of fluctuation. Jute is the primary cash crop and produced mainly for export. Consequently, past government policy was to stabilize the jute market by fixing a statutory minimum internal price to enable it to compete in the international market. The statutory minimum floor price for jute is at three levels; primary (farmer's level), secondary and terminal markets are fixed by the government at the beginning of each jute season. There are, however, controversies and complaints regarding jute price policy, as it is often alleged that the farmers do not receive the minimum prices prescribed by the government. For the purpose of this study, however, the current statutory minimum prices fixed for rice was considered for analysis. However, for jute the current market price was considered.

Regarding wheat, its total internal production is very insignificant in comparison to rice. The larger percentage of wheat is usually received either as commodity aid or procured from abroad and distributed at a government controlled price. The farm gate price of wheat appears to be closely related to the controlled price in Dacca. The present controlled price of wheat is Rs. 55.00 per maund.

Similarly, the sugarcane price is determined by the procurement price fixed by the sugar mills which is Rs. 4.00 per maund at present. The farm gate price (FGP) is considered for potatoes. The FGP is derived by deducting the price spread between farm yard and wholesale markets from the average annual wholesale price.

Based on factor price assumptions mentioned earlier, the growing and harvesting cost of each crop activity is estimated (Appendix A, B). The product prices are incorporated directly into buying, selling and consumption activities of the model in order to estimate farmer returns.

CHAPTER V

OPTIMUM CROPPING ORGANIZATION UNDER ALTERNATIVE TECHNOLOGIES: IMPLICATIONS FOR FARM INCOME, LAND USE AND RESOURCE UTILIZATION

Chapter I has provided a conceptual framework for the economies of resource use on the basis of regional comparative advantage. In Chapter III a detailed programming model was elaborated to operationalize that conceptual framework. In light of that model two alternative plans were developed representing two technological levels. In Plan I, the net returns were optimized with existing national and regional resources and existing maximum crop acreage constraints. These constraints were determined on the basis of an average of last three years. In Plan II, at higher technological levels, the net returns were optimized with limits on maximum acreages suitable for different crops as identified by the FAO/UNDP soil reconnaissance survey and projected regional resource constraints for 1985 as estimated in Chapter III.

The purpose of this Chapter is to present the basic results of the analysis of these two models. The first part of the Chapter employing Plan I focuses on three topics: (i) the possibilities of increasing net national farm income through improved allocation of existing resources, (ii) the determining of an optimal land use pattern under existing sets of regional resource constraints; and (iii) the extent of resource use such as land, labor, etc., under this plan. The second part of the Chapter employing Plan II focuses on (i) the possibilities of increasing net national farm income through efficient allocation of projected resources; (ii) the determining of optimal land use patterns, and (iii) the utilization capacity of the Bangladesh agriculture with the estimated resources for 1985.

Optimum Organization with Existing Resource Constraints [(Technology-I) (Plan I)]

In exploring the characteristics of the optimum organization in Plan I the model results were examined by focusing on three separate economic criterions, viz (i) changes in net national farm income to fixed farm resources; (ii) land use and the cropping pattern of food grains and commercial crops; and (iii) total resource use, i.e., land, labor, fertilizer, etc.

A. Returns to Fixed Factors in Farming

The model results indicate that there exists significant scope for increasing national agricultural farm incomes by devoting more lands to HYV cultivation (Table 5.1). In this table the relative performance of the agricultural sector of the nation is measured on the following economic criterions: return on fixed factors, net return per acre, net return per man-days and net return per unit of borrowed capital. The net returns to fixed factors obtained in the optimal organization is Rs. 43127.994 million as against an estimated Rs. 38783[12] million from the existing plan, a 11.2 percent increase. The average per acre income of the entire crop mix combined, as estimated in the plan is Rs. 1526.49. The resulting crop plan is specialized in rice production, particularly in different HYV's including local improved varieties due to their comparatively higher net returns than other competing crops.

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[12]The data for Net National Farm Income (NNFI) actually derived from the eleven crops during 1972-1975 is not available. Consequently, the NNFI for these years were indirectly estimated on the basis of the following equation with a view to making an income comparison between the actual (average of 1972-75) and the optimal organization in Plan I.

$$\sum_{i=1}^{n} NNFI = \sum_{i=1}^{n} (P_i Q_i - d_{it})$$

where P_i = price of the i^{th} crop assumed or estimated in the model,

Q_i = actual last 3 years average production of i^{th} crop

d_{it} = the variable cost of i^{th} crop as estimated in the model.

Table 5.1. Characteristics of Optimal Organization of National Agriculture Plan for Bangladesh - Technology-I (Plan I)

Activities	Unit	Value
1. Purchased & Hired labor	Man-days	
January	"	0
.		.
.		.
December		0
2. Selling	Tons (000)	
Rice		5386
Sugarcane		3628
Potato		1937
Wheat		109.8
Jute	bales (tons acres)	1529
3. Borrow credit	(million rupees)	6830
4. Crop enterprises	(000 acres)	
Aus local		7557
Aus HYV		251.4
B.Aman		5471
T.Aman		6565
Aman HYV		1613
Boro local		2898
Boro HYV		2091
Wheat		477
Sugarcane		224
Potato		550
Jute		555
TOTAL (national)		28253

Constraints	Region	Unit	Value
1. Land		(Acres) 000	
Summer	central		4827
Winter	central		2000
Summer	Eastern		5297
Winter	Eastern		2087
Summer	Northeast		5514
Winter	Northeast		1405
Summer	Southwest		6346
Winter	Southwest		1000
2. Family labor		Man-days	
January			106105431
February			170356165
March			55179622
April			89163280
May June			331363663
June			89018144
July			175379732
August			383224029
September			187817827
October			107252726
November			139823170
December			52627440
3. Bullock power			
Central			145426485
Eastern			156664365
Northwest			140207786
Southwest			156263772
4. Fertilizers		maunds	
Central			3030000
Eastern			4263000
Northwest			2229950
Southwest			1856400

Constraints	Region	Unit	Value
5. Consumption		Tons (000)	
Rice			7829
Wheat			52
Potato			195.6
6. Borrowed Capital		(Million rupees)	68.30
7. Irrigation Water		(Acre ft)	
Summer	Central		335236
Winter	Central		2547000
Summer	Eastern		322784
Winter	Eastern		2867000
Summer	Northwest		948697
Winter	Northwest		900185
Summer	Southwest		--
Winter	Southwest		703752
Net Returns (million Rs.)			43127.994
Net Returns per Acre (in Rs.)			1526.49
Net Return per Man-day(in Rs)			22.85
Net Return per capital(in Rs)			6.31

In the optimal plan, a total production of about 13,215 thousand tons of rice is obtained as against an actual last five years average production of 10,700 thousand tons, an increase of 23.5 percent. Out of a total estimated rice production of 13,215 thousand tons, 7829 thousand tons were consumed and 5386 thousand tons were sold in the market. A total quantity of 161.8 thousand tons of wheat was produced, of which 52 thousand tons were consumed and 109.8 thousand tons were sold. Sugarcane production was, however, decreased from an actual production of 6635 thousand tons in 1974-75 to 3628 thousand tons in the optimal plan, an approximate decrease of 45 percent. This has happened particularly due to very low market price for sugarcane, compared to rice, both at farm as well as factory gate. The entire sugarcane production was sold in the market, obviously to sugarcane industries. The optimum plan also indicates that there is great potential for enhancing income by increasing potato production. Over the years cultivation of potato has become an increasingly profitable crop. Its production has increased from 348 thousand tons in 1961-65 to 866 thousand tons in 1974-75. In the optimum plan a total production of 2132.6 thousand tons of potato was estimated, of which 195.6 thousand tons were consumed at farm level and the rest 1937 thousand tons were sold in the market.

The return per man-days to labor obtained in the optimal plan is Rs. 22.85 as against actual wage rate of

Rs. 8.0 in agriculture and Rs. 10 in nonagricultural sector. The model results indicate that (a) first, productivity of agricultural labor force could be sufficiently high if resources are allocated efficiently in between different crops according to their highest returns and (b) second, agriculture could be a profitable enterprise in comparison to other competitive sectors if it is properly organized.

B. Optimal Regional Land Use and Cropping Patterns

The previous section described the results of optimal organization of national agricultural plan and its impact on net national income. This section focuses on optimum land use pattern of each region under different crops. In the optimum plan food grains increased their share in the cropping pattern in all regions except the Northwest where the area under food grains declined from the existing situation (average of last three years as estimated in Chapter III) by 15.4 percent (Table 5.2). In the optimum plan the total area under foodgrains in Central (CN), Eastern (EST), and Southwest (SW) regions registered an increase of 37 percent, 7 percent, and 15 percent respectively over existing plan with an overall national increase of 13 percent. The cropping pattern obtained from the model shows that the food grains would account for about 95 percent of the total cultivated area as compared to 90 percent in the

Table 5.2. Total Regional Land Use Pattern of Food Grains and Commercial Crops (Area in acres)

Regions	Total Cropped Area			Total HYV Varieties			Local Improved Varieties		
	Existing	Optimum	Percentage of increase(+) or decrease(-)	Existing	Optimum	Percentage of increase(+) or decrease(-)	Existing	Optimum	Percentage of increased(+) or decreased(-)
A) Food grains									
Central	4872000	6677423	(+) 37	889000	1073710	(+) 20.7	406000	634567	(+) 56
Eastern	6558000	7010618	(+) 7	1475000	1780151	(+) 20.7	110000	783467	(+) 28
Northwest	6012435	5940464	(-) 15.4	429435	850714	(+) 98.0	115000	781750	(+) 579
Southwest	6346338	7295999	(+)151	440338	251443	(-) 42.8	1209000	2898340	(+) 795
Total(national)	23788773	26924504	(+) 13	3233773	3856018	(+) 19.2			
B) Commercial Crops									
Central	791000	150000	(-) 427	-	-	-	-	-	
Eastern	261000	354811	(+) 36	-	-	-	-	-	
Northwest	899000	773860	(-) 14	-	-	-	-	-	
Southwest	612000	50000	(-) 92	-	-	-	-	-	
Total(national)	2563000	1328671	(-) 48	-	-				
Total (A + B)	26351773	28253175	(+) 7.2	3233773	3856018		1209000	2898340	

existing plan.[13] The resultant increase of area under food grains in the optimal plan is due to the higher relative profitability of food grains as compared to commercial crops. This is accentuated further by the introduction of different HYV rice varieties which have comparatively higher net returns. The decrease of area under commercial crops in the optimal plan was shared by three regions, with CN and SW regions having the greatest decline of 427 percent and 92 percent respectively from the existing situation. The overall national acreage under commercial crops has gone down from 2.56 million acres in actual situation to 1.32 million acres in the optimal plan, a decrease of 48 percent.

The model results revealed that significant changes would take place between existing and optimal land use patterns under different food grains and commercial crops in four regions of Bangladesh (Table 5.3). In the optimal land use plan, the regional comparative advantage of certain regions in producing particular crops due to differences in regional factor endowments and agroclimatic conditions is also evidenced by concentration of wheat in CN region and jute and sugarcane in NW region. The resulting plan also indicates that there is a significant increase in the area under HYV rice in the optimum plan. Boro Irri has increased

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[13] Existing Plan -- is defined as the average of last three years actual performance (1972-1975).

Table 5.3. Existing and Optimum Land Use Pattern Under Tech-I in Four Regions of Bangladesh

(Area in acres)

	Central		Eastern		Northwest		Southwest		National Total	
	Existing	Optimal	Existing	Optimal	Existing	Optimal	Existing	Optimal	Existing	Optimal
Aus (local)	1198000	1647000	7494000	1494000	2186000	2308000	2108000	2108000	6986000	7557000 (+) 8
Aus HYV	170000	-	305000	0	64000	-	106000	251443	645000	251443 (-) 61
Boro HYV	519000	738479	748000	1134583	168763	218249	192338	-	1628101	2091311 (+) 28.4
Boro (local)	406000	634567	610000	783467	115000	781750	78000	698556	1209000	2898340 (+) 140
B. Aman	818000	981188	1076000	1090000	1154000	2000000	1206000	1400000	4254000	5471188 (+) 28.6
T. Aman	1531000	1864000	1863000	1863000	1979000	-	2421000	2838000	7794000	6565000 (-) 15.7
Aman HYV	200000	335236	422000	645568	196672	632465	142000	-	960672	1613269 (+) 68
Wheat	30000	476953	40000	-	149600	-	93000	-	312000	476953 (+) 53
Food grains	4872000	6677423	6558000	7010618	6012435	5940464	6346338	7295999	23788773	26924504
Sugarcane	47000		19000	18819	205000	205000	109000	-	380000	223811 (-) 41
Potato	64000	150000	65000	150000	89000	200000	13000	50000	231000	550000 (+) 138
Jute	680000	-	177000	186000	205000	368860	490000	-	1952000	554860 (-) 71.6
Commercial crops	791000	150000	261000	354811	899000	773860	612000	50000	2563000	1328671
National	5663000	6827423		7365429		6714324		7345999	26351773	28253175

from 1.6 million acres in the existing situation to 2.09 million acres in the optimal plan, whereas the local T. Aman crop has declined by 15.7 percent. The released acreage from local T. Aman is transferred to Aman Irri production, the area under which has increased from 0.96 million acres to 1.61 million acres in the optimal plan, an approximate increase of 68 percent. The total area brought under HYV rice cultivation is 3.85 million acres in the optimal plan as against 3.2 million in actual situation. It also appears from Table 5.2 that the adoption rate of [1] HYV is not uniform in all regions, ranging from 20.7 percent in CN and EST regions to 98 percent increase in the NW regions. The latter region has high potential for bringing more areas under HYV because of the availability of adequate ground water. During the last three years, the total area of HYV in NW region has increased from 0.259 million acres in 1969-70 to 0.649 million acres in 1973-74. The total area of HYV both in actual and optimum plan were, however, much greater in the eastern region. The local improved rice variety (LIV) has increased in all regions. The total national LIV acres has increased from 1.2 million acres to 2.89 million acres in the optimum plan with a share of 579 and 795 percent increases in NW and SW regions respectively. The CN region appears to have a comparative advantage in producing wheat. In the optimum plan, the entire wheat production has taken place in the CN region.

Potato cultivation appears to be the most profitable of cash crops. In the optimum plan the total acreage obtained under potato was 0.55 million as compared to .231 million acres in the existing plan, whereas sugarcane area had decreased from 0.38 million acres to 0.22 million acres in the optimum plan. About 90 percent of sugarcane cultivation is taking place in the NW region and the remaining 10 percent in the EST region. Jute, the principal cash crop and foreign exchange earner for Bangladesh, was found to be the most unprofitable among cash crops, given the technical coefficients and prices used in the model. The actual situation of jute corraborates the findings of optimal plan. The actual acreage under jute has decreased from 2.28 million acres in 1965-70 to 1.95 million acres in 1970-75. The per acre yield of jute has also declined from 3.6 bales/acre in 1950-55 to 2.7 bales/acre in 1970-75. In spite of significant importance to the national economy, the government policy for jute over the last two decades fails to provide sufficient incentives to farmers for jute production or to make it more viable and competitive vis-a-vis other crops. In the optimum plan, the total jute acreage has declined to 0.55 million as against 1.95 million acreage in the existing situation, a decrease of 71.6 percent. About two thirds of jute is produced in the NW region and the remaining one-third is located in the Eastern region.

C. Utilization and Marginal Value Products of Resources

The extent to which available regional resource endowments (i.e., land, water) of each region are utilized for production of different crop activities and the estimated marginal value product (MVP) of each unit of resource used is given in Table 5.4. The total cultivable land increased from 26.35 million acres to 28.47 million acres in the optimal plan. The proportion of total available summer land utilized ranged from 79 percent in the NW region to 96 percent in the EST region, whereas winter land has been fully utilized in all regions except in the EST region. The short supply of winter lands in the CN, NW and SW regions are reflected by their positive shadow price or marginal value product (MVP) in column 6 of the Table. The MVP indicates the possible gains in income through acquisition of scarce resources. The MVP's of winter land ranged from Rs. 52 in the CN region to Rs. 913 in the NW region. Thus one acre increase in winter land disposal in the CN and NW regions, with land remaining constant at 2.0 million and 1.40 million acres in those regions, profit would decrease by Rs. 52 and Rs. 913 respectively and vice-versa. The more limiting the resources the higher the MVP. The positive MVP indicates that the farmer would find it profitable to acquire that scarce resource if MVP > MFC of that resource. The optimal solution is also provided (lower and upper activity) or

Table 5.4. Resource Availability Levels and Their Utilization Under Optimum Plan Technology-I

	Unit (acres	Resource Availability	Resource Utilized	Percentage of Utilization	Shadow Price for activity in solution (in Rs.)	Income Penalty for Activity Not in Solution (in Rs.)	
1	2	3	4	5	6	7	8
1. Land							
Summer land Central		5463000	4827424	88	0	30	7.99
Winter land Central		2000000	2000000	100			0
Summer land Eastern		5537000	5297379	96	0	7.9	1116
Winter land Eastern		2087000	2086862	99.9	0	7.9	563
Summer land Northwest		6915000	5514325	79	0	111	31
Winter land Northwest		1405000	1405000	100	913	0	0
Summer land Southwest		6670000	6346000	95	0	552	198
Winter land Southwest		1000000	1000000	100	597	0	0
2. Permanent labor	Man-days						
January		396104826	106105431	27	0	3.17	.58
February		396104826	170356165	43	0	.28	26.8
March		396104826	55179622	14	0	.46	17.67
April		396104826	89163280	22	0	7.85	1.83
May		396104826	331363663	84	0	4.13	1.18
June		396104826	89018144	22	0	.50	2.33
July		396104826	175379732	44	0	3.20	.26
August		396104826	383224029	97	0	6.77	.69
September		396104826	187817827	47	0	5.33	6.26
October		396104826	107252726	27	0	8.0	7.99
November		396104826	139823170	35	0	.49	4.47
December		396104826	52627440	13	0	8.0	1.08
3. Hired labor	Man-days						
January		7922070	0		0	-	8.0
.		:			0		8.0
.					0		8.0
December		7922070	0		0		
4. Chemical fertilizers	Maunds						
Central region		3030000	3030000	100	1985	0	0
Eastern region		4263000	4263000	100	670	0	0
Northwest region		2229950	2229950	100	1612	0	0
Southwest region		1856400	1856400	100	2347	0	0
5. Irrigation water	Acre/ feet						
Summer Central		702000	335236	48	0	80	94
Winter Central		2547000	2547000	100	68	0	0
Summer Eastern		1247000	322784	26	0	3967	-
Winter Eastern		2867000	2867000	100	1099	-	-
Summer Northwest		6910000	948697	14	0	363	-
Winter Northwest		1482000	900185	61	0	59	209
Summer Southwest		739000	-	--	0	-	527
Winter Southwest		1826000	703752	38	0	109	257
6. Bullock power							
Central region		343940856	145426485	42	0	1.72	.39
Eastern region		323221584	156664365	48	0	.32	28.24
Northwest region		310546152	140207786	45	0	6.85	1.95
Southwest region		241075464	156263772	65	0	28.74	12.68
7. Credit	Rupees million	6830	6830	100	.48	0	0

range over which the shadow prices of Rs. 52 and Rs. 913 are relevant.

One of the important uses of linear programming is that it can estimate the shadow prices of excluded activities. Columns 7 and 8 of the Table show the shadow prices of the excluded activities. It indicates cost of forcing of an extra unit of activity into the solution. The shadow prices of the excluded activities also provide information regarding competitive position of these activities in the optimal solution. The income penalty of summer land in the Eastern region ranges from Rs. 7.9 on the lower side to Rs. 1116 on the upper side. The range over which the income penalty extends is obtained in the optimal solution [(5267449 acres on the lower side - to 5297379 on the upper side) -- Appendix Optimum Solution]. This means that on the upper side any quantity of land could be brought under cultivation at a loss of Rs. 1116, whereas reducing the cultivation of summer land below the 5267449 acres used in the plan would involve an income penalty of only Rs. 7.9 for each acre of land withdrawn. The lower the income penalty, the higher is the competitive position of that activity to enter into the optimum solution and vice-versa.

The permanent labor force employed in the optimum plan ranged from 13 percent in the month of December to 97 percent in August. August is usually the peak month for employment, as it is the harvesting period of

B. Aus - T. Aus; and sowing period for local transplanted and Irri Aman, the two largest crops in Bangladesh which account for about 30 percent and 56 percent of the total rice crop respectively. The income penalty likely to be incurred for using an additional unit labor beyond the optimum employment given in the solution is Rs. .69 for August labor, as against 1.08 for December labor. In other words, to force an increase of one man-day of labor employment beyond 52627440 man-days in the month of December would reduce profit by Rs. 1.08 in the optimal plan. The magnitude of labor employed or remaining surplus as shown in the Table, however, does not represent the actual employment or unemployment figures in agricultural sector, as there are about 7 million acres of land devoted to six other crops which were not incorporated into this model. However, the present study would help in providing a reasonable approximation of the rate and magnitude of unemployment in different months of the year in agricultural sector. Employment is also relatively high in the months of May, July, and September, and absorb about 84 percent, 44 percent and 47 percent of the available labor supply during those months. The labor supply is not a limiting factor in the optimal solution and is reflected by their zero MVP's in column 6 of the Table.

Fertilizers and winter irrigation water are critical elements in the production of HYV varieties and are scarce in supply. Most farmers recognize and understand the importance of these inputs for increasing production. In the optimal plan, the entire available fertilizers were exhausted in all four regions. Its MVP ranged from Rs. 670 in the EST region to Rs. 2347 in the SW region. This indicates that it is profitable to use more fertilizer under assumed fertilizer prices and output conditions.

Scarcity of winter irrigation water in the CN and EST regions is reflected by their positive MVP's of Rs. 68 and Rs. 1099 respectively in the Table. However, the same is in excess supply in the NW and SW regions as indicated by their zero MVP's; whereas in actual situation irrigation water is scarce in those regions. The optimum plan shows that there is misutilization of irrigation water in those regions and either profit could be increased or cost of production could be decreased by efficient allocation of water resources. The last few years data confirm these findings which show that the area coverage of per cusec pumps has declined from 38.5 acres in 1962-63 to 20.0 acres in 1974-75. Borrowed capital appears to be not very profitable, as anticipated. Bullock power is in excess supply in all four regions and is reflected by the zero MVP's in Table 5.4.

Optimal Organization with Technological Change [(Technology II) (Plan II)]: 1985

The first part of this Chapter shows to what extent the optimal allocation of existing regional resources under present state of technology would increase the net national farm income and change existing land use patterns. This section provides the empirical findings of the differential impact of technological change (as defined in the model -- see Chapter I for details) on (a) net national farm income, (b) regional land use and cropping pattern and (c) resource utilization. The latter part of this section will present a comparative analysis of potential utilization capacity of Bangladesh agriculture under the two technological levels in making use of total land, as identified suitable for different crops by FAO/UNDP.

A. Net Returns to Fixed Farm Resources Under Technological Change (Plan II)

The relative performance of the optimal organization of national agriculture is examined using the following economic measures: net national farm income, net return per acre, net return per man-days and net return per unit of capital. The model result indicates that there exists a significant scope for increasing net national income through adoption of the new HYV Aman varieties and the extension of existing HYV varieties. In the optimal organization under

Plan II, net national income is estimated at Rs. 65465.97 million as against Rs. 43127.99 million under Plan I, an increase of approximately 52 percent (Table 5.5).

The optimum crop plans in each region were not diversified, but found to be specialized in the production of two crops -- rice and potato -- because of their higher relative net returns. Rice production increased from 13.215 million tons under Plan I to 19.33 million tons under Plan II, an increase of 46 percent. Out of the total estimated production of 19.33 million tons, 10.41 million tons are consumed at the farm level and 8.92 million tons are marketable surplus. The crop sales figures in the activities section in Table 5.5 were the net after consumption withdrawals. Potato production increased from 2.13 million tons under Plan I to 7.05 million tons in Plan II, including a marketable surplus of 6.8 million tons. Jute is found to be a most unprofitable crop and its production remained, more or less, stagnant around 1.5 million bales, both in Plan I and II as compared to actual production of 6.0 million bales in 1973-74. Sugarcane production gained a minor thrust in Plan II, and its production increased to 4.93 million tons as against 3.62 million tons in Plan I.

The net per acre average return obtained in the optimal plan under Plan II is Rs. 2337.6 as against Rs. 1526.49 under Plan I, an increase of about 53 percent. The increase in income that occurred in the optimal Plan II is largely

Table 5.5. The Characteristics of Optimal Organization of National Agricultural Plan Under Technology-II (Plan II)

Activities	Unit	Value
1. Purchase Hired labor	Man-days	
January 1		0
		.
		.
December 12		0
2. Sell	Tons (000)	
Sell rice		6880
Sell sugarcane		4937
Sell potato		6842
Sell jute	bales	1540
3. Buy		
Wheat		694
4. Borrow	million rupees	8521
5. Crop enterprises (in acres)		
Aus local		6141015
Aus HYV		820708
B. Aman		4022973
T. Aman		4356094
Aman HYV		5524511
Boro local		1108844
Boro HYV		3535428
Sugarcane		267352
Potato		1633321
Jute		595649
Wheat		-
Total		28005895

Constraints		Unit	Value
1. Land		Acres (000)	
Summer	Central		4473931
Winter	Central		1917588
Summer	Eastern		5187677
Winter	Eastern		2211066
Summer	Northwest		6285456
Winter	Northwest		1738000
Summer	Southwest		4960531
Winter	Southwest		1499000
2. Family labor		Man-days	
January 1			132310065
			203446661
			98274725
			134655696
			316779722
			83199405
			152714842
			444411016
			199922279
			88139063
			206306030
December 12			86564886
3. Bullock power		(in pair-days)	
Central			343940856
Eastern			323221584
Northwest			310546152
Southwest			241075464

Constraints		Unit	Value
4. Fertilizers		Maunds	
Central			6135300
Eastern			97858000
Northwest			8435700
Southwest			7534800
5. Irrigation		Acre/ft	
Summer	Central		850000
Winter	Central		2748000
Summer	Eastern		912348
Winter	Eastern		3557000
Summer	Northwest		2470986
Winter	Northwest		3313000
Summer	Southwest		1202490
Winter	Southwest		3460776
6. Consumption		Tons (000)	
Rice			10410
Wheat			694
Potato			215
7. Borrowed Capital		million rupees	8521
Net Return		million rupees (in Rs.)	65465.967
Net Return/acre			2337.6
Net Return/ man-day		(in Rs.)	30.49
Net Return/ capital		(in Rs.)	7.68

due to: (i) increased adoption of HYV varieties on 6.63 million acres of land which includes 4.6 million acres transferred from local to HYV varieties; (ii) increased regional specialization reducing the number of crops from eleven to seven crops in each region (see next section); and (iii) efficient use of production resources among competitive crop enterprises, say jute vs Aus. rice.

In the optimal Plan II the net return per man-days and per unit of borrowed money increased to Rs. 30.49 and 7.68 as against Rs. 22.85 and Rs. 6.31 respectively under Plan I. The higher returns to labor and borrowed capital indicates the greater productivity of resources with technological change.

B. Land Use Pattern Under Technology-II (Plan II)

In the optimal plan at the higher technological level the area under food grains increased by 7.2 percent, whereas the total area under commercial crops has declined by 2.6 percent compared to the existing plan (Table 5.6). The optimal plan as shown in the Table determined the magnitude of interregional shifts in production pattern and land use implied for the future under specified conditions of technological improvements and resource constraints. The decrease in the area under commercial crops (cc's) is particularly due to shrinkage of area of jute and sugarcane. In fact, excluding

Table 5.6. Existing and Optimum Land Use Pattern Under Technology-II in Bangladesh

(Area in acres)

Crops	Central		Eastern		Northwest		Southwest		TOTAL		Percentage of (+) increase and (-) decrease
A) Food grains	Existing	Optimum	Existing	Optimum	Existing	Optimum	Existing	Optimum	Existing	Optimum	
Aus local	1198000	1596944	1494000	1146325	2186000	1684799	2108000	1712947	6986000	6141015	(-) 12
Aus HYV	170000	-	305000	198346	64000	-	106000	622362	645000	820708	(+) 27
Boro HYV	519000	833910	748000	1129748	168763	918022	192338	653748	1628101	3535428	(+) 118
Boro local	406000	452844	610000	476000	115000	100000	78000	80000	1209000	1108844	(-) 8.3
B. Aman	818000	782456	1076000	1023000	1154000	1095879	1206000	1121638	4254000	4022973	(-) 5.4
T. Aman	1531000	1169495	1863000	985691	1979000	1277452	2421000	923456	7794000	4356094	(-) 44
Aman HYV	200000	850000	422000	1824697	196672	1647324	142000	1202490	960672	5524511	(+) 475
Wheat	30000	-	40000	-	149000	-	93000	-	312000	-	-
	4872000	5685649	6558000	6783807	6012435	6723476	6346338	6316641	23788773	25509573	(+) 7.2
B) <u>Commercial crops</u>											
Sugarcane	47000	51000	19000	22000	205000	194352	109000	-	380000	267352	(-) 29.6
Potato	64000	579834	65000	384972	89000	525625	13000	142890	231000	1633321	(+) 607
Jute	680000	24036	177000	185964	605000	385649	490000	-	1952000	595649	(-) 69.5
	791000	654870	261000	592936	899000	1105626	612000	142890	2563000	2496322	(-) 2.6
	56630006340519			7376743		7829102		6459531	26351773	28005895	(+) 6.2

potato, the total area under cc has declined by 63 percent from the existing plan. On the other hand, the increase in area under food grains is largely due to a decrease in area under local varieties of rice by 22.7 percent and an increased total area under HYV by 206 percent.

Among HYV varieties, T. Aman HYV increased from 0.96 million acres in the existing plan and 2.09 million acres in Plan I to 5.32 million acres in Plan II. The factors responsible for increase in area under T. Aman HYV were (i) the adoption of new HYV Aman varieties like BR-3, (ii) less constraints of water during summer, and (iii) relatively high profit in comparison to other summer crops. Most of the increase in T. Aman HYV comes from a decrease in area under local T. Aman, which declined from 7.79 million acres in the existing plan to 4.35 million acres in the optimum plan. Like T. Aman HYV in the summer, Boro Irri continues to be the most profitable crop in the winter season. Its area went up to 3.5 million acres as against 1.6 million acres in actual situation. In the optimal plan, the expansion of Boro Irri is largely constrained due to its heavy dependence on both fertilizer and water, which are very scarce in supply. Like other Irri varieties, the expansion of area under Aus Irri appears to be less promising. This is particularly due to the fact that Aus Irri usually competes with Boro Irri and tends to be less profitable than the latter. In the optimal plan there is a marginal area gain of 2.6 percent under this variety as a proportion of total increase of all HYV varieties. Total acreage of traditional rice varieties have plummeted by 27 percent in Plan II. The area of local Aus has decreased by 12 percent, local Boro by 8.3 percent, and B. Aman and T. Aman by 5.4 and 44 percent respectively.

Among commercial crops, the area under jute declined by 69.5 percent as compared to existing plan. Jute usually competes with Aus rice, but remained technologically dormant for decades, and consequently, was found to be much less profitable than Aus HYV. With respect to regional land use pattern, the total area under food grains has increased in the CN region by 16.7 percent, in the EST region by 3.4 percent and in the NW region by 11.8 percent. However, the same has remained, more or less, constant in the SW region. The total area under commercial crops has decreased in the CN and SW regions by 17 percent and 77 percent respectively, whereas the same has increased by 127 percent and 23 percent respectively in the EST and NW regions. The increase in total area in these two latter regions is primarily due to increased cultivation of potato (Table 5.6). Land devoted to HYV in different regions shows that about 63 percent of the total expansion takes place in the NW and SW regions (Table 5.7). In the optimal plan the total area of HYV rose from 0.42 million acres to 2.56 million acres in the NW region and from 0.44 million to 2.48 million acres in the SW

Table 5.7. Existing and Optimal Regional Land Use Pattern of HYV's Under Tech-II
(Area in acres)

	Existing	Optimal	Existing	Optimal	Existing	Optimal	Existing	Optimal	Percentage of increase(+) or decrease(-)
Central	170000·	-	519000	833910	200000	850000	889000	1683910	(+) 89
Eastern	305000	198346	748000	1129748	422000	1824697	1475000	3152791	(+) 114
Northwest	64000	-	168763	918022	196672	1647324	429435	2565346	(+) 497
Southwest	106000	622362	192338	653748	142000	1202490	440338	2478600	(+) 463
	645000	820708	1628101	3535428	960672	5524511	3233773	9880647	

region. The increased adoption of HYV is largely due to the availability of adequate ground water in these two regions. In fact, most of the planned increase of tube-wells in coming decades will likely take place in these regions. The EST region, however, accounts for about 32 percent of the total HYV area increase. The total area of HYV in this region increased to 3.15 million acres as compared to 2.56 million and 2.47 million acres respectively in the NW and SW regions. About 53 percent of the total HYV area in the EST region is devoted to HYV Aman varieties.

A comparative statement of land use patterns under different technological adjustments in relation to land identified suitable by FAO/UNDP soil survey for different crops is shown in Table 5.8. One noticeable feature that emerged from this Table is that the higher technological levels (Plan II) utilize proportionately less area under traditional rice varieties and devote comparatively larger areas to HYV varieties in comparison with lower technological levels (Plan I). Out of 8.5 million acres of land identified suitable for Aus local in the soil survey reports, about 6.14 million acres are utilized in the optimum plan for Tech-II, as against 7.55 million acres used in Tech-I. Similarly, the optimum Plan I used about 99 percent and 71 percent of the identified suitable land of B. Aman and T. Aman local whereas the utilization of the same decreased to 73 percent and 47 percent respectively in Plan II. A total

Table 5.8. Proportion of Suitable Land Identified by Soil Reconnaissance Survey Utilized in the Optimum Plan for Tech-I and Tech-II (in acres)

Crops	Soil Survey	Optimum (Technology-I)	Percentage of suitable land utilized in the optimum plan (Tech-I)	Optimum (Technology-II)	Percentage of suitable land utilized in the optimum plan
Aus local	8500000	7557000	89	6141015	72
Aus HYV	7500000	251443	3.3	820708	11
Boro HYV	7500000	2091311	28	3535428	47
Boro local	1500000	2898340	193	1108844	74
B. Aman	5500000	5471188	99.5	4022973	73
T. Aman	9300000	6565000	70.6	4356094	47
Aman HYV	7922000	1613269	20.4	5524511	70
Wheat	5400000	476953	8.8	-	0
Sugarcane	3900000	223810	0.5	267352	7
Potato	-	550000	NI	1633321	NI*
Jute	2500000	554860	22	595649	24

NI = Not identified separately

area of 4.6 million acres released from local varieties were devoted to HYV in the optimum plan for Tech-II.

The soil survey report indicates that nearly 7.9 million acres suitable for HYV Aman, of which optimum plan or Plan II utilizes 5.5 million acres, about 70 percent compared to 1.6 million acres used in Plan I. The utilization of Boro HYV land is 20 percent higher in Plan II than in Plan I.

The utilization of land under commercial crops particularly under jute and sugarcane both in Plan I and Plan II did not make any noticeable difference. The only significant increase in areas under two technological stages comes from potato cultivation which increased from 0.55 million acres in Plan I to 1.63 million acres in Plan II.

C. Utilization and Marginal Value Productivity of Resources

The availability of national as well as regional resources was estimated for higher technological level in Chapter III. The proportion of these resources utilized in the optimum Plan II is shown in Table 5.9. The proportion of total available summer land used for cultivation ranged from 74 percent in SW region to 94 percent in the EST region. The excess supply of summer land is indicated by their zero MVP in column 6 of the table. Changing the acreage of summer land used in the optimal plan either forcing the plan

Table 5.9. Resource Availability Levels and Their Utilization Under Optimum Plan - Tech-II

	Unit	Resoorce Availability	Resource Utilized	Percent Utilities	Shadow Price (in Rs.)	Income Penalty for Activity not in solution (in Rs)
1. Land (in acres)						
Summer land Central		5463000	4473931	82	0	937
Winter land Central		3329774	1917588	57	0	1400
Summer land Eastern		5537000	5187677	94	0	835
Winter land Eastern		3141000	2211066	70	0	1117
Summer land Northwest		6915000	6285456	91	0	720
Winter land Northwest		1738000	1738000	100	1117	0
Summer land Southwest		6670000	4960531	74	0	44
Winter land Southwest		1499000	1499000	100	59	0
2. Permanent labor (man-days)						
January		552854000	132310065	24	0	10.75
February		552854000	203446661	37	0	59.7
March		552854000	98274725	18	0	24.9
April		552854000	134655696	24	0	54.5
May		552854000	316779722	57	0	48.3
June		552854000	83199405	15	0	21.9
July		552854000	152714842	28	0	11.0
August		552854000	444411016	80	0	1.1
September		552854000	199922279	36	0	2.9
October		552854000	88139063	16	0	10.5
November		552854000	206306030	37	0	2.1
December		552854000	86564886	16	0	4.3
3. Hired labor	Man-days					
January		113547000	0	0	0	8.0
.		.		0	0	8.0
.		.		0	0	8.0
.		.		0	0	8.0
December		113547000		0	0	8.0
4. Chemical fertilizers	Maund					
Central region		6135300	6135300		546	0
Eastern region		9785800	9785800		546	0
Northwest region		8435700	8435700		546	0
Southwest region		7534800	7534800		1466	0
5. Irrigation water	Acre/ft					
Summer CN		850000	850000	100	2134	
Winter CN		2748000	2748000	100	1251	
Summer EST		1508000	912348	61	0	
Winter EST		3557000	3557000	100	1209	
Summer NW		2763000	2470986	89	0	
Winter NW		3313000	3313000	100	777	
Summer SW		2096000	1202490	57	0	44
Winter SW		4245000	3460776	82	0	413
6. Bullock power (pair-days)						
Central region		343940856	139211425	40	0	38.5
Eastern region		323221584	156592597	48	0	31.6
Northwest region		310546152	171548648	55	0	65.8
Southwest region		241075464	152023737	63	0	5.9
7. Credit (in Rupees)		9400000000	8520907119	100	0	1.04

to make use of more or permitting less to be used, will reduce income. The decline in income ranges from Rs. 44 in the SW region to Rs. 937 in the CN region. The winter land is scarce in supply in the NW and SW regions. The MVP's of winter land in those regions are Rs. 1117 and Rs. 59 respectively. The positive MVP of winter land in the NW region indicates that income to the extent of Rs. 1117 can be increased by adding one acre of these restricting resources.

The total employment obtained under Plan II in the agricultural sector is 7.352 million man-years as against 6.50 million man-years under Plan I. Column 5 of the Table exhibits the seasonal employment and unemployment pattern. The farm labor force is surplus indicated by their zero shadow price in all seasons. The employment rate is highest, about 80 percent of the total available farm labor force, during the month of August. The highest employment rate in August corresponds with lowest income penalty of Rs. 1.1 likely to be incurred if one additional unit of labor is employed during that month. The lowest income penalty in August also indicates the highest competitive position of that resource to come into optimal solution. The employment rate is about 57 percent in February. The unemployment rate is highest during the month of June and October, about 85 percent and 86 percent respectively. The excess supply of labor force suggests that there is scope for transfer of farm labor to off-farm employment without affecting agricultural output significantly.

Chemical fertilizer is scarce in supply in the optimal solution in all four regions, which is reflected by the positive MVP. However, the MVP of fertilizers in Plan II is lower than that of Plan I because of its relative increase of supply in that period. The MVP of fertilizer obtained in optimal solution is greater than marginal factor cost (MVP > MFC) of fertilizers in all regions. In the previous Chapter, while estimating the fertilizer response functions, it was assumed that with given product and fertilizer input prices farmers would maximize their profit where the value of marginal product ($Mpp_n \cdot P_y = Vmp_F$) of fertilizer input is equal to the price of that fertilizer input (P_F). This occurs where $Vmp_F = P_F$. Thus, in the optimal plan the higher MVP implies that it would be profitable for a farmer to use more fertilizer if an additional quantum of fertilizer was made available at prevailing prices until the marginal value product of fertilizer becomes equal to marginal factor cost of fertilizer ($MVP_F = MFC_F$). It appears that the MVP of fertilizer in the SW region is Rs. 1466, which is about three times higher than the MVP's of fertilizers in the other three regions. This is due to the fact that in L.P., as the supply of another complementary resource is either increased or exist in excess supply, the MVP of the restricting resource resource increases tremendously (32). It may be seen that the irrigation water is scarce in supply in all three regions where the MVP of fertilizer is low whereas the same is in excess supply in the SW region as reflected by its zero scarcity value where the MVP of fertilizer is much higher.

The optimum plan indicates that credit (borrowed capital) is in excess supply in Plan II, whereas the same is in scarce supply in Plan I. This is particularly true in a situation that at higher technological levels farms usually have increased savings generated from higher production levels whereas at lower technological level farms that usually have low levels of production and which are usually exhausted in satisfying basic needs, and consequently, have a low savings rate.[14]

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[14]Source: This statement is similar to the findings of the study made by R. K. Eyvindson, E. O. Heady -- in the U.S.A. -- where they mentioned that the shadow price for capital is frequently higher on small farms than on large farms. For details, see Spatial Sector Programming Model by E. O. Heady, Iowa State University Press, p. 258.

CHAPTER VI

SUPPLY RESPONSE AND IMPACTS OF ALTERNATIVE POLICIES ON LAND USE, PRODUCTION PATTERN AND NET NATIONAL FARM INCOME (NNFI)

The foregoing Chapter has provided the results of optimum organization of the national agricultural plan in terms of its impact on net national farm income, regional land use, and cropping patterns under two alternative technological levels. The empirical results of the previous Chapter suggest that under existing prices rice is highly profitable compared to other crops. Consequently, 90 to 95 percent of the total cultivable land is devoted to rice production in these estimates. Recognizing that the country's objectives in agriculture are not limited to producing more rice but also to maintaining a balance between the production of food grains and commercial crops so as to enable the country to meet both its minimum food demand as well as the foreign exchange earnings needed for economic growth. An effective government price policy could help ensure that balance. However, before resorting to policies for bringing about a readjustment in the existing cropping pattern, it is imperative to have knowledge of supply response. An understanding of supply response provides insight for more effective agricultural policies and corresponding farm program needs. In this Chapter the effects of changes in prices, regional resource availabilities and yield on land use patterns, and income are examined. The optimum plan for a given situation depends exclusively upon resource availability, the existing production possibilities (the input-output coefficients), and the prices employed in the programming. A change in any of these three components of the programming problem affect the optimum mix of crop activities and the value of the program. The specific objectives of this Chapter are to:

(a) estimate the supply response of rice under alternative sets of price assumptions for the two technological levels;

(b) estimate the effects of alternative levels of fertilizer and irrigation water resource availability on optimal land use pattern of Bangladesh, and

(c) estimate the effect of alternative sets of yield assumptions at Technology-II on the production pattern.

These policy evaluations were intended to serve two purposes:

(i) to help estimate the performance of Bangladesh agriculture under alternative sets of government policies and constraints, and

(ii) to help examine government policies and to provide sufficient information for the formulation of new policies consistent with national economic goals.

A. Supply Response of Rice

Rice accounts for about 90 percent of the total cultivable land in Bangladesh. In spite of the dominance of rice in the agricultural economy, inadequate knowledge about the supply response of this crop has hampered the formulation of sound national agricultural price and marketing programs consistent with economic goals. This is especially significant in a country like Bangladesh, where efforts to promote agricultural growth by introducing new technology has affected the crop enterprise. Moreover, knowledge of supply response enters into a number of policy calculations including price support levels, buffer stock programs, input subsidies, and food grain imports.

Because rice is linked with all these policy questions and is crucially important in determining the production and land use pattern of all other crops, the national supply response of rice was estimated (in this section of the Chapter) assuming the two technological levels specified earlier. It is expected that these will provide the government knowledge for efficient guidance of adjustment in agriculture in four different ways: (i) by assisting the government in formulating an effective agricultural price policy and marketing program consistent with national goals; (ii) by providing policy makers with better insights to prospective changes in agriculture and corresponding farm programs needs; (iii) by enabling government to plan the best use of its resources; to realize greater incomes, and help farm input supply agencies to more accurately predict the demand for their products, and lastly, (iv) by aiding agriculture to better adopt to market demand conditions, changing resource supplies, and new technologies.

B. Analytical Procedure

Variable price programming was used to estimate the supply response for rice. Since the production possibility curve employed in L.P. is represented by a series of linear segments, adjustments to price involve a series of discrete shifts in production plans. In other words, one plan will be stable over a range of prices. However, a discrete shift between plans will occur at a critical price level at which it is profitable to shift resources between activities. A change in price alters the value of the objective function and the slope of the iso-price line. A price change does not, of course, alter the feasible region.

The basic results in the foregoing Chapter were based on a government fixed price of rice per maund. In order to determine the supply response of rice, however, a price range is selected between a high and a low level.

The high price is assumed to be 30 percent higher than the existing price of Rs. 1.61 per lb. and the low price was based on the average of four years price (1966-69) when economy was more stable and free from inflationary spiral. For Plan II, the assumed low price was further reduced to the level of the 1965-67 average price. In estimating the supply response, however, about eleven different prices for rice -- ranging from a low price of Rs. 0.46 to a very high price of Rs. 2.06 as against the fixed price of Rs. 1.61 per pound of rice, were used. The objective was to locate the optimum farm organization with different relative rice prices under two technological levels.

Optimum Organizations Under Various Price Combinations of Rice Under Tech-I (Plan I) and Tech-II (Plan II)

The impact of variable relative prices of rice assumed in the model were examined with respect to: (i) farmer response to production of rice, as the relative price of rice is increased or decreased; (ii) optimal production patterns of different crops, and (iii) net national farm income (NNFI).

Results of Technology-I (Plan I)

It was observed from the model's results that with the increase of the relative price of rice from Rs. 0.64 to Rs. 2.46 the production of rice increased from 11.42 million tons to 13.24 million tons (Table 6.1). The model result indicates that when the relative price of rice was lowest, the production of other competing crops was highest. On examination of Table 6.1, it appears that when the relative price of rice is set at Rs. 0.64, the model estimates about 20.6 million tons of sugarcane, 0.464 million tons of wheat, and 5.403 million bales of jute. But as the price of rice is raised to Rs. 0.86, production of wheat decreases to 0.136 million tons and jute to 2.543 million bales. Sugarcane and potato production remained constant. When the price of rice was further raised to Rs. 1.23, production of sugarcane decreased from 20.6 million tons to 4.39 million tons, and jute from 2.5 million to 1.669 million bales, whereas rice production increased to 13.18 million tons. The model results show that with successive rises in the price of rice, there is a corresponding increase in rice production while at the same time the relative competitive position of other crops, compared to rice, decreases.

Potato is found to be an extremely profitable crop even at very high prices of rice. Jute and sugarcane appear to be competitive with rice only within the rice price range of Rs. 0.64 to Rs. 0.86. The model results show that an increase in the price of rice beyond Rs. 1.23 would hardly provide any production gain. As the price of rice was raised from Rs. 1.23 to Rs. 2.46, production increased from 13.18

Table 6.1. Results of Variable Rice Price Programming Under Technology-I in Bangladesh

Plan Numbers	Activities					Rice Price Range (in Rs.)			NNFI at minimum price
	Rice	Wheat	Sugarcane	Potato	Jute	Min		Max	
P_1	x_1	x_2	x_3	x_4	x_5				
P_1	11.42	0.464	20.60	2.133	5.405	.64		.86	15948.87
P_2	12.32	0.136	20.60	2.133	·2.543	.86		1.23	21632.63
P_3	13.18	0.136	4.39	2.133	1.669	1.23		1.38	31987.73
P_4	13.20	0.162	3.63	2.133	1.529	1.38		2.06	36381.319
P_5	13.24	0.162	3.63	2.133	0.948	2.06	to	∞	56330.05

Production - million tons

Jute - million bales

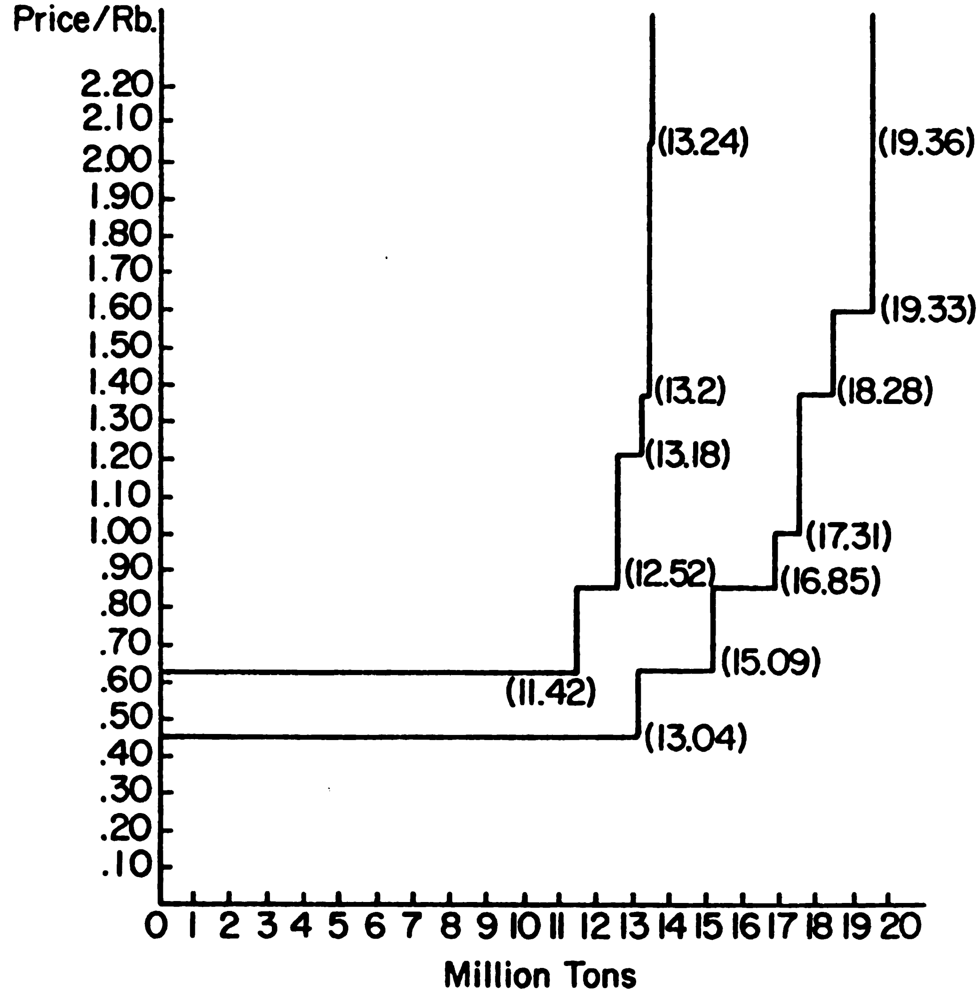
NNFI - Net Farm Income (million Rs.)

million tons to 13.24 million tons, an increase of only 0.3 percent.

The low production response was particularly due to: (1) limited availability of critical production inputs like fertilizer, water, etc., and (ii) constraints on maximum transfer of land possible in between competitive crops, etc. Column 7 of the Table indicates the stability of the optimum plan within the minimum and maximum price range.

The supply response of rice obtained under different assumed prices is shown in graph 1. The graph shows that above the price of Rs. 1.23 the supply response of rice is inelastic. As the price is raised from Rs. 1.23 to Rs. 1.38, production increased by .15 percent; and when price is further increased from Rs. 1.38 to Rs. 2.06 production increased by 0.3 percent. Beyond the price of Rs. 2.06 production remained constant. This indicates that farmers' response elasticity is higher at lower relative rice prices and is lower at higher relative rice prices. These results suggest that the existing support price of Rs. 1.51 per pound of rice fixed by the government is (i) too high, (ii) does not provide any additional rice production, and (iii) is injurious to the production of other competitive crops like sugarcane and jute. In fact, the model suggests that almost the same production of rice could have been achieved if the price had been fixed at Rs. 1.23. If the price were lowered to Rs. 0.86, the production loss of rice would be relatively

Graph I. Supply Response for Rice Under Different Technologies



small -- only 7.0 percent -- compared to a large increase in jute and sugarcane production of 66 percent and 467 percent respectively.

The resulting optimum organization shows that as the relative price of rice is increased from Rs. 0.64 to Rs. Rs. 2.06, the NNFI increased from Rs. 15948.87 million to Rs. 56330.5 million (Table 6.1). This occurrence is particularly due to the fact that rice contributes about three-fourths of the total GDP. Consequently, an increase or decrease of relative rice prices has a large impact on the level of NNFI, though the total rice production remained, more or less, constant.

Results of Technology-II (Plan II)

The model results indicate that the new rice technology exerts a profound influence on both the optimal level of output at current prices and the elasticity of farmer price responses. The two effects are readily discernible from graph 1 where the price of rice is varied parametrically. The graph shows that with the introduction of high yielding rice varieties, the supply curve of rice shift to the right and the supply response at a given price is much more elastic at the higher technological level (Plan II) than at lower technological level (Plan I).[15] The model

[15]For details on technological change, see Chapter I, pages 15-20.

estimates that at rice price of Rs. 0.64, about 15.04 million tons of rice is produced under Plan II as compared to 11.42 million tons produced under Plan I. As the price is raised in Plan II from Rs. 0.46 to 0.64, rice production increased by 15.7 percent. The graph also shows that when the price of rice is raised further from Rs. 0.64 to Rs. 0.86, rice production increases by 11.7 percent (Tech-II) as compared to 7.9 percent increase under Plan I (Tech-I). Thus, the model results show that farmer response to relative price change is higher in Plan II than in Plan I. This happens because farmers' production patterns are more flexible in the long run when they are able to adjust their enterprise combination more accurately. In order to maximize profits the detailed model results of variable rice price programming are presented in Table 6.2. There is an inverse relationship between the rise in rice prices and the production of other competing crops as expected, except for potato. As the rice price is raised successively from Rs. 0.46 to Rs. 2.06 there is a corresponding increase in rice produciton from 13.04 million to 19.36 million tons, and a gradual decline in production of all other competing crops except potato. In this rice price range sugarcane production declined from 66.71 million tons to 4.513 million tons; jute from 12.94 million bales to 0.997 million bales and wheat from 0.943 million tons to 0.695 million tons. Wheat production, however, remained constant within the rice price range between Rs. 0.64

Table 6.2. Results of Variable Rice Price Programming under Technology-II in Bangladesh (Plan II)

Plan Numbers	Activities					Rice Price Range (in Rs.)		NNFI at minimum price
	Rice	Wheat	Sugarcane	Potato	Jute	Min	Max	
P_1	13.04	0.943	66.71	7.057	12.94	.46	.64	22441.67
P_2	15.09	0.695	62.03	7.057	7.699	.64	.86	27753.13
P_3	16.85	0.695	49.73	7.057	4.143	.86	1.01	35618.60
P_4	17.31	0.695	46.17	7.057	3.013	1.01	1.38	41249.86
P_5	18.28	0.695	34.842	7.057	1.5	1.38	1.61	56061.88
P_6	19.33	0.695	4.913	7.057	1.54	1.61	2.06	64465.97
P_7	19.36	0.695	4.513	7.057	0.997	2.06	∞	84939,81

Production - million tons

Jute - million bales
NNFI - in million Rupees

to Rs. 2.06 because of the subsistence constraint that a minimum of .695 million tons wheat has to be produced. Potato production remained stable throughout the price variation plans because of its high profitability.

I. Alternative Policies with Respect to Fertilizer and Irrigation Water Constraints

The preceding section of the Chapter discussed the impact of different assumed relative prices of rice on the (i) supply response of rice and (ii) production of other competing crops. In this section the effect of alternative regional fertilizer and winter irrigation water availabilities on land use pattern and Net National Farm Income (NNFI) were examined under two technological levels. It has been observed that fertilizer and irrigation water availabilities of each region are often altered by government policies affecting land use and production patterns of different crops. The changes in government policy results mainly from (i) high price of production inputs in the international market, (ii) lack of adequate foreign exchange, (iii) national and international economic crises and above all, (iv) lack of adequate information for making policy decision at the appropriate time.

II. Policy Alternatives Considered

The previous analysis of Plan I as discussed in the foregoing Chapter incorporated an average of last three years of actual resource availabilities in each region. In this section the impact of resource expansion on land use patterns and income is considered. Specifically, the effect of additional amounts of fertilizer and irrigation water on land use pattern and net national income is examined. Three sets of irrigation water and fertilizer availabilities, representing three alternative government farm policies are analyzed. The three policy alternatives (PA) are:

(1) PA-I: 10 percent increase of fertilizer and 20 percent increase irrigation water availability in all four regions;

(2) PA-II: 20 percent increase of fertilizer and 10 percent increase of water availability;

(3) PA-III: 30 percent increase of fertilizer and 20 percent increase of irrigation water availability.

In case of Plan II, the implications of both reduction and expansion of resource availabilities from that of projected resource availabilities considered in the basic model (see Chapter III) were examined. Five different resource combinations of fertilizers and irrigation water representing five alternative government policies were analyzed to determine their effects on both (a) land use pattern and (b) net national farm income (NNFI), They were:

PA-IV: reduction of 50 percent fertilizer in all regions and 50 percent winter irrigation water availability in NW and SW regions.

PA-V: decrease of 30 percent fertilizer from the basic results and 40 percent decrease of winter irrigation water availability in NW and SW regions.

PA-VI: decrease of 10 percent fertilizer availability in all regions and 20 percent decrease of irrigation water availability in NW and SW regions.

PA-VII: increase of 20 percent fertilizer availability in all regions and 15 percent increase in winter irrigation water in NW and SW regions.

PA-VIII: increase of 30 percent fertilizer availability in all regions and 25 percent increase in winter irrigation water in NW and SW regions.

In the policy alternatives the availabilities of winter irrigation water is varied only. Because, winter irrigation is primarily dependent on mechanical devices such as power pumps, tube-wells, etc., whose availability, in turn, depends on various exogenous variables like foreign assistance, imported spare parts, and fuel, etc. Moreover,

while considering the variation of winter irrigation water, only the NW and SW regions were considered for the analysis as the plan envisaged that due to availability of adequate ground water, most of the increase in winter irrigation in the forthcoming decade would take place in those two regions.[16] Credit was not assumed as a constraint and optimum credit requirements for each policy alternative were estimated from the model.

III. Analytical Procedure

The variable resource programming is used to examine the impact of alternative regional resource availabilities on the land use pattern and net national farm income (NNFI).

IV. The Land Use Pattern and Net National Farm Income Under Alternative Policies (PA) In Tech-I (Plan I) and Tech-II (Plan II)

(a) Plan I

In this section the impact of three alternative resource combinations of fertilizer and irrigation water on land use pattern of different crops and net national farm income (NNFI) is presented. The model results indicate that as the resource availability increases beyond PAI, the

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[16]For details, see Soil Reconnaissance Survey of Bangladesh-FAO/UNDP. Soil Survey Reports, Ministry of Agriculture, 1970-75.

area under food grains decreases, though the percentage of decline was very insignificant (Table 6.3). However, the total area under commercial crops increased from 28253 thousand acres in the basic run of Plan I to 28936 thousand acres in PAI, 29205 thousand acres in PAII and 30290 thousand acres in PAIII (Table 6.3). One noticeable feature of resource expansion is that as the resource level is expanded, the area under local varieties either remained constant or decreased in each subsequent policy alternative situations, while the area under HYV increased gradually. With the expansion of resources, the area under local Aus and local T. Aman remained constant at 7557 thousand acres and 6565 thousand acres respectively in all policy runs. The local B. Aman do not usually compete for sophisticated production inputs like fertilizer and irrigation water. Consequently, the expansion or contraction of resource availabilities do not affect its cultivation. The results show that its area increased to a maximum limit of 5490 thousand acres in PAI and then remained constant in later phases of development (Table 6.3). The total area under local Boro decreased consistently from 2898 thousand acres in the basic run to 2563 thousand acres in PAI, 2418 thousand acres in PAII and 2318 thousand acres in PAIII as the resource level expanded. The acreage released from local Boro variety was allocated to HYV cultivation. Consequently,

Table 6.3. Comparative Statement of Optimum Land Use Pattern for Different Agricultural Crops Under Alternative Resource Combinations (Fertilizer and Water) Assumptions in Technology-I (Plan-I) in Bangladesh (000 acres)

Crops / Alternative policies	Basic Result of Plan I	PAI	Percentage of increase(+) or decrease(-)	PAII	Percentage of increase(+) or decrease (-)	PAIII	Percentage of increase(+) of decrease(-)
A) Food grains	1	2	3	4	5	6	7
Aus local	7557	7557	-	7557	-	7557	-
Aus HYV	252	486	(+) 93	654	(+) 160	716	(+) 184
B. Aman local	5471	5490	(+) 0.3	5490	(+) 0.3	5490	(+) 0.3
T. Aman local	6565	6565	-	6565	-	6565	-
T. Aman HYV	1613	1637	(+) 1.5	1637	(+) 1.5	1637	(+) 1.5
Boro local	2898	2563	(-) 11.6	2418	(-) 16.6	2319	(-) 20
Boro HYV	2091	2303	(+) 10	2420	(+) 16	2605	(+) 24
Wheat	477	366	(-) 23	129	(-) 73	-	-
Total food grains	26924	26967	(+) .16	26870	(-) .2	26889	(-) 13
B) Commercial crops							
Sugarcane	224	205	(-) 8.4	252	(+) 1.2	252	1.2
Potato	550	550		550		550	
Jute	555	1214	(+) 119	1533	(+) 176	2599	(+) 368
Total	1329	1969	(+) 48	2335	(+) 76	3401	(+) 156
Total National (A+B)	28253	28936	(+) 2.4	29205	(+) 3.4	30290	(+) 7.2
NNFI (in million Rs)	43127.99	45730.57	(+) 6.0	46697.08	(+) 8.3	47498.27	(+) 10
Optimum credit requirement (million Rs.)	6830.0	7116.84		7257.57		7345.22	

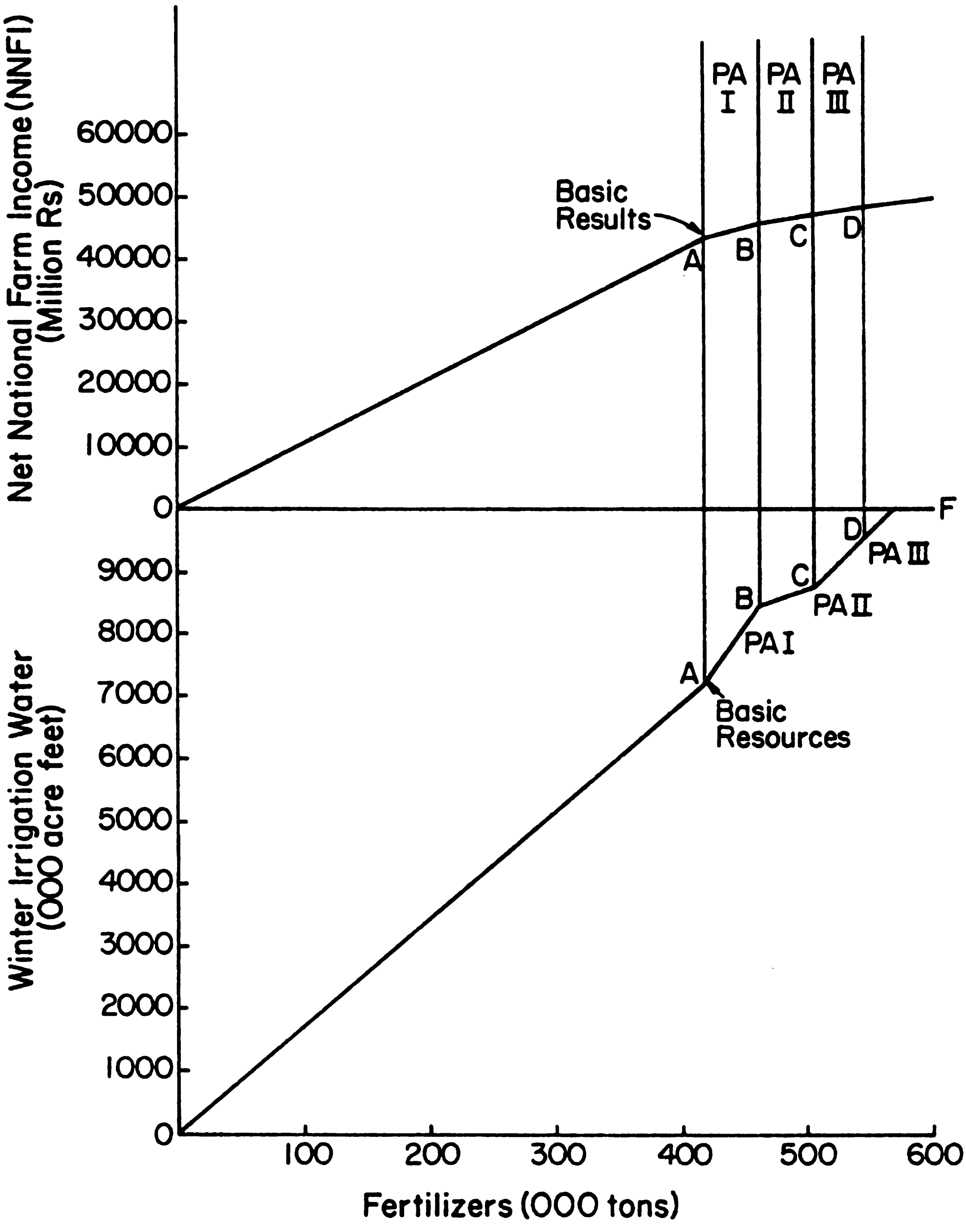
the total area under Boro HYV increased consistently from 2091 thousand acres in the basic run to 2303 thousand acres in PAI, 2420 thousand acres in PAII and 2605 thousand acres in PAIII with gradual increases of resource level. Similarly, the Aus HYV increased from 252 thousand acres in the basic run to 716 thousand acres in PAIII and T. Aman HYV increased from 1613 thousand acres to 1637 thousand acres in PAIII. Wheat appears to be an unprofitable crop and its competitive position with respect to other crops began to decline gradually as the resource levels increased. Though 477 thousand acres of wheat was estimated in the basic run, it did not enter into the optimum plan for PAIII (Table 6.3).

Among commercial crops, potato was found to be an extremely profitable crop and its area increased from 231 thousand acres in the existing situation to a maximum acreage limit of 550 thousand acres in the basic run. The area remained constant throughout the three policy runs. Jute, on the other hand, was found to be a relatively unprofitable crop, though its area increased from 1214 thousand acres in PAI to 3401 thousand acres in PAIII as against 555 thousand acres in the basic run of Plan I (Table 6.3). Most of the expansion in the jute area took place in PAIII only when most of the crops competing with jute already reached their maximum acreage limits. Similar to jute, sugarcane is not a very profitable crop, though its area increased from 224 thousand acres in the basic run to 252 thousand acres in PAIII, which is 38 percent below the actual acreage of 400 thousand acres.

The gain in Net National Farm Income (NNFI) for situation PAI to PAIII ranged from 6.0 percent to 10 percent (Table 6.3). A graphic representation of the magnitude of increase of NNFI as the resource levels are increased is shown in Graph II. The horizontal axis refers to a quantum of fertilizers between 0 and 600 thousand tons, while the vertical axis records at different points the winter irrigation water that was varied and the Net National Farm Income. Using the coordinates fertilizer and water, it is possible to locate the points in Graph II which correspond to results of each policy alternative (PA) shown in Table 6.3. In Graph II, OA represent the combination of fertilizer and water used in the basic run. Similarly, B, C, and D correspond to the PAI, PAII and PAIII with increased amounts of irrigation water and fertilizers. Since the present analysis is dealing with linear relations, it is possible to plot the points O, A, B, C, D by straight lines to indicate the water and fertilizer necessary for maximum income in three alternative policies. Any water-fertilizer combination lying above the line OABCD has the same optimum plan as the corresponding points on OABCD, except that surplus irrigation water will be allocated to disposal. The lines

AA', BB', CC' and DD' provide the basic result including three critical plans representing three policy alternatives which show income changes as the resource level increases. The fertilizer income graph is constructed by fixing irrigation water at different levels. Graph II shows that as the resource level increases the magnitude of increase of NNFI diminishes (indicated by slope of the graph). The net return per maund of fertilizer and per acre feet of irrigation water increased up to a basic result then decreased consistently as the resource level is increased further in PAI to PAIII. The model also estimated the optimum credit requirements for each policy alternative situation. About Rs. 7117 million credit is required for PAI, Rs. 7258 million for PAII and Rs. 7344 million for PAIII (Table 6.3).

Table 6.4 presents the MVP of farm resources under various levels of resource combinations assumed in three different policy alternatives. The MVP's of summer land in all regions were zero, suggesting that summer lands were not a binding constraint. As fertilizer resource levels increased gradually, their respective MVP's declined as expected. On the other hand, the MVP of other resources, which were not varied such as land and labor, etc., either remained constant or increased consistently as more fertilizer was obtained. The MVP of August labor rose from Rs. 6.37 in PAI to Rs. 34.36 in PAIII. The MVP of winter land in the SW region increased from Rs. 674 in PAI to



Graph II. The Impact of Resource Expansion on Net National Farm Income (NNFI)

Table 6.4. Optimum Credit Requirement and Marginal Value Product of Resources Under Alternative Policy Alternatives in Plan I (Tech-I) in Bangladesh (in Rupees)

Resource constrsints	Policy alternatives PA-I	PA-II	PA-III
1. Land (in acres/Rs.)			
CN Summer land	0	0	0
CN Winter land	0	0	0
EST Summer land	0	0	0
EST Winter land	1434	1434	1434
NW Summer land	0	0	0
NW Winter land	1756	1756	1756
SW Summer land	0	0	0
SW Winter land	674	1001	1756
2. Family labor (per man-days)			
January labor	0	0	0
.	0	0	0
Augûst labor	6.37	8.0	34.36
.	0	0	0
Decémber labor	0	0	0
3. Hired labor			
January labor	0	0	0
.	0	0	0
Augûst labor	0	0	26.36
:			
December labor	0	0	0
4. Fertilizers (per maund/Rs)			
Central	1866	1737	0
Eastern	0	0	0
Northwest	0	0	0
Southwest	2516	1757	0
5. Irrigation water (per acre feet/Rs)			
CN Summer	0	0	0
CN Winter	278	368	1591
EST Summer	0	0	0
EST Winter	0	0	0
NW Summer	0	0	0
NW Winter	866	866	866
SW Summer	0	0	0
SW Winter	0	230	764
6. Bullock power (per days/Rs)			
Central	0	0	0
Eastern	0	0	0
Northwest	0	0	0
Southwest	0	0	0
7. Credit (optimum requirement) (million rupees)	7116.84	7257.57	7345.22

Rs. 1756 in PAIII. The winter irrigation water of the CN region was not varied in any policy situation. Consequently, its MVP rose gradually from Rs. 278 in PAI to Rs. 1591 in PAIII. However, it was found that the MVP of winter irrigation water in the NW and the SW regions either remained constant or increased even with the expansion of resource levels. This happened because fertilizer and water are complementary inputs and there is some specified production relationship existing between them. Unless both resources are increased proportionately, as per their specified relationship, one would expect that the MVP of particular resource would increase which has proportionately less of it and vice-versa. In the present policy alternative situations the total fertilizer availabilities increased about two times than that of irrigation water in the NW and SW regions. Consequently, as the fertilizer level is varied the demand for water is also increased proportionally in those regions, which, in turn, increases its MVP.

Results of Plan II

The model results obtained for Plan II were similar to that of Plan I. As the resource levels (fertilizer and irrigation water) increased, the total area under food grains rose from 19548 thousand acres in PAIV to 25957 thousand acres in PAVII as against 25510 thousand acres in the basic run. The result shows that the area under local rice varieties either remained constant or decreased gradually as the resource levels were relaxed (Table 6.5). The area under Aus local remained constant at 6141 thousand acres, local B-Aman at 4023 thousand acres and T. Aman local at 4355 thousand acres throughout the policy runs. However, the area of local Boro declined from 1109 thousand acres in PAIV to 929 thousand acres in PAVII, whereas Boro HYV area rose from 2608 thousand acres in PAIV as the resource levels were increased gradually (Table 6.5). The total area under HYV Aus and Aman increased from 156 thousand acres and 1156 thousand acres in PAIV to 1287 thousand and 5648 thousand acres in PAVIII respectively. Wheat was not found to be a profitable crop, consequently, did not enter into optimal Plan II.

As regards commercial crops, jute and sugarcane were found to be relatively unprofitable compared to rice and potato. Jute did not enter into the initial three policy alternative situations where the resource levels were reduced from the basic model. Jute, however, entered into the optimal solution only when resource levels were substantially increased (in PAVII and PAVIII) and when most of the food crops already reached their maximum acreage limits (Table 6.5). Similarly, sugarcane did not find its place in the initial two policy situations and entered into optimal solution from PAVI onwards.

Table 6.5. Comparative Statement of Optimum Land Use Pattern for Different Agricultural Crops Under Alternative Resource Combination (Fertilizer and Water) ssumptions in Technology II (000 acres)

Crops	Basic model (Tech-II)	PA-IV	Percentage of increase (+) decrease (-)	PA-V	Percentage of increase (+) decrease (-)	PA-VI	Percentage of increase (+) decrease (-)	PA-VII	Percentage of increase (+) decrease (-)	PA-VIII	Percentage of increase (+) decrease (-)
A) Food grains											
Aus local	6141	6141	-	6141	-	6141	- -	6141	-	6141	-
Aus HYV	821	156	(-) 81	469	(-) 43	795	(-) 3	1145	(+) 39	1287	(+) 57
Aman BR	4023	4023	-	4023	-	4022	-	4022	-	4022	-
Aman TR	4356	4355	-	4355	-	4355	-	4355	-	4355	-
Aman HYV	5525	1156	(-) 79	2893	(-) 48	4669	(-) 15	5648	(+) 2	5648	(+) 2
Boro local	821	1109	(+) 35	1109	(+) 35	1109	(+) 35	1028	(+) 25	929	(+) 13
Boro HYV	3535	2608	(-) 26	3054	(-) 14	3295	(-) 7	3601	(+) 2	3602	(+) 2
Wheat	-	-		-		-		-		-	
Total food grains	25510	19548	(-) 23	22044	(-) 14	24387	(-) 4	25940	(+) 2	25957	(+) 2
B) Commercial crops											
Sugarcane	267	-	-	-		378	(+) 42	1435	(+) 437	1529	(+) 473
Potato	1633	1634	-	1634	-	1634	-	1504	(-) 8	1476	(+) 10
Jute	596	-	-	-	-	-		2136	(+) 258	2150	(+) 261
Total	2496	1634	(-) 35	1634	(-) 35	2012	(-) 19	5075	(+) 103	5155	(+) 107
Total national (A+B)	28006	21182	(-) 24	23678	(-) 15	26399	(-) 6	31015	(+) 11	31112	(+) 11
NNFI (million rupees)	65465.97	43069.27	(-) 34	52774.58	(+) 19	62353.84	(-) 5	71279.99	(+) 9.0	71722.78	(+) 10
Optimum credit requirement (million rupees)		5885.09		6900.99		7925.58		9433.17		9490.87	

The NNFI increased from Rs. 43069 million in PAIV to Rs. 71722.79 million in PAVIII. The optimal credit requirements enhanced from Rs. 5886 million in PAVI to Rs. 9490.87 in PAVIII, as the resource levels were increased gradually.

Table 6.6 presents the MVP of resources under the five alternative resource restraints. As the resource level is reduced in the initial policy situations from PAIV to PAVI land became surplus in all four regions indicated by their zero shadow price. But when the resource levels were increased from PAVIII onwards it became a limiting resource in all regions as indicated by their positive shadow price. The effects of changing the levels of fertilizer and irrigation water availability on shadow prices of various resources can also be observed in Table 6.6. As the fertilizer constraints were relaxed, its MVP decreased in all regions whereas those resources which were not changed such as land and water in the CN and EST regions, their respective MVP's increased due to increased demand.

C. Implications of Alternative Yield Assumptions on Production Pattern and NNFI in Plan II

In Chapter IV of this study the yield of different crops, particularly HYV varieties, for higher technological levels were estimated from the data received from the experimental stations. Numerous studies indicate that there are

Table 6.6. Optimum Credit Requirement and Marginal Value Product of Resources Under Alternative Policy Alternatives in Plan II (Tech-II) in Bangladesh

Constraints (Policy Alternatives)	PA-IV	PA-V	PA-VI	PA-VII	PA-VIII
1. Land (acre/Rs)					
CN Summer land	0	0	0	0	982
CN Winter land	0	0	0	0	0
EST Summer	0	0	0	531	531
EST Winter	0	0	0	0	0
NW Summer	0	0	0	531	531
NW Winter	0	0	0	1354	3632
SW Summer	0	0	0	0	0
SW Winter	0	0	0	4081	4668
2. Family labor (per man-day/Rs)					
January labor	0	0	0	0	0
.	0	0	0	0	0
August labor	0	0	0	0	0
.	0	0	0	0	0
December labor	0	0	0	0	0
3. Hired labor(man-days/Rs)					
January labor	0	0	0	0	0
.	0	0	0	0	0
August labor	0	0	0	0	0
.	0	0	0	0	0
December labor	0	0	0	0	0
4. Fertilizers (per maund/Rs)					
Central	1623	1489	1489	1407	0
Eastern	1511	1489	1489	0	0
Northwest	1489	1489	1406	0	0
Southwest	1489	1489	1489	190	0
5. Irrigation water (per acre feet/Rs)					
CN Summer	0	0	0	192	2473
CN Winter	0	159	159	258	1929
EST Summer	0	0	0	0	0
EST Winter	0	27	27	1945	1945
NW Summer	0	0	0	0	0
NW Winter	150	150	243	1205	377
SW Summer	0	0	0	0	0
SW Winter	25	25	25	0	0
6. Bullock power (per day/Rs)					
Central	0	0	0	0	0
Eastern	0	0	0	0	0
Northwest	0	0	0	0	0
Southwest	0	0	0	0	0
7. Credit (in million Rs.) (optimum requirement)	5885	6900.99	7925.58	9433.17	9490.87

serious constraints responsible for the gap between potential yield demonstrated under experimental conditions, and actual yield obtained in farmers' plots. The important reasons for this yield difference are[17] generally: (i) potential yields of the modern varieties are not fully expressed under poor environmental conditions in which farmers operate; (ii) supply of certain inputs is less than needed to achieve the economically optimum output; (iii) farmers strive for economic optimum[18], not maximum yield, etc. Considering the importance of these reasonings, in this section, alternative yield combinations for different crops were used to explore its impact on the production pattern and net national farm income. In order to determine these effects, five alternative levels of yield per acre, low I, low II, medium I, medium II and high are assumed (see Table 6.7).

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[17]Herdt and T. H. Wickham - "Exploring the gap between potential and actual yield in the Philippines". op. cit., p. 165-180.

[18]Production theory shows that, because of diminishing returns, profits are always lower at maximum yield than at some lower levels of input use. In certain cases, farmers hesitate to use profit maximizing levels of inputs because the greater cost of inputs might leave them badly in debt if the crop failed.

Table 6.7. Alternative Yield Assumptions for Sensitivity Analysis Under Technology II (Plan II) (in maund)

Alternative yield assumptions / Crops	PA-I Low I no increase	PA-II Low II 5% increase	PA-III Medium I 10% increase	PA-IV Medium II 28% increase	PA-V High 35% increase
Aus local	8.6[1]				
Aus HYV	30.3	32.0	33.3	36.4	41
B. Aman local	9.2[1]				
T. Aman local	12.5	13.0	13.7	15.0	17
T. Aman HYV	25.5	26.8	28.0	30.6	34.4
Boro local	15.0	15.7	16.5	18.0	20
Boro HYV	33.5	35.0	36.8	40.0	45
Wheat	9.2	9.7	10.0	11.0	12.4
Sugarcane	439	461	483	527	593
Potato	105	110	115.5	126	141
Jute	13.78	14.5	15.0	16.6	18.6

[1] No yield increase is assumed for local Aus and local B. Aman as farmers hardly use any improved farm practices for the cultivation of these two crops.

[2] Low I is equivalent to actual average yield obtained during 1972-75. Low II indicates 5% increase in yield over Low I. Similarly, others hold the same explanation.

(I) Low I -- represents existing yield levels (average of last five years used for Plan I).

(II) Low II --represents five percent increases in yield from the existing yield level.

(III) Medium I -- represents ten percent increase in yield from the existing one.

(IV) Medium II -- represents 20 percent increase in yield, from the existing situation.

(V) High -- represents 35 percent increase in yield from the existing situation.

No change in yields of local Aus and B. Aman are made as farmers do not use any improved farm practices for cultivation of these two crops.

Table 6.8 presents the production patterns of different crops with changed levels of yield. The Table shows that under low I assumption about 16229 thousand tons of rice is estimated in Plan II as against 19330 thousand tons in basic run. The resultant increase is mainly obtained from three sources: (1) relaxation of acreage constraints under each crop on the basis of FAO/UNDP Soil Survey; (2) projected increase in regional resource availabilities in 1985 and (3) substitution of HYV for local varieties as more fertilizer and irrigation water are available. Under high yield assumption (V), the rice production enhanced to 20530 thousand tons as compared to 16229 tons under

Table 6.8. Production of Different Crops Under Alternative Assumptions in Plan II (production - 000 tons) (jute - 000 bales)

	PA-I	PA-II	PA-III	PA-IV	PA-V
Rice	16229	16830	17390	18690	20530
Sugarcane	3982	4690	5390	6790	8900
Potato	6332	6634	6968	7602	8508
Jute	1063	1118	1157	1280	1434
NNFI (million Rs)	54509.96	57117.12	59538.48	654420.00	73334.60

assumption I in Plan II. The overall tendency of optimum organization is that as the yield levels of different crops is raised, production increased gradually keeping the overall crop mix ratio the same throughout. In the optimum plan, there is an intense competition for land and fertilizer between Irri-Aus rice and jute in the Aus season. Even in high yield assumption, Irri-Aus is likely to replace substantially the jute crop. Jute production has declined to 1434 thousand bales under assumption V as compared to 1500 thousand bales under basic results.

The NNFI increased from Rs. 54509.96 million under assumption I to Rs. 73334.60 million under assumption V.

CHAPTER VII

SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

This Chapter is comprised of seven sections. In Section I a summary of the background of the study and the methodology employed is presented. In Section II, limitations of the analytical procedure are described. In Section III, a brief indication of expected land use patterns and resource use under transitional (existing) technology and with technological change are provided. Supply response of rice under two technological levels with respect to existing government pricing policy is summarized in Section IV. Expected changes in land use and patterns of different crops resulting from alternative regional resource availabilities and the changes in yields of different crops under alternative assumptions are described in Sections V and VI respectively. The last section indicates directions for further research.

I. Summaries of Background and Methodology

The economy of Bangladesh is dominated by agriculture. The agricultural sector is the largest source of income and employment. Among crops, rice dominates accounting for 90 percent of the total cultivable land. It contributes about 70 percent of the total G.D.P. Jute, sugarcane, and potatoes are the important cash crops. However, jute is the principal export crop, earning about 80 percent of the total foreign exchange.

Unfortunately for the people of Bangladesh the growth of this sector has been very slow during the last decade. The important reasons for stagnation of the agricultural sector can be divided into three broad categories: (1) institutional; (2) informational and (3) market imperfection. The institutional problems are of two kinds: (i) the misallocation of productive resources (e.g., fertilizers, water and pesticides, etc.) among its alternative uses such as between crops and regions. Most of these productive inputs are distributed through government agencies. But the criterion governing the distribution of these inputs among crops and regions, are not based on an economic rationale. Consequently, the growing of a particular crop in a region, as well as the distribution of production inputs among alternative crops have primarily been a function of administrative and political choices; (ii) the inefficient utilization of productive resources -- results mainly from imperfect incentive policies built into the system. For instance, the present emphasis of the government policy seems to be on the number of pumps placed in the field rather than on an increase in the area irrigated per pump. The present system has generated a tendency to keep low the area irrigated.(53). Informational problem emanates from two sources which are (i) lack of knowledge on the part of the resource owner (government input distributing agencies) to prevent resources moving from low to highly profitable crops, and (ii) inadequate technical information regarding soils, climate, topography and hydrology of each region that is important for optimal use of resources. The market imperfection results mainly from an inhibition of free play of market forces due to government laws and regulations both in product and factor markets.

Recently, the FAO/UNDP Soil Survey project has completed a detailed survey of about 70 percent of the total land in Bangladesh. The survey provided an improved basis for the allocation of land among its alternative agricultural and nonagricultural uses and among specified areas or regions where particular crops are suitable. In addition, sufficient information has been obtained for the remainder of the country through aerial photo interpretation and exploratory surveys to extrapolate the results of the survey to the entire area of Bangladesh. The survey not only provides information on soil conditions, but also on present land use and on physical factors limiting agricultural development, such as depth of natural flooding, surface relief, erosion hazards, etc. The most important finding was that about 11 million acres out of a total of 22.5 million acres of agricultural land are estimated suitable for HYV varieties. The entire area of Bangladesh was brought under the scope of this investigation. The analysis is of two technological levels of farming. These technological levels are defined as: (i) transitional agriculture (Tech-I) -- the existing system of farm operation, regarded as technological level-1. This level uses relatively small amounts of improved inputs and modern technology; (ii) improved agriculture (Tech-II) -- this level of technology is defined by input-output coefficients which have changed significantly from their existing values and include substantial increases in the use of HYV Aman and increased amounts of chemical fertilizer. In this study the physical and economic characteristics were examined on a regional basis. These four regions are: (i) Central (CN); (ii) Eastern (EST); (iii) Northwest (NW); and (iv) Southwest (SW).

Linear programming methodology was used to determine the optimal enterprise combinations and land use patterns of different crops. The entire nation was used as a unit of optimization. Each region was considered to be homogenous with regard to climate, farm size, and resource distribution. The farmer was assumed to maximize monetary profit from the allocation of land to various crops subject to a set of regional and national constraints. The constraints were (i) regional land constraints; (ii) variable inputs constraints (e.g., water, fertilizer, labor); (iii) financial constraints, and (iv) maximum acreage constraints for each crop. The activities in the model are: (i) regional production activities; (ii) labor hiring activities; (iii) subsistence consumption activities; (iv) selling activities; (v) buying activities; and (vi) financial activities.

The analysis was carried out to represent two plan periods viz Plan I (1976) and Plan II (1985). In Plan I the net returns were optimized with existing national and regional resource availabilities and existing maximum crop acreage constraints. These constraints were determined on the basis of an average of the last three years. In Plan II the net returns were optimized using higher levels of agricultural technology, with limits on maximum acreages suitable for different crops, as identified by the FAO/UNDP soil reconnaissance survey, and with regional resource constraints based on projections for 1985. On the basis of the results of the two analyses the impacts of various government policies and alternative technological constraints on land use and production patterns were investigated focusing on three problem areas: supply response for rice, fertilizer and water availabilities, and yield levels. (i) Supply response for rice was estimated for the two technological levels under alternative government price policies; (ii) The effects of alternative regional fertilizer and irrigation water resource availabilities were analyzed, both for Plan I and II (iii) The effects on farm organization in Plan II of five alternative yield levels of different crops were explored.

II. Limitations of the Analytical Procedure

Recognition of the following limitations is required for the proper interpretation of the calculations of this study:

(1) The "representative farm" was developed to represent average production situations with respect to resource ownership positions, input-output relationships, etc. The "representative farm" thus, cannot be taken to represent all varieties of farms located in the country. In addition, the input-output coefficients for representative farms were developed by synthesizing secondary data available from diverse sources such as experimental findings, farm surveys, and macro-data collected by government agencies.

(2) The fertilizer input requirement and yield coefficients for different crops, particularly HYV varieties in Plan II, were estimated from secondary data received from the Soil Fertility Testing Institute and the Comilla Academy. Detailed information regarding the

trials for each crop, design of the experiments, and the extent of the total trials conducted on farmers' plots were not accurately known. Due to the lack of this information, the yield and fertilizer input coefficients for different crops used in this study may differ from the actual situation, depending on the magnitude of error present in the data. The input-output relationships are considered to be single valued. In sensitivity tests only the effects of changes in crop yields, variation of rice prices and changes in fertilizer and irrigation water resources were analyzed. All other crop prices, input-output coefficients and resources were held constant throughout.

(3) The model is constructed under static economic assumptions. In this static framework reference is not made to the management function, nor to interrelationships between the firm and household. The model assumes profit maximization is the only motivation for production. The only management decisions beyond profit maximization considered in the model involve the choice among different enterprises acceptable to the manager.

(4) The potential increase in agricultural production envisaged in the analysis is contingent upon the performance of the agricultural institutions created to ensure the supply of modern inputs, credit facilities and extension services to farmers. Not only do these

institutions or inputs have their own independent impact on production, but also there are important complementarities among them. Irrigation, for example, enhances not only the profitability of improved seeds but also increases the return to fertilizer. The unavailability of these inputs, as per projected requirements due to domestic or international politics or economic crisis would jeopardize production gains.

(5) The lack of risk and uncertainty considerations is another characteristic of the static economic assumption under which the model is constructed. One of the important characteristics of small scale farms in Bangladesh is that they are in transition from subsistence to commercial farming (shifting from local to HYV). But the cultivation of HYV is entirely dependent on the timely availability of sophisticated production inputs like fertilizer, water and pesticides, etc. Thus, a substantial element of risk is involved in the cultivation of HYV varieties as the supply of these inputs is often quite unpredictable due to political and economic reasons. This uncertainty makes the situation of the small holder quite vulnerable, as they have less flexibility to diversify their enterprise combination in order to minimize their expected income loss.

(6) The model recognizes only one category of land suitable for a particular crop in each region. In fact, there are important elements of regional diversity with respect to topography and soil characteristics. Even within each region there are small natural sub-regions with distinctive physiographic, hydrological and soil characteristics. The land use patterns in Bangladesh is preponderately determined by these different soil characteristics, and thereby provides a distinctive combination of development opportunities and physical constraints.

III. The Optimum Land Use and Production Pattern and Its Impact on Net National Farm Income

A. Results for Plan I

(i) In Plan I, showing optimal allocation of resources, food grains account for 95 percent of the total cultivated area, as against 90 percent in the existing situation (i.e., an average of 1972-75). The total area under food grains in the Central (CN), Eastern (EST), and Southwest (SW) regions registered an increase of 37 percent, 7 percent, and 15 percent respectively over the existing situations. The resultant increase of area under food grains in the optimal plan is due to the higher relative profitability of food grains, as compared to commercial crops. The net national farm income increased from Rs. 38,783 million in the existing plan to Rs. 43,128 million in the optimal plan. The increase in income obtained in the model (Plan I) is largely due to: (i) increased level of adoption of HYV varieties, (ii) increased regional specialization in crop production, and (iii) efficient use of production inputs among competitive crop enterprises (e.g., jute vs Aus rice).

(ii) The optimal land use pattern from Plan I results in considerable specialization of crops. Out of 11 crops included in the analysis only 7 or 8 crops in each of the regions appeared in the solution. Most of the shift in the cropping patterns was toward the HYV and local improved varieties (LIV) of rice. The total area of HYV and LIV increased from 3.2 million and 1.2 million acres in the existing situation to 3.85 million and 2.89 million acres respectively. The comparative advantage of certain regions in producing particular crops is also evidenced by the concentration of wheat in the Central (CN) region and jute and sugarcane in the Northwest (NW) region.

(iii) The adoption of HYV was not uniform in all regions; it ranged from 20.7 percent increase in acreage over the existing situation in the CN and EST regions to 98 percent increase in the NW region. The latter region has high potential for bringing more area under HYV because of the availability of adequate ground water for irrigation.

(iv) In the analysis the most profitable of the food and cash crops was the potato. In all regions, potatoes tended to replace HYV Boro under irrigated conditions. This adjustment was, however, limited in the model by the crop rotation or acreage constraints. In the optimal plan the total acreage under potato went up to the maximum acreage limit of 550 thousand as compared to 231 thousand acres in the existing situation.

(v) Under given yield and price assumptions, the Aus rice crop has a substantial edge over jute cultivation. In optimal organization jute acreage was drastically reduced to 550 thousand, as against 1950 thousand acres in the existing situation.

B. Basic Results of Plan II

(i) The results of Plan II, which attempt to indicate 1985 conditions have a similar trend as those in Plan I. In Plan II the relative competitive position of rice, compared to other crops, increases with the introduction of new HYV Aman varieties and the extension of existing HYV varieties. The net national farm income was estimated at Rs. 65,465 million, an increase of 50 percent over Plan I. Rice production increased to 19.33 million tons in Plan II as against 13.215 million tons in Plan I.

(ii) The optimum crop plans in all four regions were not diversified, but specialized in the production of two crops, rice and potato, because of their higher relative net returns. The increase in rice cultivation was largely due to: (a) increased adoption of HYV varieties on 6.63 million acres of land which includes 4.6 million acres transferred from local varieties; (b) increased specialization reduced the number of crops from eleven to seven or eight crops in each region; and (c) more efficient use of production resources among competitive crop enterprises, like jute and Aus rice.

(iii) Out of 7.9 million acres identified as suitable for new HYV Aman by FAO/UNDP soil survey, Plan II utilizes 5.5 million of these acres.

(iv) The acreage under commercial crops, especially jute and sugarcane, did not change very much between Plan I and Plan II. The only significant increase in areas under commercial crops between the two technological levels came from potato cultivation which increased dramatically from 0.55 million acres in Plan I to 1.63 million acres in Plan II.

IV. Impact of Alternative Rice Price Policies on Supply Response of Rice in Plan I and Plan II

A. Plan I - Rice Supply Response

(i) Supply response of rice was relatively high within the price range of Rs. .64 and Rs. 1.23. As the rice price rose from Rs. .64 to Rs. 1.23, rice production increased from 11.42 million tons to 13.18 million tons, an increase of 15.4 percent. However, supply response to increases in the relative rice price beyond Rs. 1.23 was very inelastic. Rice production increased by only 0.45 percent if the relative price of rice rose from Rs. 1.23 to Rs. 2.06.

(ii) These results suggest that the existing government support price of Rs. 1.51 per pound of rice may be unnecessarily high and provide little in the way of production incentives. The relatively high support price of rice is also detrimental to production of other competitive crops like jute and sugarcane which have declined substantially in recent years. In fact, it appears that almost the same production level of rice could have been achieved if the price had been lowered to Rs. 1.23 instead of Rs. 1.61. If the price were dropped further to Rs. 0.86 the production loss of rice would be relatively small, only 7 percent, as compared to large increases in the production of jute (66 percent) and sugarcane (467 percent). Even at the very low rice price of Rs. 0.64 per pound, production was estimated

to decline from only 13.18 million tons to 11.42 million tons. These results are a possible explanation of the inflexibility of farmer rice production patterns due to its overwhelming importance as a subsistence crop and its relatively high net returns.

(iii) Changes in relative rice price have a large effect on most of the competitive crops, particularly jute and sugarcane, but has hardly any impact on potato production. Potatoes were found to be highly profitable. They reached the maximum acreage limit, even at high rice prices. Potato production remained constant at 2.13 million tons throughout the rice price range of Rs. 0.64 to Rs. 2.06.

B. Plan II - Rice Supply Response

(i) With the expansion of HYV in Plan II, the supply curve of rice shifts to the right and the supply response at a given price is much more elastic at this higher technological level. In Plan II when the rice price is set at Rs. 0.64, about 15.04 million tons of rice is produced under Plan II, as compared to 11.42 million tons produced in Plan I. As the price of rice was raised further from Rs. 0.64 to Rs. 0.86 rice production was enhanced by 11.7 percent in Plan II, as against 7.9 percent increase in Plan I.

(ii) There is a similar inverse relationship between the increase in rice prices and the production of other competing crops in Plan II as expected, except for potato. As the rice price is raised from Rs. 0.46 to Rs. 1.61 there is corresponding increase of rice production from 13.04 million tons to 19.33 million tons, whereas sugarcane production declines drastically from 66.71 million tons to 4.9 million tons and jute from 12.94 million bales to 1.5 million bales. Variation in rice price, however, hardly produces any adverse impact on potato production, its production remained stable at 7.1 million tons throughout the analysis.

V. Results and Impacts of Alternative Fertilizer and Irrigation Water Policies on Land Use Pattern

Results of Plan I

(i) Expansion of regional resource availabilities of fertilizer and irrigation water tends to have a favorable impact on HYV varieties, while it decreases the area under local varieties in most of the subsequent policy alternatives (PA) studied. In Plan I, when fertilizer and irrigation water was increased by 30 percent, the total area under HYV increased from 8.9 million acres to 9.9 million acres, whereas the area under local varieties decreased from 22.5 million acres to 21.9 million acres.

(ii) Among commercial crops with greater resource availability the potato was found to be a highly profitable crop. Its area increased from 231 thousand acres in actual situation to a maximum acreage limit of 550 thousand acres. Jute and sugarcane, on the other hand, appear to be relatively less profitable because most of the expansion of the jute and sugarcane area took place only when all the food crops in competition with these crops have already reached their maximum acreage limit (Policy Alternative PA III).

(iii) As the fertilizer resource level increased gradually, the respective marginal value products (MVP's) in all regions declined as expected. The MVP's of resources, such as land and labor, increased consistently as more fertilizer was obtained. The MVP of August labor rose from Rs. 6.36 in PA-I to Rs. 34.36 in PA-III. Similarly, the MVP of winter land in the SW region increased from Rs. 674 in PA-I to Rs. 1756 in PA-III.

<u>Results of Plan II</u>

(i) Implications of resource expansion on land use patterns were similar in both Plan I and Plan II. There was a tendency to substitute HYV rice for local varieties as more resources were acquired.

(ii) The competitive position of jute and sugarcane relative to rice and potatoes decreased substantially as the resource levels were reduced from the basic results. Both jute and rice entered into optimal solution only when resource levels were expanded considerably.

(iii) The slope of net national farm income declined as more resources were obtained indicating, as expected, diminishing marginal returns of fertilizer and water.

VI. Results and Implications of Alternative Yield Assumption on Production Pattern in Plan II

(i) Even under the low yield assumption (average yield of 1972-1975), rice appears as the dominant crop. However, under low yield assumption production declined to 16,229 thousand tons, as compared to 19,300 thousand tons under basic results. The decrease in production is mainly due to the low yield assumption. The overall crop acreage remained, more or less, constant in both situations.

(ii) The overall tendency of optimum organization shows that as the yield levels of different crops changed upward, production increased simultaneously, keeping the overall crop mix ratio the same throughout.

(iii) There is an intense competition for land and fertilizer between HYV Aus rice and jute in the Aus season. Even under the high yield assumption Irri-Aus is likely to replace substantially the jute crop. Jute production declined to 1434 thousand bales under assumption V, as compared to 1500 thousand bales under the basic results.

POLICY IMPLICATIONS AND CONCLUSIONS

The important policy implications of this study are as follows:

(i) There is a tremendous scope for extending the areas under all HYV rice varieties, particularly HYV Aman. It appears that about 50 percent of the area under local T. Aman could be replaced by HYV Aman. The research finding that the farmers' profitability increases significantly, as a result of the introduction of HYV Aman, reinforces the possibility of success of a government policy to encourage expansion of areas under this crop. As the existing policies with respect to supply in input packages (e.g., fertilizer, water, etc.) are mainly geared to the Boro season, a similar sort of provision for HYV Aman will necessitate the reorientation of these policies.

(ii) The high profitability in rice production indicates that there is substantial scope for reduction of input subsidies involved in irrigation water, fertilizers, and pesticides without any significant adverse effects on farmers' incentives.

(iii) The existing support price of rice appears high relative to the prices of other competitive crops. Currently, rice support price appears to be fixed at a level where supply response of rice is inelastic. On the other hand, these high levels of rice price have severe detrimental impacts on production incentives for jute, sugarcane, and wheat. The finding of this research indicates that the existing support price for rice could probably be reduced by one third without appreciable adverse effects on rice production. The comparative gain to be received through large increases in production of jute and sugarcane would be much higher than the relative loss to be incurred from the decline in rice production.

(iv) The breakthrough in seed technology for HYV Aus rice has increased considerably the competitive strength of Aus rice relative to jute. With high yield potential of HYV Aus rice, the jute acreage will decline greatly, unless the relative price of jute is adjusted to maintain its competitive position.

From the long run point of view the most viable proposition, of course, lies not on enhancing jute price, but on increasing the productivity of jute. In order to realize this objective, it is necessary to initiate a vigorous research program which would help to increase the productivity through varietal improvement in seed and related production practices.

Further Research

(i) The basic prerequisite for building of any mathematical model for an agriculture sector in a particular country is the availability of sufficient amounts of basic micro-data for various regions or sub-regions. The state of existing data sources in Bangladesh is too inadequate and consequently, serves as a tremendous constraining factor in model building and effective policy making. It is necessary, on the part of the government to accord topmost priority in the collection and compilation of basic farm management production data for different categories of farms and regions.

(ii) Result of the study suggests, in further modeling, that other activities and restrictions should be added to the L.P. model used. These activities would include production activities of different categories of farms and their adjustment to technological change over a period of time. Different restrictions should be placed on off-farm employment opportunities to see which farms would go out of farming; such a restriction should permit full time off-farm employment.

(iii) Research emphasis should be placed equally on economic, physical, and institutional determinants of land use along with supply and demand considerations for farm products and farm inputs. This problem is multidisciplinary in nature and its solution requires concentrated cooperative efforts of different branches of human knowledge connected with agricultural production such as economics, agronomics, soil science, hydrology, etc.

APPENDICES

APPENDIX A

Estimated Per Acre Growing and Harvesting Cost[1/]
for Different Crops Used in the Programming Model
(Technology I - Plan I)

Crops / Items of variable cost	Fertilizers[2/] Qty (Seer)	Fertilizers[2/] Cost (Rs)	Seeds[3/] Qty (Seer)	Seeds[3/] Cost (Rs	Pesticides Qty (Seer)	Pesticides Cost (Rs)	Interest Cost (Rs)	Misc. Cost (in Rs)	Total Variable Cost
1	2		3		4		5	6	7
Aus (local)	5	6.0	40	144		-	30	20	200
Aus (HYV)	50	570	40	60		50	60	30	257
Aman B	-	40	144			-	30	20	194
Aman T	14.5	17	10	60		10	30	20	137
Aman (HYV)	60	68	10	60		40	60	30	258
Boro (local)	17.5	20	40	144		10	30	20	224
Boro (HYV	75	86	10	60		50	60	30	286
Wheat	5	6	40	66		10	30	20	132
Jute	11	13	4	32		5	43	20	116
Potato	100	114	280	255		50	30	30	479
Sugarcane	36.5	42	300	18		5	30	20	115

1/ In estimating the growing and harvesting cost of various crops certain variable cost items such as irrigation cost and hiring labor cost, etc., are not taken into account in this table as these cost items are directly incorporated in the model.

2/ Fertilizer cost was estimated on the basis of NPK ratio of 100:32:10, the actual use of fertilizer in 1972-73.

3/ Seed cost for all crops except for jute assumed 20% higher than market price.

APPENDIX B

Estimated Per Acre Growing and Harvesting Cost for Different Crops Used in the Programming Model (Technology I - Plan II)

Crops / Items of variable cost	Fertilizers[1/] Qty (Seer)	Fertilizers Cost (Tk)	Seeds Qty (Seer)	Seeds Cost (Rs)	Pesticides Qty (Seer)	Pesticides Cost (Rs)	Interest Cost (Rs)	Misc. Cost (in Rs)	Total Variable Cost
	1			2		3	4	5	6
Aus (local)	7.5	12	40	144		-	30	20	206.0
Aus (HYV)	126.5	329	40	144		50	60	30	613.0
Aman B	-		40	144		-	30	20	194.0
Aman T	12	15	10	60		10	30	20	135.0
Aman (HYV)	95	183	10	60		40	60	30	373.0
Boro (local)	40	98	40	144		10	30	20	303.0
Boro (HYV)	126.5	329	10	60		50	60	30	529.0
Wheat	20	31	40	66		10	30	20	157.0
Jute	36.5	56	4	32		5	45	20	158.0
Potato	180	210	280	255		50	60	30	600.0
Sugarcane	55	43	300	18		5	30	20	116.0

[1/] Fertilizer costs were estimated on the basis of actual procurement and distribution of the government (say Rs 42 and Rs 113 per maund of acres and TSP respectively). This means there would be no fertilizer subsidy in 1985.

REFERENCES

1. AHN, C. Y. and I. J. Singh (1972), "Distribution of Farm Incomes Under Alternative Policy Regimes: A Dynamic Analysis of Recent Developments in Southern Brazil (1960-70)," a paper presented at the seminar on Applied Welfare Economics at the Annual Meetings of the American Agricultural Economics Association, Gainesville, Florida, August 21, 1972.

2. ASADUZZMAN, M. and Mohabat Hossain. "Some Aspects of Agricultural Credit in Two Irrigated Areas in Bangladesh," New series No. 18, BIDE, October, 1974.

3. BOSE, S. R., "Trends in Real Income of Rural Poor in East Pakistan, 1949-65," Pakistan Development Review.

4. BUSE, R. C. and D. W. Bromely (1975), Applied Economics Resource Allocation in Rural America, Iowa State Press, p. 100-224.

5. CHARLES, Kennedy, H. P. Thirlwall, March, 1972. Survey in Applied Economics: Technical Progress, <u>The Economics Journal</u>.

6. CHARNES, A. and W. W. Cooper (1959), "Chance Constrained Programming," <u>Management Science</u>, Vol. 6, pp. 73-79.

7. DAY, R. H. (1963), Recursive Programming and Production Response. Amsterdam: North Holland Publishing Company.

8. DAY, R. H. and T. Heidhues (1966), "Towards a Microeconomic Model of Agricultural Production and Development," Farm and Market Workshop Paper No. 6702, Social Systems Research Institute, Universityof Wisconsin, 1966.

9. DAY, R. H. and I. J. Singh (1972), "A Dynamic Microeconometric Model of Agricultural Development," Paper No. 7135, Social Systems Research Institute, University of Wisconsin, March 1972.

10. Department of Agriculture, 1969-70, Accelerated Rice Production Plan in East Pakistan, Government of East Pakistan.

11. Department of Soil Survey, 1970, Soil Survey Reports of Bangladesh.

12. DULOY, John and Roger D. Norton (1971), "A Programming Model of the Agricultural Sector in Mexico: A Development Research Center, IBRD," A paper presented at a Conference on Agricultural Sector Analysis and Programming, Ames, Iowa: Iowa State University, May 1971.

13. East Pakistan, Agricultural Census Organization. Agricultural Census 1960, Government Press 1962.

14. East Pakistan, Bureau of Statistics. Master Survey of Agriculture, 1967-68, Eden Buildings, Dacca.

15. East Pakistan, The Registrar of Cooperative Societies, Agricultural Credit in East Pakistan: A Survey Report, January, 1966.

16. FALCON, W. P. and Carl H. Gotsch, Relative Price Response, Economic Efficiency and Technological Change: A Study of Punjab Agril. in Devel. Policy-II, The Pakistan Experience, Harvard University Press, Cambridge, Mass. 1971, pp. 160-185.

17. GOTSCH, Carl (1971), "A Programming Approach to some Agricultural Policy Problems in West Pakistan," in Studies in Program Planning, H. P. Chenery, ed., Cambridge: Harvard University, 1971.

18. GUNNAR, Mydral. Asian Drama, Part 5, Pantheon, New York, 1968.

19. HABIBULLAH, M., Pattern of Agricultural Unemployment, Bureau of Economic Research, Dacca University, 1962.

20. HAYAMI, Y. and V. W. Ruttan (1970), "Factor Prices and Technical Change in Agricultural Development: The United States and Japan 1880-1960," J.P.E., Vol. 78, No. 5, Sept.-Oct. 1970, pp. 1115-1141.

21. HEADY, E. O. and Chandler, Linear Programming Methods, pp. 225-256. Iowa State University Press, 1969.

22. HEIDHUES, Theodore(1966), "A Recursive Programming Model of Farm Growth in Northern Germany," Journal of Farm Economics, 48: pp. 668-684.

23. HEIDHUES, Theodore (1969), "Recursive Programming in Agricultural Applications," in Carter and Brody (eds.), Input-Output Techniques (in honour of Wassily Leontief), Vol. I: Contributions to Input-Output Analysis, North Holland Publishing Company.

24. HENDERSON, J. M. (1969), "The Utilization of Agricultural Land: A Theoretical and Empirical Inquiry," The Review of Economics and Statistics, Vol. XLI, No. 3 (August, 1959), pp. 242-259.

25. HERDT, R. W. and T. W. Wickham, "Gap Between Potential and Actual Yield," Food Res. Inst. Stud., Vol. XIV, No. 2, 1975.

26. IFTIKAR, Ahmed, The Green Revolution in Bangladesh, A paper presented in a seminar on HYV, April 9-11, 1975, Comilla Academy,Bangladesh.

27. JOHNSON, Glenn L., et al., (1971), A Generalized Simulation Approach to Agricultural Sector Analysis: with Reference to Nigeria, Michigan State University, East Lansing, November, 1971.

28. JOHNSTON, B. F. and J. W. Mellor (1961), "The Role of Agriculture in Economic Development," American Economic Review, September 1961.

29. JOHNSTON, B. F., J. Cownie and B. Duff, (1970), "The Quantitative Impact of Seed Fertilizer Revolution in West Pakistan," Food Research Institute Studies in Agricultural Economics, Vol. 1, No. 1, 1970.

30. KAHLON, A. S. *et al*., (1960), The Dynamics of Punjab Agriculture, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, India.

31. KOOPMANS, T. C. (ed.) (1951), *Activity Analysis of Production and Allocation*, New York: John Wiley and Sons, Inc.

32. LEE, Y. C. Adjustment in the Utilization of Agricultural Land in Southeast Michigan, Unpublished Ph.D. Thesis, Dept. of Agricultural Economics, Michigan State University, 1975, p. 79.

33. MASSELL, B. F. and R. W. M. Johnson, Economics of Small holder Farming in Rhodesia, A Cross Sectional Analysis of Two Areas, Stanford University, Food Res. Inst. Stud. Supplt. to Vol. 8, 1968.

34. MELLOR, John W. (1965), "The Subsistence Farmer in Traditional Economies," Paper presented at the A.D.C. Seminar on Subsistence and Peasant Economies, East-West Center, Honolulu, Hawaii, February-March 1965.

35. MILLER, T. A. (1972), "Evaluation of Alternative Flexibility Restraint Procedures for Recursive Programming Models Used for Prediction," *A.J.A.E.*, Vol. 54, No. 1, Feb. 1972.

36. Ministry of Agriculture, Bangladesh Agriculture in Statistics, Statistical Series No. 1, Nov., 1973, Gov't. of Bangladesh.

37. Ministry of Agriculture and Works, Survey Report on Farm Power, Machinery and Equipment in Pakistan, Dec., 1967, Govt. of Pakistan, Rawalpindi.

38. MUDAHAR, M. S. (1971). "A Dynamic Microeconomic Analysis of the Agricultural Sector: The Punjab," A paper presented at the Fifth International Conference on Input-Output Techniques, Geneva, Switzerland, January, 1971.

39. MULLER, G. P. (1970), "Forecasting and Rolling Plans for Competitive Supply with Production Lags," QME 7052, Social Systems Research Institute, University of Wisconsin.

40. NAKAJIMA, Chihiro (1957a), "Overemployment and Theory of the Family Farm," Osaka Daigaku Keisaigaku, March 1957.

41. NAKAJIMA, Chihiro (1957b), "Equilibrium Theory of Family Farms," Osaka Daigaku Keisaigaku, March 1957.

42. NAKAJIMA, Chihiro (1965), "The Subsistence Farmer in Commercial Economies," Paper presented at the A.D.C. Seminar on Subsistence and Peasant Economies, East-West Center, Honolulu, Hawaii, February-Marh 1965.

43. NAKAJIMA, Chihiro (1970), "Subsistence and Commercial Family Farms: Some Theoretical Models of Subjective Equilibrium," in Wharton, C.R., Jr. (ed.) Subsistence Agriculture and Economic Development, Aldine Publishing Co., Chicago, 1970.

44. Planning Commission, Bangladesh, 1972-73. Annual Plan, Bangladesh Government.

45. Planning Commission, Economic Development in 1973-74 and Annual Plan for 1974-75, Plan. Com. Gov't. of Bangladesh, July, 1974.

46. Planning Commission. First Five Year Plan of Bangladesh, Gov't. of Bangladesh, Nov., 1973.

47. RAIS UDDIN Ahmed, Economic Analysis of Tube-well Irrigation in Bangladesh, Unpublished Ph.D. Thesis, 1972, Dept. of Ag. Econ. Michigan State University.

48. ROBINSON, W. C., Disguised Unemployment Once Again: East Pakistan 1951-61, J. Farm Economics.

49. SCHALLER, W. Neill (1968), "A National Model of Agricultural Production Response," Agricultural Economic Research, U.S.D.A., E.R.S., Vol. 20 (2).

50. SCHULTZ, T. W. (1964), Transforming Traditional Agriculture, New Haven: Yale University Press.

51. SINGH, I. J. (1971), "A Recursive Programming Model of Traditional Agriculture in Transition: A Case Study of the Punjab, India," Ph.D. Dissertation, University of Wisconsin, 1971.

52. TARAFDAR, Rabiul Islam, "Alternative Low Lift Pump Irrigation Policies in Bangladesh: An Economic and Financial Analysis," Unpublished Ph.D. Thesis, 1973, Dept. of Agril. Economics, Michigan State University.

53. TARAFDAR, Rabiul Islam, "Socio-Economic and Institutional Factors and the Efficiency of Low Lift Pump Irrigation in Bangladesh. (Seminar paper), Michigan State University, Sept. 1976.

54. YOTOPOULOS, P. A., "On The Efficiency of Resource Utilization in Agriculture," Food Res. Inst. Stud. 8: 125-135, 1968.

55. HOPPER, W., "Allocation Efficiency in a Traditional Indian Agriculture," J. Farm Econ. 47: 611-624, Aug., 1965.

56. WHARTON, Clifton R., Jr. (1963), "The Economic Meaning of Subsistence," Malayan Economic Review, Vol. VIII (2), October 1963.

57. WHARTON, Clifton, R. Jr., (ed.) (1970), Subsistence Agriculture and Economic Development, Chicago: Aldine Publishing Company.