ALTERNATIVE LOW-LIFT PUMP IRRIGATION POLICIES IN BANGLADESH: AN ECONOMIC AND FINANCIAL ANALYSIS

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ABSTRACT

LOW-LIFT IRRIGATION POLICIES IN BANGLADESH:
AN ECONOMIC AND FINANCIAL ANALYSIS

By

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Low-lift pump irrigation constitutes 79 percent of the total irrigation in Bangladesh. Important characteristics of low-lift pump irrigation are the use of pumps, mostly in one season, a small command area per installed pump, and a heavy subsidy. These characteristics have important implications for individual farm irrigators and the economy. The purpose of this study was to evaluate the economics of alternative low-lift pump irrigation policies from the standpoint of farmers and the economy. The alternatives considered were: 1) the use of low-lift pump irrigation in (a) the Boro season only, (b) the Aus and Aman seasons, and (c) the Boro, Aus, and Aman seasons; 2) three levels of rental charge; and 3) three levels of command area per pump.

To evaluate the above alternatives, the methodology included: 1) developing of estimates for a 'typical' farm by synthesizing data available from published and unpublished

sources; 2) using the modified Penman formula to develop estimates of irrigation requirements; 3) applying linear programming techniques to determine net returns to fixed farm resources, optimum cropping patterns, marginal value products, and amounts of hired labor and bullock power required; and 4) measuring the returns to irrigation by calculating internal rates of return, net present values, and benefit/cost ratios.

The results of the programming model indicated that there would be substantial specialization of crops under irrigated conditions. With irrigation, IRRI aus rice seemed to have the competitive edge over jute. Unless the yield of jute at current prices is increased considerably, jute would be replaced on many farms by IRRI aus rice. The competitiveness of both pulses and oilseeds relative to boro rice and potatoes diminished greatly under irrigated conditions.

The profitability of low-lift pump irrigation from the farmers' standpoint was high for each of the three seasonal alternatives. Contrary to widely held views, the farmers' return to irrigation was higher in the Aus and Aman seasons together than in the Boro season. Farmers' returns from irrigation were only slightly affected by changes in rental charges and the command area per pump. However, their returns were highly sensitive to changes in the yield and price of outputs, but almost insensitive to changes in relevant irrigation requirements and interest costs.

Similarly, the return to irrigation from the point of view of the economy was high for each of the three seasonal alternatives. And the return to irrigation in the Aus and Aman seasons was almost as high as in the Boro season. The profitability of irrigation from the national standpoint was highly sensitive to changes in the command area per pump. Also, changes in yield and price of output influenced greatly this profitability of irrigation.

Several important policy implications emerge from this study. First, the government should place heavy emphasis on the year-round irrigation in areas having surface water throughout the year. Second, low-lift pump irrigation may be expanded substantially by expanding pump use to the Aus and Aman seasons. Third, the existing level of subsidy may be substantially reduced without any significant adverse effect on farmers' incentive. Fourth, national returns from investment in low-lift pump irrigation may be increased considerably by increasing the command area per pump. A package policy combining rental charges, credit, the supply of pumps, and other inputs would be required to effect a significant increase in the command area per pump.

Major research needs highlighted by this study include: 1) analysis of how relative prices and other policies affect jute and IRRI aus rice; 2) micro level studies on farmers' fields to determine water response functions and optimum irrigation water requirements; 3) research to bring about technological breakthrough in seed, especially for jute, pulses, and oilseeds, so as to make these crops more competitive with rice and generally more productive; and 4) research to shorten the maturity period of important crops, so as to increase cropping intensity.

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INTRODUCTION

Problem Setting

Bangladesh is predominantly an agricultural economy. The importance of agriculture with respect to its contribution to production, consumption, employment, and exports can hardly be overstated. Agriculture accounted for 55 percent of gross domestic product (GDP) in 1969-70. This share of agriculture in GDP remained virtually constant during 1960-70 indicating hardly any structural transformation of the economy. Because of this heavy share of agriculture in the GDP, the rate of growth of the economy varied erratically from 1 to 8 percent mainly with the variation of agricultural output. About 95 percent of the population is rural and 83 percent of civilian labor is directly employed in agriculture (28). In addition, agriculture accounts for over 80 percent of the country's exports.

The annual rate of growth in the demand for food grains in Bangladesh during 1962-70 is estimated at about 3.62 percent, on the basis of income elasticity of demand for food grains at 0.6, and annual rate of increase in population and per capita income at about 3 and 1 percent respectively.[1] However, domestic production of food grains increased at the rate of only 2.9 percent per annum. About half the population is affected by malnutrition mainly because of the scarcity of protein-rich food like pulses, meat, milk, and milk products (73). The continuing shortage of food grains and the deteriorating nutritional level underline the critical importance of the rapid development of agricutlure in Bangladesh. Moreover, the development of agriculture will be the pre-requisite for the overall development of the Bangladesh economy because the agriculture sector is and continues to be in the foreseeable future the largest employer of labor, the biggest earner of foreign exchange, the most important source of domestic savings, and the market for the bulk of the manufactured consumer goods. The government of Bangladesh has, therefore, accorded the topmost priority to the development of agriculture.

Bangladesh agriculture is still largely traditional, having a level of productivity which is one of the lowest in the world. And with only 2 percent[2] cultivable waste

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[1]The formula for estimating the growth of demand for food grains is:

$D = (1 + P)(1 + ng) - 1$ where,

D = rate of increase in demand for food grains

P = rate of population growth per annum

n = income elasticity of demand for food grains

g = rate of growth in per capita income per annum.

[2]For further details, see Table 2.7.

land in the country, the increase in the production of agricultural products will have to come almost entirely from the existing cropped area. This means that the increased agricultural production will have to be achieved mostly by raising the yield per acre, and increasing the cropping intensity. To achieve this, in turn, involves increases in the use of modern agricultural inputs like irrigation water, fertilizer, improved seed, and pesticide. And most importantly, the provision of controlled irrigation creates a condition for rapid expansion in the use of other inputs because of high complementarity of water with these inputs. The recent introduction of the high yielding varieties (HYV's) of rice (IRRI varieties) in Bangladesh further increases the importance of irrigation since the IRRI varieties of rice are subject to substantially greater reduction in yield for lack of adequate water than the low yielding but relatively drought resistant local varieties of rice. A poor performance of the IRRI varieties of rice especially during the initial period of introduction will have adverse effects on their diffusion among farmers. Moreover, assured water supply through controlled irrigation will greatly reduce the risks and uncertainties involved in the production of various crops.

Most of the crops are still grown under unirrigated conditions in Bangladesh. Only about 7 percent of the cultivated area was irrigated in the dry winter (Boro) season of 1969-70. In order to expand rapidly the irrigation facilities in the country, the government has already put a high priority on the expansion of low-lift pump irrigation. The government plans to increase the area under low-lift pump irrigation from 631,057 acres in 1969-70 to over 2 million acres in 1974-75 (16, and Table 2.7).

Research Problem

Important characteristics of the low-lift pump irrigation program in Bangladesh are: 1) the use of low-lift pumps mostly in one season (Boro season) although possibilities exist for their use in the remaining two seasons;[1] 2) a much smaller area irrigated per pump[2] (command area) than could be irrigated with full capacity utilization; and 3) a heavy subsidy.[3] These features significantly affect the profitability of low-lift pump irrigation and cause differential impact on the economy and individual farm irrigators.

The information about the extent to which the existing operational features influence the profitability

[1] In Bangladesh, there are 3 crop seasons, namely, Boro season (December-April), Aus season (April-August), and Aman season (August-December).

[2] For the purpose of this study, the capacity of a low-lift pump is assumed to be 2 cusecs.

[3] Subsidy per acre of low-lift pump irrigation is the difference between the cost incurred by the government and the amount realized as rental charge from the farm irrigators.

of low-lift pump irrigation from the point of view of the economy and individual farmers is mostly unknown. Also, very little is known about how changes in the operational features would affect the profitability. However, such information is highly important for making appropriate policy decisions relating to the expansion of low-lift pump irrigation in Bangladesh. The importance of this information has increased further because the expansion of low-lift pump irrigation has become one of the major strategies to increase agricultural production in Bangladesh. The importance of each of these operational features and the issues it raises for investigation are indicated below.

The emphasis on the Boro season irrigation in government policy seems to be based on some implicit assumptions. First, since the lack of soil moisture is the most limiting constraint and, consequently, land has very little alternative uses in the Boro season, the provision of irrigation in this season makes possible an additional crop. As crops are grown under rainfed conditions during the Aus and Aman seasons, irrigation would account for only a part of the total production of crops during these seasons. As a result, the return to low-lift pump irrigation in the Boro season was believed to be much higher than in the Aus and Aman seasons. Thus, there was apparently a general belief that the profitability of irrigation in the Boro season would be high and visible

enough to constitute a strong incentive for farmers to adopt pump irrigation rapidly. Second, the reduction of risk for irrigated Boro season crops, because of the absence of flood hazard, seemed to have reinforced the belief that the Boro season irrigation provides a strong incentive to farmers for the expansion of low-lift pump irrigation. Third, as agricultural unemployment is relatively high in the Boro season, the increase of crop production activities through the provision of irrigation in this season would ease the unemployment situation.

A considerable protential exists for extending low-lift pump irrigation into the Aus and Aman seasons. Adequate surface water is available in many areas for the operation of low-lift pumps throughout the year (Boro, Aus, and Aman seasons). Thus, supplemental irrigation in the Aus and Aman seasons can considerably increase the productivity of Aus and Aman seasons' crops. The lack of adequate rainfall during the planting period of Aus season crops and the flowering period of Aman season crops often reduces the yields. The introduction of high yielding IRRI varieties of rice in the Aus and Aman seasons has substantially increased the importance of supplemental irrigation in these seasons. As there is scope for extending the use of low-lift pumps to the Aus and Aman seasons, the use of these pumps in only the Boro season may represent a severe underutilization of the available capacity and an

inefficient use of scarce resources. The hypothesis of this study is that the use of low-lift pump irrigation throughout the year will result in higher economic[1] and financial[2] returns than when the use of low-lift pumps is limited to the Boro season alone. The relevant questions are how much of an increase in return can be expected from year-round irrigation and whether the additional return will justify the additional costs.

An important but related question is whether it is profitable enough to justify investment in the low-lift pumps even if these are used only in the Aus and Aman seasons. This question arises because there are many areas in Bangladesh where adequate surface water is available for low-lift pump irrigation in the Aus and Aman seasons but not in the Boro season.

With respect to the command area per pump, an average area of 39.2 acres was irrigated in 1969-70 as compared to the widely held view that 60 acres could reasonably be irrigated by a 2 cusec pump.[3] This smaller command area per pump suggests that a much larger area could be irrigated with the available pump capacity. Since most of the

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[1]Economic returns refer to the returns estimated from the point of view of economy.

[2]Financial returns refer to the returns estimated from the point of view of individual farmers.

[3]For further information see Chapter II.

costs of the low-lift pump irrigation program are charged to the public sector, a lower command area per pump has greater adverse effects from the national point of view than from the standpoint of individual farmers. The relevant issues are the extent to which an increase in the command area per pump increases the profitability of irrigation from the economy's and private farmer's point of view and the extent to which the expansion of the command area per pump affects farmers' incentive.

The third major feature of the low-lift pump irrigation program is that it is heavily subsidized. The rate of subsidy is estimated to have been as high as 95 percent in 1969-70.[1] To aid in the introduction of an agricultural innovation, a subsidy is often used especially at the initial stage. The relevant issue is how much subsidy is justified to attain a given objective given its cost. In Bangladesh, a heavy subsidy for the low-lift irrigation seems to be based not on any careful study but on a general notion that heavy subsidy is necessary to expand the low-lift pump irrigation. For further policy decisions about the level of subsidy, it is important to estimate the impact of different levels of subsidy on profitability from the point of view of farmers and the economy.

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[1]Subsidy rate is estimated on the basis of annual cost of Tks 5072 per pump (Table 5.9) and annual rental of Tks 250 per pump.

The important problems connected with the low-lift pump irrigation program in Bangladesh and the relevant issues to be examined are indicated above. However, the lack of previous studies on the problems and issues raised above adds to the importance of the present study. Only a few studies on the impact of low-lift pump irrigation have been made. In addition, these studies are quite limited in scope.

Mohammad in his study (67) examined the return to low-lift pump irrigation in the Boro season. He estimated the return to irrigation from the point of view of the economy only. This analysis suffered, however, because of his failure to consider shadow prices in evaluating the return to irrigation. Mohsen (69) found low-lift pump irrigation to be profitable to farmers. This study was concerned mainly with the evaluation of different aspects of the Thana Irrigation Program and only the farm level profitability of the Boro season irrigation was examined.

The World Bank Mission in its report (49) found a high rate of return to low-lift pump irrigation and recommended its expansion. However, this analysis was limited to return to irrigation in the Boro season from the point of view of the economy.

Although the low-lift pump irrigation program is one of the most important agricultural programs in Bangladesh and will continue to be the major source of irrigation at least up to 1980, systematic studies to evaluate important aspects of the program are lacking. The present study is thus designed to fill part of this gap. Its objective is to aid government decision makers in improving low-lift pump irrigation policies in Bangladesh.

Research Objectives

The purpose of this study is to identify and measure the impact of alternative policies for low-lift pump irrigation in Bangladesh. The specific objectives of the study include:

1. To measure and analyze the return to low-lift pump irrigation from the national (economy) and private farmer's point of view for various seasonal alternatives. The seasonal alternatives considered are low-lift pump irrigation in (a) Boro season only, (b) Boro, Aus, and Aman seasons (i.e., the whole year), and (c) Aus and Aman seasons.[1]
2. To evaluate the impact of three alternative rental levels on farms as well as the economy under the three seasonal alternatives indicated above.
3. To evaluate the impact of three alternative levels of area irrigated per pump (command area) on farms

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[1]The impact of the seasonal alternatives on the return to irrigation is also subjected to the sensitivity analysis by changing the original levels of prices, yields, interest cost, and irrigation requirements.

and the economy under the three seasonal alternatives mentioned above.

The farm level analysis will indicate to farmers the profitability of options for using low-lift pump irrigation in one season or combination of seasons given their particular resource ownership position. The farm level analysis will also show the extent to which the farmers' return to irrigation is affected by changes in the rental level and the command area of a 2 cusec low-lift pump. This information will be important for farmers for their decision making with respect to the adjustment and organization of various crop enterprises with the changing conditions. The government policy makers will also gain from this farm level analysis a valuable insight into the incentive structure facing farmers. The knowledge of the incentive structure facing farmers is important in formulating public policy with respect to low-lift pump irrigation and other inputs.

The economic analysis will indicate how the net return to the economy of investment in low-lift pumps is affected by the alternatives considered in the study. The economic analysis provides to government policy makers answers to such questions as (a) the returns to public investment in low-lift pump irrigation under the various alternatives involved and (b) suitable modification in the existing policies or the adoption of new policies to increase the return to the low-lift pump irrigation.

Analytical Framework

The analytical framework includes the conceptualization of the procedure to identify the factors affecting benefits and costs, the theory underlying the farm adjustment to changes in irrigation alternatives considered in the study, and the methodology used in measuring the impact of these alternatives on farms and the economy.

In this study, the net return exclusively attributable to the low-lift pump irrigation is defined as the net return (gross return minus cost) with irrigation minus the net return (gross return minus cost) without irrigation. The provision of irrigation creates a dynamic condition under which the levels of inputs and outputs and their interrelationships are changed. This in turn, affects the production function as well as the cost function. On the other hand, crop production environment without irrigation will not remain completely static. However, as irrigation serves as the crucial catalyst in the whole process of changes in the organization of crop production activities, changes in the level of inputs and outputs without irrigation are expected to be small.

The additional per acre gross return to irrigation (the gross return with irrigation minus the gross return without irrigation) will result from a combination of several factors. This additional gross return and the factors causing it may be identified as $\Delta R_y = \Delta Y_h + \Delta C_l + \Delta C_p + \Delta S_t$ where,

1. ΔR_y is the additional gross return to irrigation per acre (R_y with irrigation minus R_y without irrigation).
2. ΔY_h represents additional yield per acre due to improvement of yield under irrigated conditions over unirrigated conditions. Irrigation changes the production environment in such a way that higher levels of associated inputs may be used resulting in increased yield.
3. ΔC_l stands for additional return per acre due to increased cropping intensity under irrigated conditions over unirrigated conditions. Lack of soil moisture in the Boro season is the most limiting constraint on the growing of crops in that season. In addition, farmers are sometimes faced with the choice between growing either Aus or Aman season crops due to lack of moisture at the right time of planting of Aus season crops in April. By removing these soil moisture constraints, irrigation increases the intensity of cropping.
4. ΔC_p reflects additional return per acre due to improved cropping pattern under irrigated conditions over unirrigated conditions.

5. ΔS_t represents additional return per acre resulting from the use of new and improved varieties of seed under irrigated over unirrigated conditions. However, for this study, the IRRI varieties of rice are assumed to be grown only under irrigated condition. Although the latest indication is that these HYV's may be grown without irrigation in the Aus and Aman seasons in some areas in Bangladesh, the above assumption has been made for the following reasons:

   a. Until 1969-70, the entire IR-8 (IRRI boro rice) and the IR-20 (IRRI aman rice) were grown under irrigated condition.

   b. Until 1969-70, IR-20 growers thought that "supplementary irrigation is a must for IR-20" (85, p. 25). No boro rice can be grown without irrigation in Bangladesh.[1] Since the success of the IRRI varieties of rice was believed to depend critically on the assured supply of adequate water, controlled irrigation was the necessary condition for the growing of these varieties.

   c. The extent to which farmers will grow IRRI varieties of rice without irrigation and the

[1]Until 1970, no IRRI variety of aus rice was introduced to farmers in Bangladesh.

information on the input-output relationships of these HYV's without irrigation are mostly lacking.

The change in the additional gross return to irrigation would be associated with additional cost. This additional cost is determined by deducting total cost (TC) without irrigation per acre from the TC with irrigation per acre. The additional costs may be identified as $\Delta TC = C_w + \Delta C_a$ where,

1. ΔTC is the additional cost per acre under irrigated conditions over unirrigated conditions.
2. C_w is the cost of irrigation water per acre.
3. ΔC_a reflects the change in cost per acre on account of the change in the level of other associated inputs used under irrigated over unirrigated conditions.

The additional per acre net return to irrigation is, therefore, estimated by deducting the additional cost with irrigation per acre (ΔTC) from the additional gross return with irrigation (ΔR_y) per acre.

Theory of Farm Adjustment to Irrigation Alternatives

This theoretical framework will show the farm adjustment process as a result of changes in the production and cost functions under the irrigation alternatives considered in this study.

There will be separate production functions for irrigated and unirrigated conditions. Under unirrigated conditions, the output will be a function of land, labor, bullock power, fertilizer, seed, and pesticide. The provision of irrigation changes the crop production environment in such a way that new HYV's of seed (especially IRRI varieties of rice) and higher levels of other variable inputs of labor, bullock power, fertilizer, and pesticide will be used. The production function with irrigation is specified as follows.

$$Y = f(x_1 \mid x_2, x_3, x_4, x_5, x_6, x_7, x_8)$$

where,

Y = Output per acre

x_1 = Irrigation water per acre

x_2 = Land (one acre)

x_3 = Labor

x_4 = Bullock power

x_5 = Fertilizer

x_6 = HYV's of seed

x_7 = Pesticide

x_8 = Equipment

In addition to the specification of the production function, the following assumptions are necessary for the purpose of the theoretical analysis. First, the water response function is assumed to be known. Second, levels of all inputs per acre other than irrigation water are

given for each season. Third, prices of inputs and outputs per unit remain constant. Fourth, the farm operators are profit maximizers and will, therefore, produce at that output level where the marginal factor cost (MFC) of irrigation water equals the marginal value product (MVP) of irrigation water.

With the production function under irrigation, and assumptions specified as above, it is possible to present a theoretical exposition of the farm adjustment process under the irrigation alternatives considered in this study. First, the case of the farm adjustment process for one season irrigation is presented. Figure 1 illustrates the total value product (TVP), marginal value product (MVP), total factor cost (TFC), and marginal factor cost (MFC) of irrigation in one season. The TVP curve is obtained by multiplying total physical product (TPP i.e., output of crops) by the price of product. The TFC curve represents the variable cost of irrigation water on account of the diesel and oil to run the low-lift pump. The variable cost of providing irrigation is thus a linear function of the amount of irrigation water applied per acre. The TVP curve originates from M because the OM amount of value product is assumed to result from natural rainfall. The TFC curve starts from P because of the fixed cost involved on account of fixed rental charge, preparation of field channel, pump shed, etc. The MFC and MVP of irrigation water are equal at Q. This

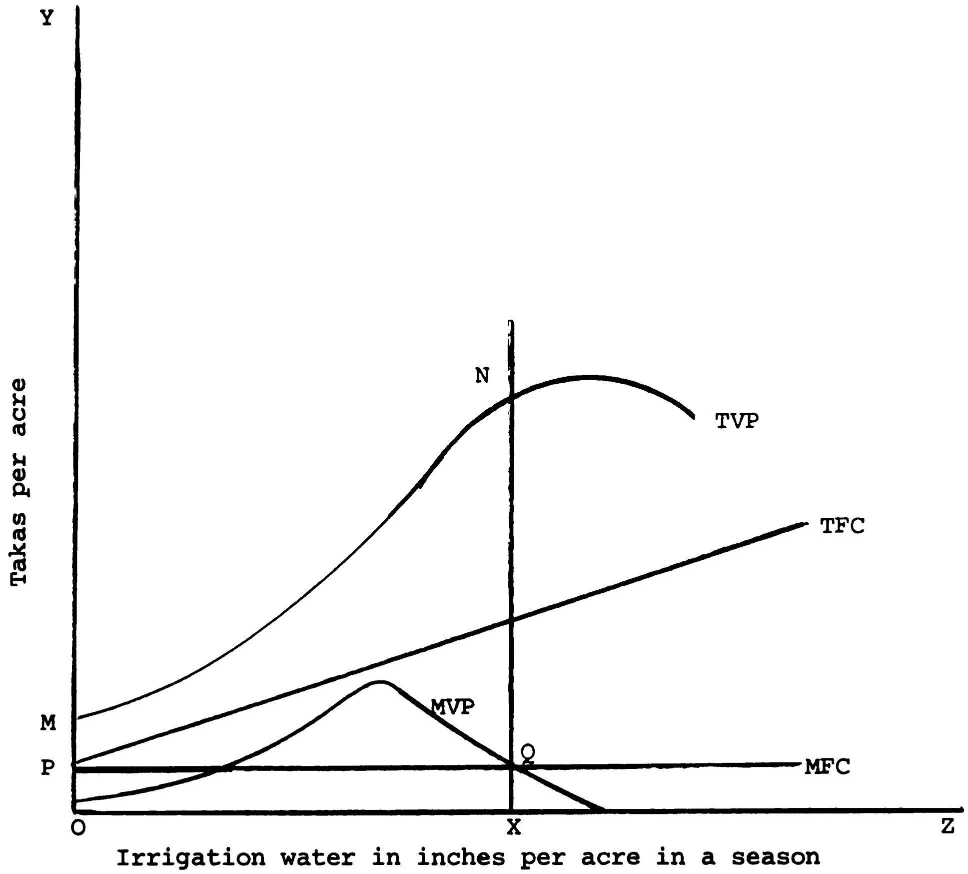

Figure 1. Production and cost functions for irrigation in one season.

equality is at the irrigation water application level of X. The optimum amount of irrigation water is thus represented by OX. Under the specified assumptions, production, and cost functions, a profit maximizing farmer will tend to use OX amount of irrigation water and to attain the high profit point at N.

Second, with the provision of irrigation in three seasons, there will be separate cost and production functions for each of the three seasons. Thus, in case of irrigation in three seasons, the TVP and TFC will be the horizontal summation of the TVP's and TFC's associated with the three seasons.

Third, in the case of the farm adjustment process when the levels of rental charge and command area per pump are changed is represented in Figure 2. Since the rental charge is fixed per pump, a change in the rental charge for a given level of command area per pump will change total fixed rental cost per pump, that is, the average fixed rental cost per acre. This means TFC curves should shift up or down with the change in the rental charge. Similarly, a change in the command area per pump for a given level of rental charge per pump will change the average fixed cost per acre on account of rental charge. In Figure 2, TFC_o has shifted up to TFC_1, because of an

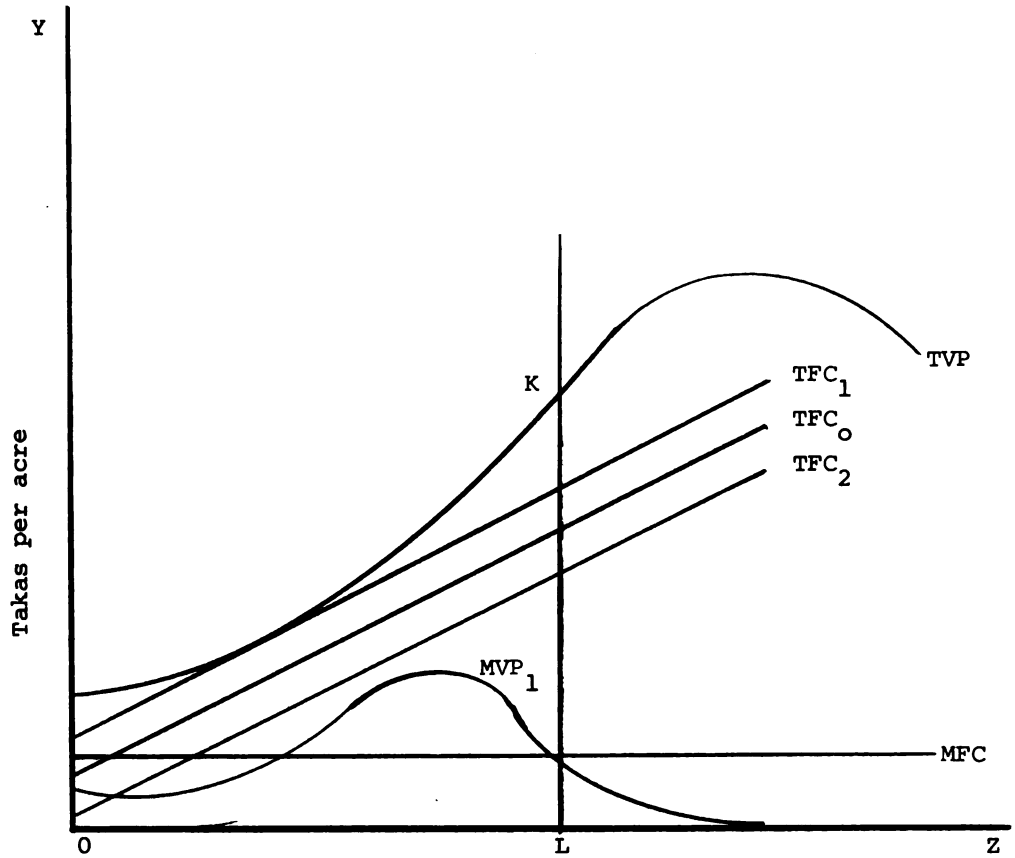

Figure 2. Value products and costs with changed levels of rental charge and command area.

increase in rental charge given the level of command area or a decrease in the level of command area given the level of rental charge. The TFC_o shifts down to TFC_2 when either the rental charge is decreased given the level of command area or the command area is increased given the rental charge. The changes in the levels of rental charge and command area do not affect the production function, the TVP and TFC thus remain the same. These changes affect only the average fixed cost. The MFC thus remains unaffected. And with no change in the MFC and MVP as a result of changes in the levels of rental change or command area, the optimum irrigation intensity and the high profit point remain the same at the level of L and K respectively. However, the effect of an increase in rental charge given the command area or a decrease in the command area given the level of rental is a fall in the amount of total profit per acre to farmers. Similarly, the total profit per acre rises when the reverse is the case.

Methodology for Farm Level Analysis

A linear programming model is developed to estimate the net return to irrigation at the farm level. The model provides estimates of (a) net return to the labor of the farmer and his family, bullock power, fixed capital, management, and risk taking, (b) cropping pattern, and (c) marginal value product (shadow price) of fixed resources

under irrigated and unirrigated conditions. The model is also suitably adjusted in case of seasonal alternatives and changes in the levels of important variables like yield, price, interest cost, and irrigation requirements to provide information under these alternative specifications. Finally, using the model results, the net present value of net return resulting from irrigation has been estimated. The period during which the return accrues to farmers is assumed to be eight years. Since the timing of farmers' receipt of return is very important for their incentive structure, the path by which net return to farmers grows from the first to the eighth year has been traced through. And the net present values of the streams of net returns are shown for the purpose of analysis.

Methodology for Analysis from the Standpoint of the Economy

The methodology used in evaluating the impact from the point of view of the economy includes the use of three measures: the internal rate of return (IRR), the benefit/cost (B/C) ratio, and the net present value (NPV). These measures are defined below (13, 40, 59, 63). Internal rate of return (IRR) is defined as the rate of discount which just makes the discounted present value of benefits equal to the discounted present value of costs. Mathematically, it is the discount rate r such that

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} = 0$$

The benefit/cost (B/C) ratio is the ratio of discounted value of the benefit stream to the discounted value of the cost stream using an appropriate interest rate. Mathematically,

$$\text{B/C ratio} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}}$$

The net present value (NPV) is the discounted value obtained by discounting the stream of benefits and costs to present time using an appropriate interest rate. Mathematically,

$$\text{NPV} = \frac{\sum_{t=1}^{n} B_t - C_t}{(1+r)^t}$$

where,

B_t = benefits in each year

C_t = costs in each year

n = number of years

r = discount rate.

In estimating the benefits and costs for economic analysis prices of outputs and inputs should reflect true

scarcity value. This means that these prices often will diverge from those used in evaluating the return from the farmers' point of view. The application of the three criteria as defined above will, therefore, involve the estimates of appropriate shadow prices for the outputs and inputs.

CHAPTER II

SALIENT CHARACTERISTICS OF AGRICULTURE AND LOW-LIFT PUMP IRRIGATION IN BANGLADESH

Bangladesh, a predominantly agricultural country, stretches over 55,126 square miles with a population of 75 million. Its climate, soils, and hydrology combine to influence greatly its crop production environment. The first part of this chapter focuses on the important elements of climate, soils, topography, floods, drainage, farm structure, and cropping pattern so as to place the study in its context. In the second part of the chapter, main features of the low-lift pump irrigation program are described. This discussion will help in identifying important elements with respect to institutional arrangements, rental and subsidization policies, utilization pattern of low-lift pump irrigation in Bangladesh.

Topography and Soils

The characteristics of topography and soil in Bangladesh have influenced the evolution of the cropping pattern and are important in determining irrigation, and other agricultural development possibilities. A detailed reconnaissance survey over 70 percent of the area of the country was already completed under a Soil Survey Project assisted by the FAO and UNDP (8). In addition, a substantial amount of information is available from other sources, namely, soil fertility tests conducted by the Directorate of Agriculture[1], and some exploratory surveys. These sources provide considerable information about the soil properties, topography, and hydrologic conditions for most of Bangladesh. The information available from these sources serve as a valuable basis for planning comprehensive agricultural development strategies.

Topography

Bangladesh may be broadly divided into two main divisions: 1) alluvial plain, and 2) marginal hills in the east and south-east (3, p. 11). About 90 percent of the country is an alluvial plain. Land generally slopes upward to the north with very low gradients from a few feet above sea level of the coastal lands in the south. Most of the country lies less than 60 feet above sea level. The overall gradient on the river flood plains is less than a foot per mile. However, it increases to about 3 feet per mile in the extreme north-west.

[1]Many of the results were available from the unpublished reports (1960-70) of the Soil Fertility and Soil Testing Institute under the Directorate of Agriculture.

Although the overall topographic characteristics of this vast alluvial plain is gently sloping, there is considerable variability in local topography. Most of the flood plains are characterized by a succession of broad ridges and depressions varying in size and shape. The difference in elevation between the adjoining ridges and basins generally ranges from less than 5 feet in the Ganges tidal and the old Meghna flood plains to 20-30 feet on the boundary between the old Brahmaputra flood plain and the Sylhet basin. The local variability in elevation is of considerable importance in planning irrigation and drainage facilities. The requirement of level land in farm fields might serve as an important constraint in using irrigation facilities.

Soils

The greater part of Bangladesh lies within the delta of the combined Ganges-Brahmaputra-Meghna River system. Soils fall into three broad divisions, namely, new alluvium, old alluvium, and hill soils. About 80 percent of the soils are formed in new alluvium and 10 percent in old alluvium (3, p. 51). The new alluvial soils are generally deficient in phosphoric acid, nitrogen, and humus but not usually in potash and lime. But old alluvial soils contain less of all these chemical ingredients (3 p. 64).

A general pattern of differences in soil texture and permeability is observed between flood plain ridges and basins. Soils are lighter and more permeable on the ridges than in the basins. Silty loams and loams are highly suited for increased productivity with irrigation.

In the process of future development of agriculture with increased irrigation and use of HYV's the differences in physical and chemical characteristics of soils will assume greater importance. Extensive soil fertility trials showed that almost all soils of Bangladesh respond well to fertilizer. The results of the Soil Survey Project (8) conclusively indicate that the soils of Bangladesh have high potentials for increased yield and most of the cultivated land is capable of having a substantial increase in yields with the HYV's, irrigation, and modern inputs.

Climate

Bangladesh has a tropical monsoon climate with high rainfall, humidity, and temperature. Its climatic environment has influenced markedly the types of crop grown, their rotation and the efficiency with which combinations of crops can be grown.

Rainfall

Bangladesh has an average rainfall of over 80 inches annually (Table 2.1). However, its distribution varies considerably among seasons and regions. Seasonally, the rainfall distribution may be divided into three distinct

Table 2.1. Mean monthly rainfall in Bangladesh, 1934-1969.

Districts	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
							Inches						
Rajshahi	0.56	0.51	0.91	1.37	4.72	10.06	12.06	10.02	8.08	4.92	0.39	0.08	53.68
Rangpur	0.57	0.53	1.11	3.40	12.14	19.41	17.69	13.24	11.03	6.71	0.28	0.04	86.15
Bogra	0.50	0.48	0.96	2.20	7.06	13.04	13.68	13.48	9.66	6.76	0.36	0.07	68.25
Khulna	0.56	0.54	1.25	3.11	6.30	13.48	14.03	12.13	8.93	6.02	1.02	0.10	67.47
Dacca	0.43	0.84	1.80	4.68	9.46	13.83	12.84	13.58	9.32	5.74	0.94	0.09	73.55
Mymensingh	0.46	0.64	1.83	4.46	11.68	17.97	15.29	15.74	12.39	6.77	0.54	0.08	87.85
Barisal	0.64	0.65	1.64	3.60	8.38	18.55	18.65	18.50	12.82	9.43	1.32	0.22	94.40
Comilla	0.37	1.25	1.74	6.33	11.25	20.94	19.32	16.07	11.96	9.23	1.71	0.17	100.34
Chittagong	0.43	0.77	2.17	4.48	10.14	22.29	25.35	22.72	12.58	8.78	1.45	0.57	111.73
Sylhet	0.40	1.30	4.40	11.90	23.20	32.80	26.00	24.80	20.20	10.60	1.40	0.10	157.10

Source: East Pakistan (Bangladesh), Water and Power Development Authority, "Draft Technical Guidelines, Rainfall Analysis, East Pakistan." (Prepared by Acres International Ltd. Dacca: WAPDA, 1971).

periods: 1) pre-monsoon period of April and May, 2) monsoon period of June to mid-October, and 3) dry period of mid-October to March. About 75 percent of the annual rainfall is concentrated in the monsoon period. And during mid-October to March, rainfall is quite negligible. The annual variability of rainfall for the country as a whole is less than 15 percent (3, p. 54). The small variability in average annual rainfall is, however, a poor index for planning an irrigation schedule or for projecting the impact of rainfall on crop yields. The small annual variation in rainfall disguises the considerable variability of the amount of rainfall received within a month or a fortnight. The variability of rainfall in a month or a fortnight as well as the variation in the number of rainy days and intensity of each shower have important implications for costs and returns resulting from irrigation.[1]

With respect to regional variations, the annual rainfall varies from 54 inches in Rajshahi to over 157 inches in Sylhet (Table 2.1). In general, the amount of annual rainfall is the highest in the east, north-east, and south-east parts of the country; and it is the lowest in the west and south-west parts of the country. The central part of the country receives the medium amount of rainfall.

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[1]For further information, see discussion in Chapter IV.

The annual rainfall might appear to be adequate in absolute quantity for one or even two crops. But the lack of timeliness (too little or too much at different times) becomes the crucial determinant of its effectiveness. The uneven distribution of rainfall over time offers some important constraints for cropping. First, the dry period of about 5 months decisively limits the Boro season crops to soils having superior moisture-holding capacity and to irrigated lands. Second, the monsoon rainfall resulting in widespread waterlogging and flooding restricts crop alternatives to rice and jute. However, with good drainage conditions, the crop options increase. Third, the uncertainty of pre-monsoon showers, in April-May, often causes a reduction in yield as well as acreages of jute, aus and aman rice. If the pre-monsoon showers come late, the sowing of aus rice and jute is delayed. This delay in sowing increases the possibility that an early and heavy monsoon shower in June might submerge these crops at an early stage. Similarly, the option of double cropping of aus rice or jute followed by transplanted aman rice is restricted because a relatively long delay in the pre-monsoon showers makes the growing of two crops impossible. Fourth, the aman rice often suffers substantial reduction in yield due to lack of adequate rainfall at its flowering time in October or early November.

Temperature

The mean monthly temperature ranges between 60° and 90°F in Bangladesh (Table 2.2). The period of November through February is cold with January being the coldest month in the country. The highest temperature is reached in April and May. The temperature during June through October is moderated by monsoon rains. For most of the country, the mean maximum temperature remains around 86°F and the mean minimum is about 10°F less during this period (80, p. 55).

The mean monthly range of temperature (60°F - 90°F) is a year with a limited variation is suitable for crop production throughout the year. The temperature does not appear to be a constraint for the growth of a wide range of tropical, sub-tropical, and some temperate zone crops.

Floods and Drainage

Floods and drainage problems affected Bangladesh agriculture and will constitute important constraints against tapping the agricultural development potential in the future. Under the conditions of heavy monsoon rainfall, the flat and low-lying topography impedes drainage and causes flooding. According to the Water and Power Development Authority (WAPDA)[1] (30), about six million acres are flooded every year and moderate or severe floods occur every four years. Table 2.3 indicates that 30 percent of the land area is flooded to a depth greater than 3 feet and 14 percent of the area is

[1]WAPDA is a semi-government (autonomous) agency in Bangladesh.

Table 2.2 Range in monthly mean temperature at selected recording stations in Bangladeah, 1953-1957.

Recording Station	Range	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
							Fahrenheit							
Chittagong	Low	66.3	70.4	77.2	81.0	81.8	80.6	80.1	81.3	81.2	78.9	73.4	67.8	76.7
	High	68.3	74.1	79.9	83.4	84.9	82.9	82.9	82.6	83.0	83.0	76.8	70.0	79.2
Cox's Bazar	Low	67.2	70.4	76.5	81.4	81.8	80.4	80.1	80.8	81.0	80.5	75.3	69.1	77.0
	High	68.7	73.4	79.0	84.3	86.3	84.3	81.7	82.6	82.9	88.3	77.0	71.5	80.0
Dacca	Low	63.3	66.5	76.0	81.4	83.7	81.3	82.5	82.3	82.5	79.3	71.6	65.3	76.3
	High	69.9	73.6	80.6	85.2	88.9	83.6	83.2	84.6	83.8	82.8	75.0	67.8	79.9
Narayanganj	Low	65.0	67.7	73.3	82.4	84.2	80.0	82.0	82.5	83.5	77.8	72.5	68.4	76.6
	High	68.3	73.7	81.3	85.7	86.4	85.0	83.4	85.6	85.5	83.4	76.9	70.5	80.5
Mymensingh	Low	62.7	67.4	76.2	81.6	82.1	81.7	82.2	82.1	82.7	79.0	72.7	66.3	76.4
	High	69.5	72.2	78.3	84.7	85.0	84.9	84.1	85.5	84.6	83.0	75.7	68.1	79.6
Comilla	Low	63.2	69.2	77.0	81.9	83.0	80.7	80.9	81.9	82.1	80.6	73.3	67.2	76.7
	High	66.9	69.5	79.9	85.2	85.5	83.6	82.2	84.0	84.1	82.7	75.9	70.0	79.1
Brahmanbaria	Low	65.1	69.1	76.7	82.0	83.9	81.3	82.2	81.9	82.9	80.5	73.7	67.7	77.2
	High	66.9	74.3	80.6	84.7	85.0	83.4	83.3	84.4	84.5	83.2	78.6	69.4	79.9
Barisal	Low	65.0	70.4	78.7	83.9	85.1	82.9	82.3	82.4	82.8	81.1	73.4	68.4	78.0
	High	68.8	75.7	82.3	86.2	87.3	87.1	85.3	84.1	84.6	83.2	76.6	70.6	81.0
Faridpur	Low	63.0	66.7	75.4	81.1	83.1	81.1	82.0	83.8	81.9	79.2	71.3	65.3	76.2
	High	69.0	73.1	82.3	86.2	85.1	85.2	82.7	82.7	83.9	81.8	75.9	67.3	79.6
Jessore	Low	60.0	67.0	76.8	84.9	85.7	82.1	82.8	83.0	82.7	79.9	70.9	65.0	76.7
	High	67.3	73.5	81.9	87.3	91.2	87.3	84.1	85.5	90.6	81.8	75.6	68.0	81.2

Khulna	Low	64.9	70.9	81.7	84.6	83.3	81.0	80.1	83.7	83.5	78.3	72.8	69.0	77.8
	High	70.8	76.7	85.0	86.9	89.3	87.4	85.1	85.3	85.2	83.1	76.2	70.9	81.8
Satkhira	Low	63.4	68.7	76.0	82.4	83.5	81.7	82.8	81.6	82.9	79.7	72.7	67.2	76.9
	High	68.7	75.5	83.5	85.1	88.2	85.2	83.7	84.5	84.6	82.4	75.0	68.9	80.4
Maijdi Court	Low	65.1	69.3	76.7	81.3	82.4	80.1	81.0	81.5	81.8	80.0	72.1	68.0	76.6
	High	67.6	74.4	79.3	83.9	85.2	84.2	82.2	82.8	83.6	83.9	90.6	68.6	80.5
Bogra	Low	64.2	68.0	76.3	83.2	84.2	82.1	81.2	82.5	83.4	79.6	71.7	66.2	76.9
	High	68.2	72.3	79.6	86.3	90.8	86.9	84.4	85.4	84.7	82.4	75.1	68.8	80.4
Dinajpur	Low	62.5	64.4	77.0	81.8	83.6	82.6	82.2	81.6	82.8	78.7	71.1	65.2	76.1
	High	64.1	71.3	79.1	83.8	87.6	84.8	83.7	85.2	85.2	82.1	79.2	67.1	79.4
Serajganj	Low	62.8	68.6	76.0	82.4	83.5	81.7	82.8	81.6	82.9	79.7	72.7	67.2	71.0
	High	65.6	72.0	83.5	85.1	88.2	85.2	83.7	84.5	84.6	82.4	75.1	68.9	79.9
Sreemangal	Low	60.1	64.8	73.0	79.1	81.3	80.9	82.1	81.8	81.7	77.6	69.2	63.5	74.6
	High	63.3	70.3	77.7	83.0	88.5	84.7	83.4	83.6	83.6	81.3	71.2	65.3	80.0

Source: East Pakistan (now Bangladesh), Provincial Statistical Board and Bureau of Commercial and Industrial Intelligence, Statistical Abstract for East Pakistan, Vol. IV (Dacca: Government Press, 1958).

flooded with over 6 feet of water. The regional and local differences in depth of flooding, however, depends on the topographical conditions in relation to the adjoining river levels.

Farm Structure

The average size of farms in Bangladesh is 3.5 acres varying from the smallest average size of 1.8 acres in Comilla to 5.8 acres in Kushtia (72). The average size of cultivated area per farm is 3.1 acres, representing 88 percent of the total area under a farm. The farms of less than 2.5 acres in size constitute 51 percent in number but occupy only 16 percent of the land. The farms ranging between 2.5 acres and below 7.5 acres constitute 38 percent of farms and occupy 45 percent of the area. About 78 percent of the farms are 5 acres or less in size.

In addition to small size, farms in Bangladesh are highly fragmented. About 90 percent of the farms are fragmented and 29 percent of them have more than 10 fragments (72).

There are three types of tenure groups in Bangladesh: (a) owner farmer, (b) owner-cum-tenant farmer, and (c) tenant farmer. The owner operated farms predominate with 60 percent of the farms and 52 percent of the farm area (72). The owner-cum-tenant operated farms are second in importance with 37 percent of the farms with 47 percent of the total farm area leaving only 1 percent of the farm area under tenant operation (72).

Table 2.3. Estimated distribution of area according to flood-depth,[a] Bangladesh.

Region	Total Area	Area Under Settlement and Water	Per-cent	Classification According to Flood-Depth							
				Less than 1 foot		1-3 feet		3-6 feet		Beyond 6 feet	
				Area	Per-cent	Area	Per-cent	Area	Per-cent	Area	Per-cent
				1,000 acres		1,000 acres		1,000 acres		1,000 acres	
Northwest	7,357	631	9	3,131	42	2.357	32	671	9	566	8
Central	4,643	399	9	1,188	26	1,260	28	752	16	1,064	21
East	5,461	600	11	524	10	1,334	24	1,546	28	1,458	27
Southwest	7,732	496	6	1,435	19	4,158	54	1,167	15	472	6
Total	25,193	2,126	9	6,278	25	9,109	36	4,136	16	3,560	14

[a]Estimates are based on the data available from the Soil Survey Project of Pakistan (8) and other exploratory surveys. This estimate does not include hill areas, sunderbans, active flood plains, channels of major rivers, and urban land.

Land Use and Crops

Topography and flooding depth determine to a large extent the pattern and intensity of cropping. Other factors like rainfall pattern, soil permeability, dry season moisture storage, irrigation facilities, and population density also have important influences on land use.

Land Use Intensity

The land use intensity[1] is 94 percent in Bangladesh (Table 2.4). However, it varies from 93 percent in Dinajpur to 99 percent in Comilla (28). The near absence of unused cultivable waste land (2 percent) decisively excludes the option of extensive cultivation as an important policy variable.

Relative Importance of Crops

Bangladesh grows a wide variety of crops. Among the crops grown, rice is by far the most dominant both in terms of acreage under this crop and its contribution to GNP. Rice accounted for about 78 percent of the cropped area in 1967-68 (Tables 2.4 and 2.5). The total area under rice increased from 21.1 million acres in 1960-61 to 25.6 million acres in

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[1]Land use intensity =

$$\frac{\text{Net sown area (cultivated area - current fallow)}}{\text{cultivable area}} \times 100$$

Table 2.4. Land utilization in Bangladesh, 1955-1968.

Item	Average of 5 years (1955-56 to 1959-60)	Average of 5 years (1960-61 to 1964-65)	1967-68
	Million acres		
Forest	5.46	5.46	5.54
Uncultivable Area	5.59	5.97	6.24
Cultivable Waste	1.95	1.82	1.03
Uncultivated Area	13.00	13.25	12.81
Net Cropped Area	20.33	20.98	21.75
Current Fallow	1.32	0.93	0.73
Cultivated Area	21.65	21.91	22.48
Total Cropped Area	25.91	27.88	31.44
Cropping Intensity (%)[a]	128%	133%	145%
Land Use Intensity (%)[b]	86%	88%	94%

Source: Compiled from: East Pakistan (now Bangadesh), Bureau of Statistics, Statistical Digest of East Pakistan No. 5 (Dacca: Bureau of Statistics, 1968).

[a] $\frac{\text{Net cropped area}}{\text{Total cropped area}} \times 100$

[b] $\frac{\text{Net cropped area}}{\text{Total cultivable area (i.e., cultivated area plus cultivable waste)}} \times 100$

Table 2.5. Area under principal crops in Bangladesh, 1960-61 to 1969-70.

Year	Rice			Jute	Pulses	Oilseeds[a]	Potato	Wheat	Sugar-cane	Tobacco
	Boro	Aus	Aman							
	Million acres									
1960-61	1.01	6.30	14.58	1.52	0.82	0.59	0.14	0.14	0.28	0.10
1961-62	1.00	5.87	14.08	2.06	0.80	0.61	0.14	0.15	0.29	0.11
1962-63	1.07	6.19	14.22	1.72	0.63	0.58	0.14	0.18	0.32	0.10
1963-64	1.07	6.59	14.60	1.70	0.56	0.52	0.14	0.14	0.35	0.10
1964-65	1.05	6.64	15.11	1.66	0.77	0.52	0.14	0.13	0.36	0.10
1965-66	1.14	7.32	14.67	2.09	0.85	0.50	0.15	0.14	0.38	0.11
1966-67	1.39	6.96	14.06	2.33	0.87	0.53	0.17	0.18	0.41	0.11
1967-68	1.53	8.22	14.68	2.40	0.79	0.59	0.19	0.19	0.41	0.11
1968-69	2.02	7.66	14.40	2.22	0.92	0.64	n.a.[b]	0.29	0.41	0.11
1969-70	2.18	8.46	14.84	2.46	n.a.[b]	n.a.[b]	0.21	0.28	0.50	n.a.[b]

Sources: 1) East Pakistan (now Bangladesh), Bureau of Statistics, Statistical Digest of East Pakistan, No. 5 (Dacca: Bureau of Statistics, 1968); 2) East Pakistan (now Bangladesh), Planning Department, Economic Survey of East Pakistan, 1969-70 (Dacca: Planning Department, 1970).

[a]Does not include minor oilseeds like sesamum, cotton seed and linseed.

[b]Not available.

1969-70. The absolute amount of increase in acreage under rice is higher than the combined increase of acreage under all the rest of the crops.

Of the three seasonal rice varieties, aman rice is the major crop. It occupied 58 percent of the total acreage under rice in 1969-70 followed by aus rice with 33 percent and boro rice with 9 percent (Table 2.6). Within the aman rice variety, transplanted (t) aman represents 65 percent of the total aman area compared to 35 percent under broadcast (b) aman. Most of the increase in rice area during 1965-70 was gained by boro and aus rice. However, the rate of increase in the area under boro rice was greater than that under aus rice. The acreage under rice is fairly well distributed throughout the country. Most of the country has rice acreage varying from 70 to 90 percent of the respective cropped acreage.

Jute is the second most important crop. It occupied 7.6 percent of the cropped area in 1967-68. It is the most important cash crop and the biggest foreign exchange earner in the country. The acreage under jute increased from 1960-65 average of 1.73 million acres to 1965-70 average of 2.28 million acres.

Important minor crops include pulses, oilseeds, potato, wheat, sugarcane, and tobacco. The combined area under these crops constituted about 8 percent of the cropped area in 1967-68 (Tables 2.4 and 2.5). Among the minor crops,

Table 2.6. Paddy-area and production in Bangladesh, 1969-70.

Crop	Area		Production	
	Million Acres	Percent of Total	Million Tons	Percent of Total
Boro	2.2	8.5	2.9	16.1
Aus	8.5	33.2	4.5	25.1
B. Aman	5.2	20.2	3.3	18.4
T. Aman	9.7	38.1	7.1	40.4
Total	25.6	100	17.8	100

Source: East Pakistan (now Bangladesh), Planning Department, <u>Economic Survey of East Pakistan 1969-70</u> (Dacca: Planning Department, 1970) pulses occupy the largest area closely followed by oilseeds. Rape and mustard represent over 65 percent of the total area under oilseeds. During 1965-70, the area under pulses showed an erratic trend while the area under oilseeds registered some increase. Potato and wheat occupy a relatively small area but acreage under these crops is steadily rising. Sugarcane and tobacco are important cash crops only in some limited areas.

According to the Agricultural Census (72), 80 percent of the land was under crops during the Aus and Aman seasons in 1960 leaving only 20 percent under crops during the Boro season. In spite of some gain in acreage by boro and aus rice, there was no significant change in the proportion of seasonal distribution of area under crops during 1965-70.

Cropping Intensity and Pattern

Cropping Intensity

The cropping intensity[1] in Bangladesh steadily increased from 128 percent in 1955-60 to 145 percent in 1967-68 (Table 2.4). The development of irrigation, drainage, and flood protection facilities is likely to cause more rapid increase in cropping intensity in the 1970's.

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[1]Cropping intensity =

$$\frac{\text{Total cropped area}}{\text{Net cultivated area (total cultivated minus current fallow)}} \times 100$$

Cropping Pattern

The existing cropping pattern in Bangladesh has evolved by an interaction of crop variety, climatic, soil, topographic, and hydrologic factors. Topography in relation to the level of flooding, however, appears to be the major determinant. Four important cropping patterns as related to topography may be identified as follows.

Cropping Pattern on High Land.--In this land, which is either not flooded or flooded less than one foot, t. aman rice is the important Aman season crop. B. aus rice is grown in areas having relatively permeable soil. In some areas, b. aus rice is followed by t. aman rice. Oilseeds, pulses, and fruits are important Boro season crops in many areas under this land. This type of land occupies 25 percent of the area (Table 2.3).

Cropping Pattern on Medium Land.--Medium land is usually flooded 1 to 3 feet and is the most intensively cropped in the country. The dominant pattern includes aus rice or jute in the Aus season followed by t. aman rice in the Aman season. In some areas, after the harvest of b. aus rice or jute, land remains fallow until December when oilseeds, pulses, and other minor Boro season crops are grown. This type of land represents 36 percent of the area (Table 2.3).

Cropping Pattern on Medium Low Land.--Medium low land includes mainly ridges and basin margins and occupies 11 percent of the area (Table 2.3). The flooding depth in this land ranges from 3 to 6 feet. B. aman rice or mixed aus and aman rice are the principal crops. Jute is also grown in many areas. A substantial portion of ridges are used for minor Boro season crops.

Cropping Pattern on Low Land.--Low land is deeply flooded and constitutes 14 percent of the area. Those areas having flood depths from over 6 feet to about 12 feet are used for t. aman rice followed partly by Boro season crops, especially pulses. In those areas having flood depths beyond 12 feet, a single crop of boro rice is grown depending on the residual water and irrigation. A portion of this type of land remains uncultivated and is used for grazing.

Development Potentials of Crops

Land capability potentials in Bangladesh can be identified on the basis of the detailed information on soil properties, topography, flood depth, drainage, and other hydrologic conditions available from the FAO/UNDP assisted Soil Survey Project and other exploratory surveys. The report of the Soil Survey Project (8) indicates that the physical potential is fairly high for many crops, especially rice and jute.

Traditional seed varieties have limited potentials in terms of increasing the productivity. Until 1965-66, Bangladesh was dominated by traditional seed varieties. From 1967-68, a major breakthrough occurred in the rice seed varieties and opened up the opportunity of a substantial increase in the production of rice.

New Seed Technology

The first major breakthrough in rice seed technology came in the form of the IR-8 variety suitable for Boro season. This HYV was tested under Bangladesh field conditions and was found to yield an average of over two tons of paddy per acre as compared to less than one ton per acre from local varieties. The IR-8 variety was introduced to farmers in 1967-68 and the area under this variety expanded to about half a million acres by 1969-70. The major deficiencies of this variety were: a) a longer growing season than the local varieties, b) susceptibility to infestation with tungro virus and bacterial leaf blight, and c) damage due to cold if planted early.

A major breakthrough in the aman rice variety was IR-20. In 1970, this variety was grown as t. aman rice on 170,000 acres. The average yield was reported to be 43 maunds. The rate of adoption of the IR-20 variety was quite high and over 600,000 acres were planted with this variety in 1971.

The HYV, IR-532-1-176 (Chandina) underwent intensive testing under Bangladesh field conditions and showed good potential as t. aus rice in the Aus season and replacement of IR-8 in the Boro season. It matures 20-30 days earlier than IR-8. It has more pest and disease resistance than IR-8 and good grain quality.

Other HYV's which showed good promise are IR-272-4-1-2 as b. aus rice in the Aus season and IR-442 as b. aman rice for areas with a flood depth of 3-5 feet.

A large number of field trials indicate that the jute yield can almost be doubled from its existing level to 28 maunds per acre by using the available jute technology package which includes an improved local variety, timely sowing, line sowing, fertilizer, and plant protection. Under the climatic conditions of Bangladesh, the dwarf (Mexican) HYV of wheat did not perform well. A new variety, Sonalika developed by the International Maize and Wheat Breeding Center in Mexico has some promise. But it has to be tested intensively before its introduction to farmers in Bangladesh. The available seed technology in potato is enough to increase the existing yield per acre by using modern inputs and improved cultural practices. Varietal improvements in oilseeds and pulses are completely lacking in Bangladesh at present and no improvement is in sight in the near future.

Table 2.7. Low-lift pump irrigation in Bangladesh, 1960-61 to 1969-70.[a]

	Number of Pumps in Operation	Average Cusec Capacity per Pump	Total Acres Irrigated	Acreage Irrigated per Cusec
1960-61	1,267	n.a.[b]	64,528	n.a.
1961-62	1,543	n.a.	98,163	n.a.
1962-63	2,024	1.70	133,043	38.5
1963-64	2,456	1.85	156,281	34.1
1964-65	2,238	1.95	131.129	30.0
1965-66	3,420	2.05	173,553	24.6
1966-67	3,990	2.14	225,105	26.4
1967-68	6,558	2.08	317,903	23.3
1968-69	10,852	1.89	424,799	20.7
1969-70	17,844	1.84	639,000	19.6

Source: East Pakistan (now Bangladesh), Agricultural Development Corporation, Annual Report for 1969-70 (Dacca: ADC, 1970).

[a]Does not include the low-lift pumps (small in number) operated under WAPDA projects.

[b]Not available.

Present Status and Growth of Low-Lift Pump Irrigation

The low-lift pumps under operation in Bangladesh consist of centrifugal pumps powered by diesel engines. Both pump and engine are mounted on a trolley. These pumps, in general, have a static lift capability of up to 30-40 feet. Most of the low-lift pumps are of 2 cusec capacity each, though there are small numbers of pumps of 1, 3, and 5 cusec size. The average capacity of the pumps used in 1969-70 was 1.84 cusecs (Table 2.7). The projection of the Agricultural Development Corporation (ADC)[1] indicates that the pumps of 2 cusec capacity will continue to be predominant in the future (16). For the purpose of this study, a low-lift pump is assumed to be of 2 cusec capacity.

In 1969-70, 17,844 pumps were used to irrigate 639,000 acres (Table 2.7). Of the three types of irrigation available in Bangladesh, namely, low-lift pump, tubewell, and gravity flow, low-lift pump irrigation accounted for about 79 percent[2] of the total irrigated area in 1969-70. The proposed irrigation program of the Government of Bangladesh indicates that the low-lift pump irrigation will continue to be dominant for at least the next 10 years.

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[1]ADC is a semi-government (autonomous) agency in Bangladesh.

[2]Estimated from information available in (36) and Table 2.7.

The low-lift pump irrigation with 50 pumps was introduced in the country in 1951-52. During the 50's, the pump irrigation, although it increased considerably, remained at a low level with only 1150 pumps irrigating 47,370 acres in 1959-60 (19). Low-lift pump irrigation increased substantially from 64,528 acres in 1960-61 to 317,903 acres in 1967-68, representing an annual rate (simple average) of growth of 42 percent (Table 2.7). However, the most remarkable expansion in the pump irrigation occurred during 1967-70 both in terms of absolute increase and rate of increase. The area irrigated by pumps rose by a total of 413,895 acres in 1969-70 over the area irrigated in 1966-67, representing an annual growth rate (simple average) of 61 percent. Several factors responsible for the phenomenal expansion in the pump irrigation during 1967-70 can be identified. First, pump irrigation formed one of the most important strategies in the program for attaining self-sufficiency in food grains (29). Second, a new institutional arrangement in the form of Thana Irrigation Program[1] was put into operation from 1967-68. Third, the Government gave a strong financial and administrative support to the low-lift pump irrigation. Fourth, the HYV's of rice with their vastly increased productivity probably created a strong incentive for the adoption of irrigation by farmers.

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[1]For detailed description of the Thana Irrigation Program, see p. 52.

Surface Water Supplies and Potentials for Low-Lift Pump Irrigation

The expansion of low-lift pump irrigation is contingent on the supplies of surface water. In the 50's and 60's static bodies of water[1] were the major source of surface water utilized by the low-lift pumps. However, a high potential for the expansion of low-lift pump irrigation lies in the utilization of rivers. With the greater part of the usable static bodies of water already under utilization of low-lift pumps, most of the future expansion in pump irrigation is expected to depend on the water supplies from river flows.

The use of rivers for the low-lift pump irrigation is limited by the flows of rivers in the critical months of March and April when there is peak demand for irrigation water. Another limitation to the use of rivers lies in the large sand accretions between the bank and channel. The Padma and the Brahmaputra, two of the three major rivers in the country, are braided with shifting channels. The channels containing flows during the dry season are isolated from cultivated lands by wide sand banks in some locations. The typical low-lift pump (2 cusec size) under operation in

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[1]Haor is one of the important static sources of water. Haor is the depressed water filled areas. During the monsoon period, water is too deep to grow any crop. During the dry season, these areas have enough water to use low-lift pump irrigation for growing Boro season crops.

Bangladesh can not be used in such locations. Finally, the requirements of the flow of water for navigation, household use, fisheries, and insurance against salinity penetration impose an important limitation to the use of rivers. The utmost caution through careful planning of the use of river water is needed because an overuse of river flows is most likely to result in a socially unacceptable externality.

Based on the information available from WAPDA (33, 37, 38), it may be estimated that about 2100 miles of the bank (each side) and 800 miles of cut bank (total bank line) of rivers where the flows are adequate for placing 10 low-lift pumps per mile of river bank (both sides). The data available from these sources also indicate that 6000 cusecs of water (60 percent of lowest flow) may be utilized from those rivers where low flows are considered inadequate to support the operation of 10 pumps per mile of river bank (both sides). An estimated total of 28,000 low-lift pumps of 2 cusec capacity each may, therefore, be put under operation depending on the supplies of water from rivers.[1] But a much larger number of pumps up to about 40,000 could be used depending on this same source of water if the criteria of estimates are adjusted slightly[2]. The use of this

[1]The use of 28,000 pumps is estimated as follows: (2100 x 10) + (800 x 5) + (6000 ÷ 2).

[2]The adjustment might take the form of 1) 60 percent lower quartile flow and 2) an increase in the density of pumps per mile of river bank. A discussion with experts of the World Bank also indicated the use potential of 40,000 pumps.

increased number of pumps should, however, be subject to further investigation in order to avoid any unacceptable externality.

Administrative and Institutional Arrangements

The Directorate of Agriculture was in charge of the low-lift pump irrigation program when it was started in 1951-52. This agency continued to operate the program up to 1962 when ADC took over the responsibility for the operation of the program. Under the ADC, the pump irrigation expanded relatively rapidly, from 98,163 acres in 1962-63 to 225,105 acres in 1966-67 (Table 2.7). The expansion of pump irrigation was given one of the top-most priorities in attaining self-sufficiency in food production and a new institutional set-up was devised to accelerate further the rate of expansion of pump irrigation. This new institutional set-up was the Thana Irrigation Program (TIP) established in 1967-68. Since the TIP is considered to be a major institutional innovation contributing to the phenomenal increase in the pump irrigation from 1967-68, we focus on some of its major elements in the following section.

Thana Irrigation Program (TIP)

The Thana Irrigation Program provides organization and coordination at the thana, union, and village level for the use of irrigation facilities, other inputs, and technical knowledge. Under the situation in Bangladesh where an average farm of 3.5 acres is fragmented into several pieces, the utilization of a low-lift pump involves the participation of an average of 20 to 40 farmers. The formation of pump groups is, thus, crucial for pump irrigation.

The main features of the TIP are the institutional arrangements and administrative linkages under which farmers are organized into pump groups by their local leaders; and the government agencies and semi-government organizations at the thana level closely coordinate their activities to provide to the pump groups pumps, required physical inputs, training, and technical assistance. It also provides a feedback mechanism among the officials and farm irrigators.

The Thana, which is the lowest administrative unit of the government, serves as the central place. The Thana Training and Development Center (TTDC) located at the thana provides offices for most of the agriculture related agencies. At the TTDC, members of the thana council, consisting of government officials and public representatives, meet for coordination and planning, farmers are given training, pumps are stored, and repairs are carried out. At the farmers' level, the union councils and ward committees are responsible for organizing farmers into groups. After its formation, a pump group becomes collectively responsible for making detailed arrangements for irrigation like making field channels, collection and payment of rental, transportation of the pump to the pump site, and paying for fuel.

The TIP does not replace any established government or semi-government agencies. Of the three major agencies, ADC remains as the supplier and maintainer of pumps; WAPDA continues to provide technical assistance in hydrology and planning of irrigation projects, and to supply water from larger projects; and the Agriculture Directorate retains its role of supplier of technical agricultural knowledge. Under the TIP organizational framework, these agencies effectively coordinate their activities and deliver their services more efficiently.

Pattern of the Utilization of Low-Lift Pump

One of the noticeable features in the utilization of pumps is the small area irrigated per cusec and the short hours of operation. The area irrigated per cusec was 19.6 acres (i.e., 39.2 acres per 2 cusec pump) in 1969-70. However, it showed almost continuous decline (except in 1966-67) from 38.5 acres per cusec in 1962-63 (Table 2.7). According to the Evaluation Reports on the TIP (68, 69), a low-lift pump was run an average of 6.28 and 6.30 hours per day in 1968-69 and 1969-70 respectively. Assuming a peak water demand of 10 inches a month and running of a low-lift pump for a little over 16 hours, an area of 100 acres could be irrigated by a 2 cusec pump. However, due to topographical factors, shorter critical period of peak water demand (i.e., a fortnight instead of a month) and other considerations, a command area of 100 acres by a 2 cusec pump may not be a realistic target. But the command area of 39.2 acres by a 2 cusec pump and operation of pumps for 6.3 hours a day certainly represents a heavy underutilization of the available pump capacity. Lack of emphasis by the government to increase the rate of utilization might be an important reason for the existing underutilization of capacity. Rinnan (84) observed that too much attention was concentrated on the number of pumps under operation. Even the fixation by the government of the minimum command area at 15 acres per cusec in 1968-69 and 20 acres per cusec in 1969-70 demonstrated the bias toward the increase in the number of pumps under operation.

Another feature of pump utilization in Bangladesh lies in its distribution among seasons and geographic regions. The low-lift pump was first introduced in the country for irrigation in the haor areas during the Boro season. And until 1966-67, pumps continued to be used exclusively during the Boro season. However, from 1967-68 to 1969-70, a limited number of pumps were used during the Aus and Aman seasons. ADC projected the use of 5000 pumps in the Aus and Aman seasons out of the total utilization target of 40,000 pumps in 1974-75 (16).

Low-lift pumps were heavily concentrated in 5 districts, Mymensingh, Sylhet, Comilla, Dacca, and Chittagong. An important reason for this concentration appears to be the emphasis of the use of haor areas as the major source of water. However, low-lift pump irrigation expanded rapidly in other districts from 1968. The share of the area under pump irrigation in the 5 districts mentioned above declined from about 84 percent in 1967-68 to 64 percent in 1969-70 (69, 20).

Rental and Subsidization Policy

Until 1965-66, a rental rate of 37 takas was charged for irrigation per acre with fuel provided free to pump groups. This rate was reduced to 30 takas from 1965-66. The rental arrangement was changed in 1967-68 to a flat rate charge of 250 takas per pump with the pump group paying for the fuel. The flat rate per pump was, however, proposed to be increased gradually.

Low-lift pump irrigation in Bangladesh has been heavily subsidized. Mohammad (67) estimated the rate of subsidy at about 77 percent per acre in 1966. Under the TIP rental arrangement, the rate of subsidy increased to about 95 percent. Unless the level of rental is increased, the rate of subsidy will continue to remain at a very high level.

CHAPTER III

LINEAR PROGRAMMING MODEL AND THE TYPICAL FARM

In the first part of this chapter, a linear programming model is set forth to analyze the impact of irrigation. The return to irrigation depends on the way farmers allocate their limited resources among alternative activities for maximizing their objective function. Linear programming is an efficient tool for obtaining estimates of optimum allocation in a problem involving several resource restrictions and alternative activities.[1] The application of linear programming involves the accurate estimate of input-output coefficients, prices of inputs and outputs, constraints, and alternative activities. The 'typical' farm containing these estimates has, therefore, been developed in the latter part of this chapter. This 'typical' farm is then analyzed using linear programming technique.

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[1]For detailed discussion on the linear programming see (15), (42), and (45).

Linear Programming Model

A profit maximizing linear programming model is used to determine the return to irrigation and to identify the impact of changes in some important variables. This model is used rather than conventional budgeting technique because this study involves the consideration of a large number of alternatives. Profit maximization is selected over cost minimization because it seems more realistic that farmers in Bangladesh are generally concerned with the increase of their profit.

The Assumptions

The standard assumptions made in linear programming technique are: Linear relationships of input-output, output-output, and input-input; and constant unit product prices and costs. These assumptions do not overly restrict the model or make it unrealistic. Based on the existing information, the assumption of linear relationship will, in general, hold specifically because the size range for farms and low-lift pump remain constant in the study and the inputs of fertilizer, pesticide, and seed are generally neutral to scale. Future relative prices are always uncertain. But the present relative prices are usually fairly good indicators of future prices. In addition to the assumption of linearity, other assumptions made for the linear programming include additivity, divisibility, finiteness, and single value expectation (45, pp. 17-18).

The Objective Function

The objective of the model is to maximize net returns by allocating resources of the 'typical' farm among alternative land uses subject to the farm's resource constraints. Specifically, the linear programming model used here will answer the following questions:

1. The magnitude of net returns when resources are optimally allocated subject to the constraints.
2. Particular crop activities or combination of crop activities to be undertaken.
3. The effect of varying important variables like yield, prices, costs, etc. on crop activities and net return.
4. The marginal value produce of the limiting resources.

The objective function of the model is:

(1) $R_o = Y_i X_i - C_i L_i - H_i B_i$

where:

R_o = objective value

Y_i = net return (gross return minus variable costs on account of seed, fertilizer, pesticide, interest, and irrigation) per acre from i th crop activity.

X_i = level of i th crop activity

C_i = cost of labor hiring activity per unit (Manday) for i th crop activity.

L_i = level of hired labor for i th crop activity.

Y_i = cost of bullock power hiring activity per unit (bullock-pair day) for i th crop activity.

B_i = level of hired bullock power for i th crop activity.

The Constraints

The objective function is to be maximized subject to the specified constraints. A 'typical' farm has fixed amount of land, labor, bullock power, and savings. In addition, his crop production environment might impose some special constraints.

The fixed farm resources available over a year are converted into monthly constraints for 9 months and fortnightly constraints for 3 months of December, April, and August when harvesting of one crop and sowing of another overlap. The distribution of fixed resources of the farms in this manner is done in order to reflect the critical importance of seasonal nature of demand for resources and to enable the model to capture the timeliness of harvesting and sowing of crops.

The levels of constraints are estimated on the basis of available studies and reports concerning the resource ownership position of farmers in Bangladesh.[1] The available

[1]References to the studies and reports are mentioned in the latter part of this chapter where estimates for 'typical' farm are developed.

data were also supplemented by the author's personal knowledge of the farming operations in Bangladesh.

Land Constraint

(2) $\Sigma a_{ij}\ x_i \leq \Sigma d_{ij}$

where:

a_{ij} = requirement of jth land for ith crop activity

x_i = level of ith crop activity

d_{ij} = jth land available for ith crop activity

The average cultivated area per farm is 3.1 acres in Bangladesh (72). In this study, therefore, level of land constraint is assumed to be 3 acres per farm. A farmer might increase or decrease the size of his farm by buying or selling land. Since land is physically fixed, buying and selling will merely be transfer from one to another and the average size might remain constant. The implication of land being completely fixed is that it will exert one of the most limiting influences on the operation of the model.

Labor Constraint

(3) $\Sigma l_{ij} x_i \leq \Sigma (l_{fij} + l_{hij})$

where;

l_{ij} = requirement per acre of jth labor for ith crop activity

x_i = level of ith crop activity

l_{fij} = jth family labor available for ith crop activity

l_{hij} = jth labor hired for ith crop activity.

The number of family labor available is determined mainly by the size of farm family. The family labors consist of adults and minors, both male and female on full or part time basis. According to Agricultural Census (72, p.), the average size of farm family consists of 6 members. Based on information on part and full time work of farm family, it is estimated that a 'typical' farm has labor available of two full time adult equivalent.[1] Farmers also tend to work more hours a day during the peak labor demand period. Farmers are thus, assumed to work 28 days a month for peak demand period of December, April, and August, and 25 days a month for the rest of the year (Table 3.1). Unlike land, the supply of labor is not completely fixed to farms. An individual farmer has the opportunity to hire labor as long as he is willing to pay the market wage rate. Since most of the labor hiring is likely to be concentrated in the months of peak demand, the market wage rate is expected to rise during those months. The higher wage rate for peak demand periods is reflected in the model and it will exert its constraining influence within the operation of the model. The total amount of labor to be hired will also be determined within the model subject to the condition of profit maximization.

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[1]A man day of work is assumed to equal 8 hours.

Table 3.1. Estimated fixed farm resources for the "Typical" farm, Bangladesh.

Months	Land (Acres)	Family Labor (Man Days)	Bullock Power (Pair Days)	Water Supply from LLP (Acre Inches)
January	3	50	28	58
February	3	50	28	58
March	3	50	28	58
April (1st half)	3	28	15	29
April (2nd half)	3	28	15	29
May	3	50	28	58
June	3	50	28	58
July	3	50	28	58
August (1st half)	3	28	15	29
August (2nd half)	3	28	15	29
September	3	50	28	58
October	3	50	28	58
November	3	50	28	58
December (1st half)	3	28	15	29
December (2nd half)	3	28	15	29

Bullock Power Constraint

(4) $\Sigma b_{ij}x_i \leq \Sigma(b_{fij} + b_{hij})$

where:

l_{ij} = requirement per acre of jth bullock power for ith crop activity.

b_{fij} = jth family bullock power available for ith crop activity.

b_{hij} = jth hired bullock power for ith crop activity.

According to Agriculture Census (72), a farm family in Bangladesh owned an average of two work animals. In this study a 'typical' farm is assumed to have one pair of bullock.[1] As in the case of labor, bullock power has also a highly seasonal demand. The bullocks are assumed to work 30 days a month during December, April, and August having peak demand and 28 days a month during the rest of the year. An individual farm operator has the option to hire bullock power if he is willing to pay the hire charges. A higher rate of hiring is assumed for the peak demand period and its constraining influence is determined within the model.

Irrigation Water Constraint

(5) $\Sigma W_{ij}x_i \leq \Sigma(W_{rij} + W_{pij})$

where:

W_{ij} = requirement per acre of jth water for ith crop activity.

x_i = level of ith crop activity.

[1]The bullock power is measured in terms of bullock-pair day. A day is equivalent of 8 hours.

W_{yij} = jth water available from rainfall for ith crop activity.

W_{pij} = jth water supplied by low-lift pumps for ith crop activity.

A low-lift pump is designed to work 24 hours a day under conditions of efficient operation and maintenance as recommended by manufacturers. However, considering the problem of maintenance and repair in Bangladesh, it is assumed that a low-lift pump can run a maximum of 16 hours a day for 30 days a month. Even 16 hours of working per day appears to be high in view of 6.3 hours of working per day in 1969-70 (69, p 85). The assumption is, however, considered feasible because a pump will have to be operated for 16 hours a day if at all, for only a limited period to meet the peak water demand[1], especially in December and April. Accordingly, a total of 960 acre inches of water can be supplied by a 2 cusec low-lift pump to meet the requirement of irrigation.

Cropping Intensity Constraint

(6) $\Sigma\, c_i x_i \leq 2.5$ (acres)

where:

c_i = ith crop grown in one acre of land in a year.

x_i = level of ith crop activity in one acre of land in a year.

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[1]Irrigation requirements have been estimated in Chapter IV.

Bangladesh had an average cropping intensity of 145 percent in 1967-68 (Table 2.4). The provision of irrigation is expected to increase substantially the cropping intensity. In this study, the maximum cropping intensity to be attained is assumed at 250 percent. Lack of soil moisture, flooding depth, and maturity period of crops may be identified to be the most important physical constraints on the increase in cropping intensity. The provision of irrigation removes the soil moisture constraints. As the 'typical' farm is assumed to be located topographically on the medium land, flooding depth will not normally be a problem. However, the maturity period of crops is likely to continue as an important limiting factor. For example, the HYV of boro rice (IR-8) has a maturity period of over four months (130-140 days). Also, the maturity period of of IRRI aus rice is longer than the local varieties. Islam in his study concerning the impact of irrigation on cropping pattern (52, p. 35) found that only one out of 25 farmers could achieve a cropping intensity of 276-300 percent. The attainment of 300 percent or close to 300 percent cropping intensity, thus, will be rare, if at all. On the other hand, medium land physically has potential for higher cropping intensity than high or low land. At present, it is also the most intensively cropped land in Bangladesh (31). Considering all these factors involved, the assumption of 250 percent cropping intensity under irrigated conditions seems realistic.

Constraint for the Provision of Aus Rice for the Consumption of Farm Family

During the Aus season, jute and aus rice mainly compete for land. Two considerations seem to weigh heavily on the farmers' decision making during this season. One is that a farmer likes to have at least a major portion of rice required for the consumption of his family between the period of aus and aman rice harvests. In general, a farmer is unlikely to take risk with the survival of his family by not planting any portion of his land under aus rice. The other consideration is that jute is generally the most important cash crop for farmers. In this study, we assume that a farmer will at least allocate 25 percent of his land to aus rice during the Aus season.

Credit Constraint

Credit constraint is not explicitly incorporated into the model by putting it on the right hand side. However, its constraining influence is recognized in the study and can be traced in three ways. First, credit requirement has been estimated based on certain specified proportion of input cost for different crop activities. Thus, crops with high input costs have high credit requirements. Second, a proportion of credit is assumed to be supplied from non-institutional sources at a high interest rate. Third, the estimated level of relatively high interest cost affecting net return of crops used in the model exerted the constraining influence.

Special Constraints for Unirrigated Condition

The constraints with respect to land, labor, bullock power, credit, and the minimum quantity of aus rice for the consumption of family as discussed before are equally applicable to the unirrigated condition. However, the cropping intensity without irrigation is expected to be much lower than it would be with irrigation because the availability of soil moisture is the crucial variable affecting the cropping intensity. In the past, cropping intensity without irrigation increased at a slow rate. The average cropping intensity increased from the 1955-60 average of 128 percent to only 133 percent, the average of 1960-65[1] (Table 2.4). Accordingly, in this study, the cropping intensity of the 'typical' farm under unirrigated condition is assumed not to exceed 170 percent, an increase of 10 percent within the period under consideration (Table 3.2). With respect to combinations of crop enterprises under unirrigated condition, the existing relationships among various crops are assumed to hold. This assumption may be justified on two grounds.

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[1]Up to 1965, irrigation was quite negligible in the country.

First, for the purpose of explaining the existing crop combinations under unirrigated condition, we accept the Schultzian hypothesis (88, p. 37) that "there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture." In line with this hypothesis[1], we assume that the farmers in

Table 3.2. Estimated crop enterprise combinations for the 'typical' farm under unirrigated condition, Bangladesh.

(Acres)

	Local Aman Rice[a]	Local Aus Rice	Jute	Wheat	Oil-seeds[b]	Pulses	Total
Existing	2.45	1.35	0.48	0.06	0.26	0.20	4.8
Future[c]	2.55	1.46	0.49	0.06	0.26	0.28	5.1

[a]Local aman rice is entered into the model as two separate activities, local b. aman and local t. aman.

[b]Oilseeds are entered into the model as two separate activities, rape and mustard, and groundnut.

[c]Starting from the fifth year.

Bangladesh under the existing technology and resource ownership position tends to allocate efficiently their lands among various crop enterprises under unirrigated condition. Second , since no significant variable affecting the crop production environment is introduced without irrigation, it is reasonable to expect that there will hardly be any change

[1]Khan's study (58) indicates the validity of this hypothesis in Bangladesh.

in the existing relationships among the crop enterprises without irrigation during the period under consideration. For the purpose of this study, the estimated combinations of crop enterprises under unirrigated conditions are presented in Table 3.2.

In addition to the constraints as mentioned before, three accounting equations with respect to labor, bullock power, and irrigation requirements have been put into the model. The purpose of putting these equations in the model is to get additional information on the actual amount of hired labor, hired bullock power, and irrigation water used.

The Activities

The model includes two types of activities: the crop production and the resource hiring activities. The crop production activities include 12 crops with irrigation and 8 crops without irrigation as the basic land use alternatives. These crops are taken to represent most of the crops grown by a 'typical' farm in Bangladesh. Rape and mustard, and groundnut[1] serve as proxy for all kinds of oilseeds, and khesari pulse[2] serves as a proxy for all kinds of pulses.

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[1]Rape and mustard, and groundnut constitute 73 percent of total area under oilseeds in 1967-68.

[2]Khesari pulse constitutes 24 percent of total area under pulses in 1966-67. Of the various kinds of pulses, khesari has the single highest acreage under it.

Two of the minor cash crops, sugarcane and tobacco are not included in the model activities because these crops are highly localized. Moreover, sugarcane which occupy land for most of the year is assumed to be less likely to be produced on lands where two or more than two crops can be produced. Other minor crops constitute a very small area and no change occurred in the production technology of these crops. Therefore, it is assumed that the impact of these crops will continue to be negligible.

Some of the crop activities are differentiated on the basis of technology. A technological breakthrough in the form of high yielding varieties of seed has been achieved for rice.[1] Therefore, technological differences with respect to rice in the form of IRRI and local varieties are used in the model. Thus, same rice in each season appears as two separate activities in the model.

The resource hiring activities include the hiring of labor and bullock power. These resources are hired only when these are needed beyond the supply available from the fixed farm resources.

The Typical Farm

The development of a 'typical' farm involves the estimates of input-output relationships, prices of inputs and outputs, net returns obtained from different crop

[1] For detailed discussion, see Chapter II.

enterprises, and 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 hypothetical farms by using estimates based on data the researcher feels are most relevant under the specified conditions. The synthetic farm developed here is designed to be 'typical' under the physical and economic environment it operates. This is 'typical' in the sense that it displays identical internal and external characteristics with respect to resource ownership position, production facilities, input-output relationship, and input and product market situation.

The estimates were made by examining data from a number of sources and making judgments based on these data. The data were obtained from many sources: published and unpublished reports and studies from 1) Government Ministries (11, 23, 24, 25, 27, 51, 53, 71, 72); 2) semi-government agencies like ADC and WAPDA (16, 17, 18, 20, 30, 31, 34, 36); and 3) educational and research institutes, e.g., Mymensingh Agricultural University, Bangladesh Academy for Rural Development, and Bangladesh Institute of Development Economics (47, 50, 52, 56, 58, 66, 67, 68, 69, 77, 78, 79). In some instances, it was necessary to make estimates based on limited information. For example, IRRI aus and aman rice being relatively recent, limited data were available to make estimates about these crops. The estimates developed on the basis of above sources of information were then compared with the similar estimates made by the World Bank in order to check accuracy, relevancy, and consistency.

Location

The 'typical' farm is assumed to lie within Bangladesh. However, the crucial qualifying assumption is that the farm lands are located topographically on the medium land having the surface water source for irrigation. This assumption is made so that farmers can choose among various crop production alternatives available in all the three crop seasons in a year based on their decision criterion of profit maximization. This assumption would, therefore, enable us to examine the implication of low-lift pump irrigation during three seasons. In the absence of this assumption, some physical constraints make cropping impossible in some seasons. For example, low and very low land physically preclude cropping in one or two of the three seasons, and high land is less likely to have surface water source to be used by low-lift pumps.

Fixed Farm Resources

The fixed resources available to the 'typical' farm impose restrictions in the process of profit maximization. These fixed resources are discussed in the sections under constraints. The availability of these resources divided among different time periods is presented in Table 3.1.

Input-Output Relationships and Prices of Inputs and Outputs

Under a given agronomic and physical environment, output is functionally related to the quantities of inputs used per unit of land. Inputs have both separate and joint (interaction) effect on yield. In addition, quality of inputs, timing of use, balance between different components of an input like NPK ratio with regard to fertilizer, and balance between inputs influence the input-output relationships of crops. In estimating the input-output relationships, all these aspects of input use and their impact on yield have been considered.

Prices of inputs and outputs discussed in this section are the market and administered prices faced by the 'typical' farm. After the emergence of Bangledesh as an independent nation in 1971, prices of the relevant inputs and outputs have been in the process of considerable change. The prices have not yet stabilized. Therefore, for the purpose of this study, the prices prevailing in 1969-70 have been used because 1969-70 is considered to be a normal year just before the independence. The use of 1969-70 prices is not likely to affect significantly the results of this study as it may be assumed that although prices have gone up considerably, the relationships among prices (relative prices) remain mostly unaffected.

Inputs

The important inputs in crop production activities in Bangladesh include human labor, bullock power, seed, fertilizer, pesticide, water, and credit.[1] In discussing the amounts of inputs needed for different crop production activities, no physical amounts for pesticide and seedlings could be used for lack of data on physical amount used and standard units of measurement.

Human Labor and Bullock Power.--The labor requirement for crops per acre under irrigated and unirrigated conditions are presented in Table 3.3 and 3.4. The period of sowing and harvesting represent the peak labor demand period. The type of crops grown and the technology used influence the amount of labor requirement. The potato is the most labor intensive followed by jute. The IRRI varieties of rice requires close to 50 percent higher amount of labor than the traditional varieties of rice under irrigated conditions. The bullock power is mostly used in land preparation and threshing. Unlike human labor, few bullock-pair days are needed in the interculture operations of crops. The demand for bullock power is, thus, relatively concentrated (Table 3.5). Because of seasonal peak demand, the wage per man day of human labor and rent per bullock-pair day are

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[1]Credit is an indirect input. Credit is required to buy other physical inputs. In that sense, it has a derived demand.

Table 3.3 Estimated labor requirement per acre under irrigated conditions, Bangaldesh.

Items	Rice						Man Days					
	IRRI Boro	IRRI T Aman	IRRI T Aus	Local Boro	Local T. Aman	Local B. Aus	Jute	Potato	Wheat	Mustard	Ground-nuts	Pul-ses
Raising of Seedlings	12	12	12	6	6	--	--	--	--	--		
Land Preparations	16	16	16	14	13	14	16	42[b]	14	12	13	5
Sowing/ Transplanting	13	13	13	11	11	1	1	20	1	1	16	1
Irrigation	2	2	2	2	2	2	2	2	2	1	2	1
Fertilizer and Manure Use	3	3	3	2	2	2	2	5	2	1	2	1
Spraying	2	2	2	1	1	1	1	3	1	1	1	--
Weeding	12	10	12	8	7	15	25	8	14	7	10	2
Harvesting and Carrying	16	15	15	12	12	11	18	25	12	11	28	10
Threshing, Win-nowing, Drying and Storing	16	14	16	10	10	10	30[a]	3	10	8	12	8
TOTAL	92	87	91	66	64	56	95	108	56	42	84	28

[a]Post harvest operations for jute include retting, taking off fibre, washing, drying, and storing.

[b]Includes ploughing and hilling.

Table 3.4. Estimated labor requirement per acre under unirrigated conditions, Bangladesh.

Items	Rice			Man Days				
	Local T. Aman	Local B. Aman	Local B. Aus	Jute	Wheat	Mustard	Ground-nut	Pulses
Raising of Seedlings	5	--	--	--	--			
Land Preparations	12	12	12	16	12	11	12	5
Sowing/ Transplanting	11	1	1	1	1	1	15	1
Irrigation	--	--	--	--	--	--	--	
Fertilizer and Manure Use	1	1	1	1	1	1	1	--
Spraying	1	1	1	1	1	1	1	--
Weeding	6	15	14	20	12	6	8	2
Harvesting and Carrying	10	10	10	17	10	8	25	8
Threshing, Winnowing, Drying and Storing	8	8	8	25	6	5	10	6
TOTAL	54	48	47	81	43	33	73	22

Table 3.5. Estimated bullock power requirement per acre under irrigated and unirrigated conditions, Bangladesh.

Item	Irrigated Condition			Unirrigated Condition		
	Pre-harvest	Post-harvest	Total	Pre-harvest	Post-harvest	Total
			Bullock-pair days			
IRRI Boro Rice	18	8	26	--	--	--
IRRI T. Aman Rice	18	8	26	--	--	--
IRRI T. Aus Rice	18	8	26	--	--	--
Local Boro Rice	16	6	22	--	--	--
Local T. Aman Rice	15	6	21	14	5	19
Local B. Aman Rice	16	5	21	12	5	17
Local B. Aus Rice	14	6	20	12	5	17
Jute	16	1	17	16	1	17
Potato	22	1	23	--	--	--
Wheat	14	5	19	12	4	16
Mustard	12	1	13	11	1	12
Groundnut	13	1	14	12	1	13
Pulses	5	1	6	5	1	6

estimated to be Tks 3.5 for peak demand period and Tks 2.5 for the rest of the year.

Fertilizer and Manure.--The types of fertilizer and manure used in Bangladesh include urea, triple superphosphate, muriate of potash and cowdung. Table 3.6 indicates that level of fertilizer use is much higher for irrigated and IRRI varieties of rice than the unirrigated and traditional varieties (36, 58). Potato and IRRI varieties of rice are the two heaviest users of fertilizer. In addition to the level of fertilizer used, balance in dosage is important for yield response to fertilizer. The pattern of fertilizer use indicates that there is no significant imbalance in fertilizer dosage in IRRI varieties of rice (58, 89).

The use of fertilizer increased steadily over years in Bangladesh. With the expansion of irrigation and IRRI varieties of rice, the rate of increase will be further accelerated. Most of the requirements of urea is produced internally and major portion of the triple superphosphate and muriate of potash is imported. Fertilizers are distributed by ADC through the decentralized channels extending to villages. It is expected that the supply of fertilizers will not be a constraint on their use by farmers. Fertilizers are subsidized by about 57 percent in Bangladesh (17). The subsidized prices of fertilizers are fixed per maund[1]

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[1]One maund equals 82.286 lbs.

Table 3.6. Estimated variable cost per acre used in the programming model for crops under irrigated conditions, Bangladesh.

Crops	Seed/ Seedlings[a]		Chemical Fertilizer[b]				Manure[c]		Plant Protection[d] Cost (Tks)	Interest Cost (Tks)	Variable Cost of Irrigation Water (Tks)	Total Variable Cost (Tks)
			Urea and Phosphate		Potash							
	Qty. (Seers)	Cost (Tks)	Qty. (Seers)	Cost (Tks)	Qty. (Seers)	Cost (Tks)	Qty. (Seers)	Cost (Tks)				
IRRI Boro Rice	--	40	190	48.1	40	6.4	400	5.0	4	11.2	26.5	141.2
IRRI T. Aman Rice	--	40	175	44.3	35	5.6	400	5.0	7	10.2	5.2	117.3
IRRI T. Aus Rice	--	40	175	44.3	35	5.6	400	5.0	5	10.8	7.6	118.3
Local Boro Rice	--	25	100	25.3	25	4.0	200	2.5	2	7.1	26.5	91.6
Local T. Aman Rice	--	25	100	25.3	25	4.0	200	2.5	2	7.1	5.2	70.3
Local B. Aus Rice	40	26	40	10.1	5	0.8	200	2.5	2	5.7	6.6	53.7
Jute	4	7	60	15.2	40	6.4	200	2.5	2	8.0	1.0	42.1

Potato	280	210	155	39.2	80	12.8	200	2.5	4	22.1	12.2	298.8
Wheat	40	24	100	25.3	20	3.2	200	2.5	2	6.6	11.6	75.2
Mustard	5	8	50	12.7	10	1.6	200	2.5	1	3.9	10.2	39.9
Groundnut	10	12	80	20.2	15	2.4	200	2.5	2	7.1	11.1	57.3
Pulses	5	3	20	5.1	--		--			2.1	11.6	21.8

[a]Cost of seedlings for transplanted crops do not include the labor cost to raise seedlings.

[b]The price to farmers is fixed at Tks 10.12 per maund of urea and phosphate, and at Tks 6.37 for muriate of potash.

[c]Farmers generally use cowdung, oilcake and ash as manure. Since most of the manure used is in the form of cowdung, we have used only cowdung in estimating cost for manure. The cost is assumed at Tk 0.5 per maund.

[d]Farmers get pesticides free and they incur only small cost for spraying. Cost of plant protection is based on author's subjective judgment.

Table 3.7. Estimated variable cost per acre used in the programming model for crops without irrigation, Bangladesh.

Crops	Seed/ Seedlings		Chemical Fertilizer: Urea and Phosphate		Chemical Fertilizer: Muriate of Potash		Manure		Plant Protection	Interest	Total
	Qty.	Cost	Qty.	Cost	Qty.	Cost	Qty.	Cost	Cost	Cost	Cost
	Seers	Tks	Seers	Tks	Seers	Tks	Seers	Tks	Tks	Tks	Tks
Local B. Aus Rice	40	26	30	7.6	5	0.8	200	2.5	2	5.6	44.5
Local B. Aman Rice	40	26	30	7.6	5	0.8	200	2.5	2	5.7	44.6
Local T. Aman Rice		25	75	19.0	15	2.4	200	2.5	2	6.9	58.8
Jute	4	7	40	10.1	24	3.7	200	2.5	2	6.8	32.1
Wheat	40	24	40	10.1	--	--	120	1.5	2	5.3	42.9
Mustard	5	8	10	1.3	5	0.8	120	1.5	1	2.9	15.5
Groundnut	10	12	70	17.7	10	1.6	120	1.5	2	7.0	41.8
Pulses	5	3	10	1.3	--		--	--	--	1.7	6.0

at the farmers' level at Tks 10.12 for urea and triple superphosphate, and Tks 6.37 for muriate of potash (17). Cowdung largely comes from the farmer's own yard. In the absence of any regular market price, price of cowdung is assumed to be Tk 0.5 per maund.

Seed.--The requirements of seeds and seedlings are presented in Table 3.6. Technological breakthrough in seed is confined to rice. The supply of good quality seed is important for having increased yield. There had been some difficulties in the past in the supply of quality seeds to farmers (74). However, no significant bottleneck on the supply side restricting farmers' use of IRRI varieties of rice is expected.

Pesticide.--Effective control of pest and disease involves the application of the right type of pesticide at the right time. With the expansion of IRRI varieties of rice, effectiveness of plant protection measures will have to be increased because these varieties are more susceptible to attack of pests and disease. Until 1969-70, plant protection services were provided almost free to farmers. Farmers' cost involved labor and a nominal fee for rental of sprayers. Therefore, a nominal cost and a few labor days are calculated to be cost for plant protection services (Tables 3.6 and 3.7).

Credit.--Most of the farmers in Bangladesh require credit. According to Survey Report on Agricultural Credit (25), 81 percent of farmers require credit. Credit is needed for investment in farming operations. But credit need also exists for current consumption of the farm families. The agricultural credit supplying agencies in Bangladesh generally use the criterion of investment need in farming operations to determine the credit requirement of farmers. Since bulk of the human labor comes from farm families, credit required to maintain farm family can legitimately be regarded as investment in farming operations. However, the above criterion of determining credit is used perhaps for operational convenience and not on conceptual ground. For the determination of the portion of credit needed for current consumption is highly difficult. Since the major portion of credit is needed for investment in farming operations, a slight upward adjustment of the credit requirement established on the basis of investment need is likely to yield a reasonable estimate of credit need for farmers. In this study, credit requirement is estimated on the basis of 25 percent of the labor cost and 75 percent of the other variable input costs to farmers.

One of the important aspects of the supply of credit in Bangladesh is that major portion of the credit is supplied by noninstitutional sources.[1] The share of agricultural

[1]Noninstitutional sources include village money lenders, friends, and relatives.

credit supplied from noninstitutional sources varied from 77 percent (72) to 84 percent (25) leaving only 16 to 23 percent supplied by institutional sources.[1] As the supply of credit has been linked with the low-lift pump irrigation under the TIP institutional arrangement, it is expected that the supply of credit will be increased from institutional sources. The rate of interest charged by noninstitutional sources is much higher than the rate charged by institutional sources. In the absence of any reliable information, the rate of interest charged by noninstitutional sources is assumed to vary from 20 to 40 percent.[2] In this study, interest cost is estimated at two levels (Table 3.8). The first level (average level) is estimated assuming 50 percent of credit requirement supplied from institutional sources at 8 percent rate of interest per annum and 50 percent supplied from noninstitutional sources at 20 percent rate of interest per annum. The second level (higher level) assumes 25 and 75 percent supplied from institutional and noninstitutional sources at the rate of 8 and 40 percent rate of interest per annum respectively.

Irrigation.--Irrigation water requirements for crops are estimated on the basis of the modified Penman approach

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[1]Institutional sources include Government and semi-government agencies.

[2]The information is based on the subjective judgment of the author.

Table 3.8. Estimated cost of credit for irrigated and unirrigated crops, Bangladesh.

	Irrigated Crops		Unirrigated Crops	
	Cost (Average)	Cost (High)	Cost (Average)	Cost (High)
		Tks		
IRRI Boro Rice	11.2	25.5		
IRRI Aman Rice	10.2	23.3		
IRRI Aus Rice	10.8	24.5		
Local Boro Rice	7.1	16.3		
Local T. Aman Rice	7.1	16.2	6.9	15.7
Local B. Aman Rice	5.7	13.0	5.7	13.0
Local B. Aus Rice	5.7	13.0	5.6	12.8
Jute	8.0	18.3	6.8	15.6
Potato	22.1	50.8		
Wheat	6.6	15.0	5.3	12.1
Mustard	3.9	9.0	2.9	6.7
Groundnut	7.1	16.5	7.0	15.9
Pulses	2.1	4.8	1.7	3.8

NOTE: Credit requirement is estimated to be 25 percent of the total labor cost and 75 percent of other variable costs. For each crop, credit will be required for six months.

Average level of interest cost is estimated under the assumptions:

1) 50 percent of credit will be available from institutional sources at 8 percent per annum.
2) 50 percent of credit will be available from nonistitutional sources at 20 percent per annum.

High level of interest cost is estimated under the assumptions:

1) 25 percent of credit available from institutional sources at 8 percent per annum.
2) 75 percent of credit will be from noninstitutional sources at 40 percent per annum.

in Chapter IV. Cost of irrigation to farmers can be divided into fixed and variable costs. Rental charge per pump per season (or year) was fixed at Tks 250 in 1969-70. In addition, fixed costs which include costs on account of pump transportation, pump shed, guard for pump, field channel and miscellaneous items are estimated at Tks 32 per acre per annum and Tks 16 per acre for either Boro or Aus and Aman seasons.[1]

Variable costs vary with types of crop enterprises depending on respective water requirements. These costs include costs of diesel and oil for running the pumps. For an average lift of 15 feet and fuel use pattern of diesel engines used in Bangladesh, the fuel (diesel) consumption is estimated to be 0.625 imperial gallons per hour for a 2 cusec low-lift pump. The farmers' price of diesel per imperial gallon including ex-depot price, transportation cost and dealers' commission is calculated at Tks 2.37. The cost of diesel per hour of operation of a pump is, thus, worked out to be Tks 1.48. To allow for the cost of oil at the rate of 15 percent of the cost of diesel, the farmers' price per hour of operation of a pump becomes Tks 1.70. It means

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[1]Mohsen in his study (69) found the fixed cost for these items to be Tk 16.1 per acre for Boro season.

that the estimated variable cost per acre inch of water to a farmer is Tk 0.85 (Tks 1.70 ÷ 2).[1] Table 3.9 presents the estimated variable costs per acre.

Output

Until 1970, the yield of crops per acre was low. Low level of input use, lack of irrigation and varietal improvement in seed mainly account for the low level of yield. In addition to the low yield, there was considerable variation in yield between years mainly due to uncertainty about the soil moisture conditions.

Rice.--Until 1969-70, Bangladesh grew mostly the traditional varieties of rice.[2] The yield of different seasonal varieties of rice is presented in Table 3.10 It appears from the table that of the local varieties of rice, boro rice is the highest yielding followed by t. aman, b. aman, and aus respectively. Except the boro rice which was entirely irrigated, other varieties mostly unirrigated.[3] High yielding IRRI varieties of rice suitable for growing in Boro, Aus, and Aman seasons have already been

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[1]If a low-lift pump of 2 cusec capacity runs an hour, it usually provides an average of 2 acre inches of water.

[2]In 1969-70, HYV of boro rice (IR-8) was grown in 500,000 acres and HYV of aman rice (IR-20) was grown in 170,000 acres in Bangladesh.

[3]A negligible portion of other varieties was provided irrigation under WAPDA projects.

Table 3.9. Estimated variable cost[a] of irrigation per acre of crop activities used in the programming model, Bangladesh.

Items of Cost	Rice				Jute	Potato	Wheat	Mustard	Ground-nut	Pulses
	IRRI and Local Boro	IRRI and Local T. Aman	IRRI T. Aus	Local B. Aus						
Cost Per Acre Inch (Tks)	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Irrigation Requirements (Acre Inch)	31.2	6.1	8.9	7.8	1.2	14.3	13.6	12.0	13.0	13.6
Cost Per Acre (Tks)	26.5	5.2	7.6	6.5	1.0	12.2	11.6	10.2	11.1	11.6

[a]Includes the cost of diesel and oil.

Table 3.10. Average yield per acre of different seasonal varieties of Paddy[a] in 1969-70, Bangladesh.

Crop	Yield of Paddy (Maunds Per Acre)
Boro Paddy	35.6[b]
Aus Paddy	14.3
B. Aman Paddy	17.1
T. Aman Paddy	20.1
Total	18.6

Source: Compiled from: East Pakistan (now Bangladesh). Planning Department, Economic Survey of East Pakistan 1969-70, (Dacca: Planning Department, 1970).

[a]Paddy is unhusked rice

[b]Includes the yield of HYV (IR-8) occupying a portion of the total boro paddy area. The yield of boro paddy between 65-67 before the introduction of IR-8 to farmers ranged between 21.7 and 24.7 maunds per acre.

evolved. In case of IR-8 under farmers' field conditions, Hoque (47) found an average yield of 45 maunds of paddy per acre in 1968 while Masud and Underwood (89) found an average yield of 53 maunds of paddy per acre. The average yield of IR-20 was 43 maunds of paddy per acre (41). In this study, the yields of paddy per acre for IRRI varieties are estimated to be 45 maunds for boro and 42 maunds for aus and aman. Yields of IRRI and traditional varieties of rice under irrigated and unirrigated conditions are presented in Tables 3.11 and 3.12.

Table 3.11. Estimated gross revenue, variable cost, and net revenue per acre used in the programming model for crops under irrigated conditions, Bangladesh.

	Yield of Main Product (Maund)	Price Per Maund (Tks)	Value of Main Yield (Tks)	Value of By-Product[a] (Tks)	Gross Revenue (Tks)	Variable Cost (Tks)	Net Returns (Tks)
IRRI Boro Paddy[b]	45	22	990	54	1044	141.2	902.8
IRRI Aman Paddy	42	22	924	51	975	117.3	857.7
IRRI Aus Paddy	42	22	924	46	970	118.3	851.7
Local Boro Paddy	30	22	660	72	732	91.6	640.4
Local T. Aman Paddy	28	22	616	66	682	70.3	611.7
Local B. Aus Paddy	20	22	440	36	476	53.7	422.3
Jute	25	30	750	114	864	42.1	821.9
Potato	105	13	1365	--	1365	298.8	1066.2
Wheat	25	18	450	--	450	75.2	374.8
Mustard	10	50	500	--	500	39.9	460.1
Groundnut	20	37	740	--	740	57.3	682.7
Pulses	10	18	180	--	180	21.8	158.2

[a]Yield of straw relative to the yield of paddy is assumed to be 40 percent for IRRI boro and aman, 80 percent for local boro and aman, 35 percent for IRRI aus and 60 percent for local aus. Jute stick is assumed to be 150 percent of jute fibre. Price of straw and jute stick is assumed to be Tks 3 per maund.

[b]Paddy is unhusked rice. Paddy constitutes 66.6 percent of rice.

Table 3.12. Estimated gross revenue, variable cost, and net revenue per acre used in the programming model for crops without irrigation, Bangladesh.

Crops	Yield of Main Product (Maund)	Price Per Maund (Tks)	Value of Main Yield (Tks)	Value of By-Product[a] (Tks)	Gross Revenue (Tks)	Variable Cost (Tks)	Net Revenue (Tks)
Local T. Aman Paddy	24	22	528	57	582	58.8	526.2
Local B. Aman Paddy	17	22	374	42	428	44.6	371.4
Local B. Aus Paddy	18	22	396	33	429	44.5	384.5
Jute	16	30	480	72	552	32.1	519.9
Wheat	12	18	216	--	216	42.9	173.1
Mustard	7	50	350	--	350	15.5	334.5
Groundnut	17	37	629	--	629	41.8	587.2
Pulses	8	18	144	--	144	6.0	138.0

[a]Yield of straw relative to the yield of paddy is assumed to be 80 percent for aman and 60 percent for aus. Jute stick is assumed to be 150 percent of jute fibre. Price of straw is Tks 3 per maund of paddy. Price of jute stick is Tks 3 per maund.

Jute.--In 1969-70, the average yield of jute was 13.9 maunds per acre in Bangladesh. At present, jute is almost entirely grown under unirrigated conditions. No major breakthrough in jute seed variety has been achieved. However, a significant improvement in yield is achievable by using improved local seed, improved cultural practices, and inputs.[1] The yield of jute under irrigated and unirrigated conditions is presented in Tables 3.11 and 3.12.

Potato, Wheat, Pulses, and Oilseeds.--Tables 3.11 and 3.12 present the yields of potato, wheat, pulses, and oilseeds under irrigated and unirrigated conditions.[2] The average yield of potato in the country was about 91 maunds in 1967-68 (22). On the other hand, Islam (50) found a lower yield of 87 maunds in Comilla. However, with the available seed variety and use of inputs, the yield of potato can be increased. The dwarf (Mexican) HYV of wheat did not perform well under the climatic conditions of Bangladesh. The improvement in yield is limited for wheat unless a suitable HYV is evolved. There has been no varietal improvement in pulses and oilseeds. These crops are drought resistant but low yielding. Without varietal improvement, no significant increase in yield of these crops is achievable by using irrigation and use of other inputs.

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[1]For further information, see Chapter II, p. 46.

[2]Potato is assumed to be grown only with irrigation.

Output Price.--For determining the returns from crop activities to individual farmers, the relevant price is what farmers actually receive for their crops, that is, the farm gate price. In the absence of published data on the farm gate price, estimates are made on the basis of wholesale price and the price spread between the farm gate and wholesale market.

The important characteristics of the price of rice is its seasonal fluctuation. Its price is generally lowest in December and highest in June-July (27). Aman rice which constitutes about 59 percent of total production of rice in the country is harvested in December. In addition, average farmers in Bangladesh have low holding capacity and they generally sell a major portion of their surplus just after harvest to pay debt and replenish cash for their maintenance. Both these factors account for substantial increase in the supply (positive shift of supply function) of rice and price falls significantly due to lack of corresponding expansion in demand. The existing marketing pattern of paddy by farmers shows that price of paddy within two months following harvest may be relevant for estimating profitability for farmers. Prices are reported for three qualities of rice, coarse, medium, and fine. The price spread for paddy between the farm yard and wholesale markets is about Tks 2 in Bangladesh (24, p. 68). The farm gate prices of paddy are estimated by converting rice into paddy, and deducting milling cost of rice and the price spread between the farm gate and whole-sale markets (Tables 3.11 and 3.12).

The statutory minimum internal price of jute at three levels, primary (farmers' level), secondary, and terminal markets are fixed by the government at the beginning of each jute season. In 1969-70, the statutory minimum prices at farmers' level were fixed at Tks 28 per maund for 'Jat' and 'District' areas and Tks 27 for 'Northern' area.[1] On the other hand, according to Bureau of Statistics, average growers' price, ranged between Tks 30 and Tks 32 in 1970 (23, p. 19). The price of jute was often subject to wide fluctuations. There were complaints that farmers sometimes received prices which were lower than the fixed minimum. In this study, average farm gate price of jute is estimated to be Tks 30 per maund.

Prices of wheat, potato, pulses, and oilseeds are presented in Table 3.11. Wheat is a fairly good substitute for rice and therefore, the prices of both are positively related. Most of the wheat consumed in the country is imported and distributed at a controlled price. Farm gate price of wheat appears to be closely related to the controlled price in Dacca. Potato poses storage problems to farmers. The farmers, therefore, tend to sell major portion of potato

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[1]'Jat', 'District', and 'Northern' refer to specific growing areas within the country.

just after harvest. In estimating farm gate price, the price of potato in April-May has been considered. For pulses and oilseeds, the farm gate price is derived by deducting price spread between farm yard and wholesale markets from the average annual wholesale price.

CHAPTER IV

IRRIGATION REQUIREMENTS

This chapter first considers the physical factors involved in determining the irrigation water requirements for different crop enterprises. The discussion also focuses on the nature of irrigation during the three seasons of the year. Finally, the estimates of irrigation requirements for crops vis-a-vis some empirical evidence in this respect are analyzed and the necessity of empirical investigation of the economic optimum use of water is emphasized.

Plant and Soil Moisture Relationship

Plants derive water from soil moisture reserves which may be built up by rainfall or irrigation. For maximum crop growth, levels of soil moisture should fluctuate only within a narrow range between field capacity[1] and permanent wilting point.[2] The application of water in excess of field capacity is wasted through surface run-off or deep percolation. The

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[1]Field capacity is the amount of moisture that the soil can hold against the forces of gravity.

[2]Permanent wilting point occurs when roots can no longer derive water from soil for transpiration of plants.

excess water might also have negative effect by excluding air that supplies oxygen or washing away plant nutrients from root zones.

A considerable disagreement exists among the plant physiologists over the precise relationship of soil moisture to plant growth. Some are of the view that the growth rate continuously falls as the available soil moisture content falls below field capacity (43). Another group holds that growth of plant is retarded only slightly until the soil is very near the permanent wilting point. However, the majority of them views that the relative rate of plant growth, in general, is a function of the mean soil moisture stress in the active root zone. In this study, however, we will not attempt at examining the impact of irrigation water application schedule under a controlled experimental situation.[1] For the purpose of this study, we will assume an average irrigation schedule to permit the soil moisture to remain above the permanent wilting point.

Variables Determining the Irrigation Requirements

The determination of the irrigation water requirements for crops is one of the important factors in examining the feasibility of any irrigation project. Irrigation water

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[1]Data of this nature are mostly lacking in Bangladesh.

requirements of crops depend on the following factors: 1) evapo-transpiration, 2) land preparation requirements, 3) surface run-off, 4) deep percolation, 5) available moisture at the beginning, 6) effective rainfall, and 7) irrigation efficiency. Nature and influence of each of these factors in determining the irrigation requirements under the conditions in Bangladesh are discussed below.

Evapo-transpiration

Water is required to provide for transpiration, transporting of nutrients from soil, and building of plant tissue. In addition, soil loses moisture through evaporation from its surface. These two processes are jointly called evapo-transpiration. The amount of water required for evapo-transpiration is the actual amount used for plant growth. The estimates for evapo-transpiration have been developed in this section. Much of the data used in the estimation came from WAPDA (35).

The determination of evapo-transpiration requirement involves the computation of evaporation index and consumptive coefficient of crops. Evaporation represents the combined effect of various meteorological factors such as temperature, wind velocity, water vapour pressure deficit, and available energy determined by solar radiation etc. Crop consumptive coefficient depends on crops, their stages of growth, and specific physiological properties. In order to determine the evaporation index, the modified Penman formula was applied to meteorological data on temperature, humidity, duration of bright sunshine and cloud cover, and wind velocity. These data covering a period of 1959-68 were available from 15 stations spread over Bangladesh. The estimated evaporation index for different districts in Bangladesh is presented in Table 4.1.

The crop consumptive coefficient represents "the ratio of consumptive use requirements (i.e., evapo-transpiration requirements) of crops to the potential evapo-transpiration of a lawn covered with short-cut grass as calculated by means of the modified Penman formula" (35). Table 4.2 presents the estimate of fortnightly consumptive coefficients of crops. The maximum value for paddy is estimated on the basis of assumption that the increase in evapo-transpiration caused by the physiological characteristics of the crop and a possible direct evaporation from water layers on the field does not exceed 50 percent of the potential evapo-transpiration from short-cut grass. The estimates of maximum values for other crops are made by examining the ultimate height of plants and its influence on the evapo-transpiration. For paddy, evapo-transpiration, immediately after transplanting is assumed to be 1.2 times the potential evapo-transpiration of short-cut grass. As ripening of crops begins, the consumptive coefficients fall gradually until harvesting takes

Table 4.1. Estimated mean monthly evaporation index[a] based on modified penman formula, Bangladesh.

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rangpur	1.8	2.3	3.7	4.9	5.0	4.3	4.5	4.5	4.0	3.5	2.4	1.7	42.6
Bogra	2.0	2.7	4.0	4.9	5.0	3.9	3.9	3.8	3.6	3.4	2.5	2.0	41.7
Rajshahi	2.0	2.7	4.1	5.1	6.0	4.7	4.2	4.1	3.8	3.6	2.5	1.9	44.7
Khulna	2.2	2.8	4.5	5.1	5.5	4.6	4.6	4.4	3.9	3.7	2.7	2.2	46.2
Sylhet	2.2	2.9	3.9	4.4	4.3	3.6	3.9	3.5	3.2	3.3	2.7	2.1	40.0
Dacca	2.1	2.7	4.3	5.4	5.5	4.1	4.3	4.2	3.7	3.5	2.6	2.0	44.4
Comilla	2.0	2.7	4.2	4.9	5.3	4.4	4.6	4.2	3.9	3.7	2.6	2.0	44.5
Barisal	2.2	2.7	4.2	4.9	5.1	4.2	4.0	3.9	3.7	3.8	2.6	2.1	43.4

Source: East Pakistan, WAPDA, "Technical Guideline Crop Consumptive Use Requirements, East Pakistan (Prepared by Acres International Ltd.), (Dacca: WAPDA, 1970).

[a]The table represents a reduction of 15 percent of the results obtained by using the modified Penman formula. This was done because the reduction results in more consistent data.

Table 4.2. Half-monthly crop consumptive coefficients, Bangladesh.

Crops	1		2		3		4		5		6		7		14		15	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Aman Rice	1.20	1.25	1.25	1.30	1.40	1.45	1.50	1.35	--	--	--	--	--	--	--	--	--	--
Aus Rice	1.20	1.25	1.25	1.30	1.40	1.45	1.50	1.35	--	--	--	--	--	--	--	--	--	--
Boro Rice	1.20	1.25	1.25	1.30	1.35	1.40	1.45	1.50	1.30	--	--	--	--	--	--	--	--	--
Jute	0.50	0.65	0.90	1.15	1.30	1.40	1.40	1.40	--	--	--	--	--	--	--	--	--	--
Wheat	0.50	0.50	0.55	0.70	0.85	1.00	1.15	1.20	1.20	1.00	--	--	--	--	--	--	--	--
Lentils	0.50	0.55	0.75	1.05	1.10	1.10	1.10	0.95	--	--	--	--	--	--	--	--	--	--
Mung beans	0.50	0.55	0.75	1.05	1.10	0.95	--	--	--	--	--	--	--	--	--	--	--	--
Oilseeds	0.50	0.55	0.65	0.95	1.10	1.10	0.95	--	--	--	--	--	--	--	--	--	--	--
Groundnut	0.50	0.50	0.55	0.60	0.75	0.95	1.10	1.10	1.10	1.10	0.80	--	--	--	--	--	--	--
Potato	0.50	0.55	0.65	1.05	1.20	1.20	1.00	1.20	0.80	--	--	--	--	--	--	--	--	--
Sugarcane	0.50	0.50	0.55	0.60	0.70	0.80	0.95	1.10	1.20	1.30	1.30	1.30	1.30	1.30	1.30	1.25	1.20	0.95

Source: East Pakistan, WAPDA, "Technical Guideline Crop Consumptive Use Requirements, East Pakistan," (Prepared by Acres International Ltd.), (Dacca: WAPDA, 1970).

place. After determining the evaporation index and consumptive coefficients of crops, the water requirement budget for evapo-transpiration is estimated from the formula:

$$u = ef$$

where:

u = monthly water requirement for evapo-transpiration in inches.
e = monthly evaporation index in inches.
f = monthly crop consumptive coefficient.

Table 4.3 presents the estimated evapo-transpiration requirements for crops.

Other methods like Blaney-Criddle (7) and Pan evaporation could be used to determine the evaporation index. However, the modified Penman formula was preferred over other methods for the following reasons. First, the Blaney-Criddle technique (7), disregards the relative humidity and duration of bright sunshine, and wind movement.[1] These factors have important influence on evaporation in Bangladesh. A comparison of the evapo-transpiration requirements based on Blaney-Criddle technique with those based on modified Penman formula indicates that Blaney-Criddle technique results in higher evapo-transpiration requirements perhaps due to the exclusion of the factors mentioned above (Table 4.4). Second, it is sometimes argued that for paddy which requires ponded field conditions, Pan evaporation data might be more

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[1]Blaney-Criddle technique was used in WAPDA's Master Plan, Supplement B, Agriculture (31).

Table 4.3. Estimated evapo-transpiration requirements[a] for crops based on modified Penman formula, Bangladesh.

Months and Seasons	Rice	Jute	Potato	Wheat	Mustard	Ground-nut	Pulses
				Inches of water			
Boro Season							
Dec. (2nd half)	1.20		0.50	0.50	0.50	0.50	0.50
January	2.63		1.26	1.11	1.26	1.11	1.37
February	3.65		3.05	2.10	2.78	1.84	2.92
March	6.45		5.16	4.64	4.43	4.43	4.73
April (1st half)	3.65		3.24	6.48	--	5.94	2.56
Aus Season							
April (2nd half)	3.24	1.35					
May	6.88	4.29					
June	5.54	5.04					
July	6.36	6.02					
August (1st half)	2.84	2.94					
Aman Season							
August (2nd half)	2.52						
September	4.63						
October	4.73						
November	1.92						
December (1st half)	1.35						

[a]Evapo-transpiration requirement is the product of evaporation index (Table 4.1) and crop consumptive coefficient (Table 4.2).

Table 4.4. Estimated irrigation requirements of boro rice per acre based on Blaney-Criddle Technique and modified Penman Formula, medium rainfall region, Bangladesh.

Months and Season	Irrigation Requirement										
	Inches of Water Blaney-Criddle Technique[a]										Modified Penman Formula
	Consumptive Use Factor	Consumptive Use Coefficient	Evapotranspiration Requirement	Land Preparation Requirement	Available Moisture at the Beginning	Portion of Land Prep. Water for Evapotranspiration	Deep Percolation	Effective Rainfall	Net Water at Fieldhead	Irrigation (Pumping) Requirement	Irrigation (Pumping) Requirement
December (2nd half)	4.95	1.4	3.47	5	0.64	2.50	1.5	0.04	6.79	7.99	5.32
January	4.96	1.4	6.94	-		--	3.0	0.34	9.60	11.29	6.16
February	5.01	1.4	7.01	-		--	3.0	0.67	9.34	10.98	6.93
March	6.66	1.4	9.32	-		--	3.0	1.44	10.88	12.79	9.21
April (1st half)	7.37	1.4	5.16	-		--	1.5	1.87	4.79	5.63	3.57
										48.68	31.19

[a]Evapo-transpiration requirement is computed using the Blaney-Criddle Technique and other variables influencing the irrigation water requirements are the same as those used for modified Penman formula.

accurate. In Bangladesh, a slightly modified US weather Bureau Class A Pan was installed in some places. Pan evaporation was found to be strongly influenced by exposure and environment. Moreover, the influence of the modifications made to class A Pans is still unknown. Third, the modified Penman formula is based on a sound physical model and its application to relevant variables produces consistent results which seem to fit better under the conditions in Bangladesh.

Land Preparation Reauirement

Water is required to bring the level of soil moisture to a level suitable for the preparation of land for sowing or transplanting of crops. Lack of soil moisture often impedes the ploughing of land with the country plough drawn by bullock power. Also, the puddling of field before transplanting is not possible without adequate water applied to the field. In this study, water for land preparation is assumed to be 5 inches for t. rice and 3 inches for other crops. But the entire amount of water is not used for land preparation. A portion of the water is left for its use in evapo-transpiration. It is assumed that 50 percent of the water applied for land preparation will be available for use in the evapo-transpiration of crops.

Water Losses

In the course of providing irrigation, water is lost through deep percolation, surface run-off, and losses in distribution channels. Deep percolation loss is largely a function of soil characteristics, water management practices, and level of water table. The characteristics of soil determines the infiltration rate and is considered to be the most important variable in estimating deep percolation losses. For the purpose of this study, the type of soil represents some combination of clay, loam, and sand. The water management practices include importantly the timing of irrigation, amount and rate of water applied per irrigation. Given the relatively short experience with irrigation of farmers in many areas of Bangladesh, water management practices can not be expected to be high. In general, the level of water table is relatively high in Bangladesh. The water table gets even closer to surface in the monsoon months.[1]

Rice as distinct from other crops requires generally ponded water in the field. The deep percolation loss of rice would, therefore, differ from that of other crops. The deep percolation loss has been assumed at two levels, average and high (Tables 4.5 and 4.6).

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[1]The influence of water table as between monsoon and non-monsoon months could not be specifically considered due to lack of data.

Table 4.5. Estimated irrigation requirement per acre for Boro, T. Aus and T. Aman rice in the medium rainfall region, Bangladesh.

Months and Seasons	Evapo-Trans-piration Requirement	Land Prepa-ration Requirement	Available Moisture at the Beginning	Portion of Land Prep. Water for Evapo-Trans-piration
		Inches of water		
Boro				
December (2nd half)	1.20	5.00	0.64	2.50
January	2.63	--		--
February	3.65	--		--
March	6.45	--		--
April (1st half)	3.65	--		--
Total				
T. Aus				
April (2nd half)	3.24	5.00	--	2.50
May	6.88	--		--
June	5.54	--		--
July	6.36	--	2.52	--
August (1st half)	2.84	--	0.14 3.43	--
Total				
T. Aman				
August (2nd half)	2.52	5.00	6.06 1.59	2.50
September	4.63	--	4.97	--
October	4.73	--	4.80	--
November	1.92	--	1.66	--
December (1st half)	1.35	--	--	--
Total				

[a]Rainfall is assumed to be effective at 80 and 90 percent of average rainfall in May-October, and November-April respectively in case of average level. For the high level, rainfall is assumed to be effective at 70 and 85 percent of average rainfall in May-October, and November-April, respectively.

Average Level			High Level		
Deep Perco-lation	Effective Rainfall[a]	Irriga-tion (Pumping Requirement)	Deep Percolation	Effective Rainfall[a]	Irriga-tion (Pumping Requirement)
		Inches of water			
1.50	0,04	5.32	2.00	0,04	7.08
3.00	0.39	6.16	4.00	0.34	7.86
3.00	0.76	6.93	4.00	0.67	8.73
3.00	1.62	9.21	4.00	1.44	11.26
1.50	2.11	3.57	2.00	1.87	4.72
		31.19			39.65
1.50	2.11	6.03	2.00	1.87	7.33
3.00	7.57	2.89	4.00	6.62	5.66
3.00	11.06	--	4.00	9.68	--
3.00	10.27	--	4.00	8.99	1.64
1.50	5.43	--	2.00	4.75	0.12
		8.92			14.87
1.50	5.43	--	2.00	4.75	0.90
3.00	7.46	--	4.00	6.50	2.83
3.00	4.59	--	4.00	4.02	6.26
3.00	0.85	2.84	4.00	0.75	6.46
1.50	0.04	3.30	2.00	0.04	4.14
		6.14			20.59

Table 4.6. Estimated irrigation requirements per acre for jute, potato, wheat, mustard, groundnuts and pulses in the medium rainfall region, Bangladesh.

Months and Seasons	Evapo-Transpiration Requirement	Land Preparation Requirement	Portion of Land Prep. Water for Evapo-Transpiration	Average Level: Available Moisture at the Beginning	Average Level: Effective Rainfall	Average Level: Net Requirement at Fieldhead[a]
	Inches of water					
Jute						
April (2nd half)	1.35	3.0	1.5	--	2.11	0.74
May	4.29				6.15	
June	5.04				8.99	
July	6.02				8.35	
August (1st half)	2.94				4.42	
Total						
Potato						
December (2nd half)	0.50	3.0	1.5	0.64	0.04	1.32
January	1.26				0.39	0.87
February	3.05				0.76	2.29
March	5.16				1.62	3.54
April (1st half)	3.24				2.11	1.13
Total						
Wheat						
December (2nd half)	0.50	3.0	1.5	0.64	0.04	1.32
January	1.11				0.39	0.72
February	2.10				0.79	1.34
March	4.64				1.62	3.02
April (1st half)	6.48				4.21	2.27
Total						

Average Level		High Level				
Total Requirement at Fieldhead[a]	Irrigation (Pumping Requirement)	Available Moisture at the Beginning	Effective Rainfall	Net Requirement at Fieldhead	Total Requirement at Fieldhead	Irrigation (Pumping Requirement
		Inches of water				
0.99	1.16	--	2.11	0.74	1,24	1.55
			5.20			
			7.61			
			7.06			
			3.74			
	1.16					1.55
1.76	2,07	--	0,04	1.96	3.27	4.09
1.16	1.36		0.39	0.87	1.45	1.81
3.05	3.59		0,76	2.29	3.82	4.78
4.71	5.54		1.62	3.54	5.91	7.39
1.50	1.76		2,11	1.13	1.89	2.36
	14.32					20.43
1.76	2,07	--	0,04	1.96	3.27	4.09
0.96	1.13		0,39	0.72	1.20	1.50
1.78	2.09		0,76	1.34	2.24	2.80
4.02	4.73		1,62	3.02	5.04	6.30
3.02	3.55		4.21	2.27	3.79	4.74
	13.57					19.43

Table 4.6. Continued.

Months and Seasons	Evapo-Trans-piration Requirement	Land Prepara-tion Require-ment	Portion of Land Prep. Water for Evapo-Trans-piration	Average Level: Available Moisture at the Beginning	Effec-tive Rain-fall	Net Require-ment at Fieldhead[a]
	Inches of water					
Mustard						
December (2nd half)	0.50	3.0	1.5	0.64	0.04	1.96
January	1.26				0.39	0.87
February	2.78				0.76	2.02
March	4.43				1.62	2.81
April (1st half)						
Total						
Groundnuts						
December (2nd half)	0.50	3.0	1.5	0.64	0.04	1.96
January	1.11				0.39	0.72
February	1.84				0.76	1.08
March	4.43				1.62	2.81
April (1st half)	5.94				4.23	1.71
Total						
Pulses						
December (2nd half)	0.50	3.0	1.5	0.64	0.04	1.96
January	1.37				0.39	0.98
February	2.92				0.76	2.16
March	4.73				1.62	3.11
April (1st half)	2.56				2.11	0.45
Total						

[a]Total requirement at the field head is equiped to net requirement at field head plus deep percolation loss. Percolation loss for these crops is estimated at 75 and 60 percent of the field efficiency for average and high level, respectively.

Average Level		High Level				
Total Requirement at Field-head[a]	Irrigation (Pumping Requirement)	Available Moisture at the Beginning	Effective Rainfall	Net Requirement at Fieldhead	Total Requirement at Fieldhead	Irrigation (Pumping Requirement
Inches of water						
2.61	3.07	--	0.04	1.96	3.27	4.09
1.16	1.36		0.39	0.87	1.45	1.81
2.69	3.16		0.76	2.02	3.37	4.21
3.74	4.40		1.62	2.81	4.69	5.86
	11.99					15.97
2.61	3.07	--	0.04	1.96	3.27	4.09
0.96	1.13		0.39	0.72	1.20	1.50
1.44	1.69		0.76	1.08	1.80	2.25
3.74	4.40		1.62	2.81	4.69	5.86
2.27	2.67		4.23	1.71	2.86	3.58
	12.96					17.28
2.61	3.07	--	0.04	1.96	3.27	4.09
1.30	1.53		0.39	0.98	1.64	2.05
2.87	3.38		0.76	2.16	3.61	4.51
4.14	4.87		1.62	3.11	5.19	6.49
0.60	0.71		2.11	0.45	0.75	0.94
	13.56					18.08

Surface run-off is mainly determined by the height and quality of the bund of the field. The rate and amount of application of irrigation water at specific time periods also have some influence on the surface run-off. Monsoon months will have increased run-off because major portion of the rainfall is concentrated during this period. In this study, surface run-off from irrigation is assumed to be lower than that from rainfall. The main basis for this assumption is that farmers are generally more careful about the use of irrigation water which entails some cost to them than the rain water which is completely free. In addition to surface run-off, water will also be lost in the distribution channels due to evaporation and deep percolation. This loss in distribution channels is likely to be low for low-lift pump irrigation because the command area under each pump is small[1] and the supply of water in relation to demand can be adjusted easily. The loss of water in distribution channels and due to surface run-off has been distinguished between monsoon and non-monsoon months and between rice and other crops (Table 4.7). These distinctions are considered realistic because of the concentration of rainfall in monsoon months affecting specially surface losses and the difference in the nature and amount of water required by rice[2] vis-a-vis other crops.

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[1]The command area under each 2 cusec pump is assumed to be 50 acres at full development.

[2]Rice requires greater amount of water than other crops. As distinct from other crops, it requires ponded field conditions.

Table 4.7. The assumed rate of effectiveness of irrigation (pumped) water and rainfall, Bangladesh.

Crops and Months	Average Level		High Level	
	Irrigation Water	Rainfall	Irrigation Water	Rainfall
	Percentages			
Rice				
Monsoon Months (May-Oct.)	80	80	75	70
Non-Monsoon Months (Nov.-April)	85	90	80	80
Other Crops				
Monsoon Months (May-Oct.)	85	65	75	55
Non-Monsoon Months (Nov.-April)	85	90	75	90

Initial Moisture

A portion of the water requirement for crops is met from the soil moisture available at the beginning of crop season. This initial moisture might be available from two sources, rainfall and residual moisture from irrigation in the preceding season. Since the residual moisture from previous irrigation is of highly uncertain nature, rainfall in the week preceeding the start of the season is assumed to be the relevant variable for estimating the amount of initial moisture.[1]

Effective Rainfall

Rainfall provides a significant amount of water required by crops specially during the Aus and Aman seasons. A portion of the total rainfall is effective in providing the net water requirements for crops. The effective rainfall which is estimated by deducting surface run off from total rainfall would be available for use as evapo-transpiration and deep percolation.[2] The effectiveness of rainfall depends on the amount, intensity and duration of showers, timing of the application of irrigation relative to rainfall, and

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[1]Rainfall in the preceding week is assumed to be one fourth of the monthly rainfall.

[2]The net effective rainfall available for evapo-transpiration is thus the total rainfall minus losses due to deep percolation and surface run-off.

condition of the field bund. In general, the large amount of rainfall during the monsoon months is likely to increase the surface run-off. In addition, the heavy and concentrated showers which might occur during the monsoon months result in increased run-off losses. Loss of rain water due to run-off is thus assumed to be higher in monsoon months than in non-monsoon months. In addition to run off, a portion might have to be lost through necessary drainage. If the level of water exceeds certain level in the field, excessive water has to be disposed of through additional drainage. Since rice generally uses ponded fields, the additional necessary drainage of water is lower for rice, than for other crops.

The effective rainfall for any time period may, therefore, be computed as:

$$\sum_{i=1}^{n} R_{e_i} = \sum_{i=1}^{n} R_{m_i} - \sum_{i=1}^{n} (S_{w_i} + A_{d_i})$$

where:

R_{e_i} = effective rainfall in the ith period.

R_{m_i} = average rainfall in the i th period.

S_{w_i} = surface run-off loss of rain water in the ith period.

A_{d_i} = necessary drainage in the i th period.

Estimates of Irrigation Water Requirements

At first, an irrigation water requirement budget is developed in this section on the basis of the foregoing discussions in the chapter. Then, the irrigation water requirements are estimated for low, medium, and high rainfall regions. For medium rainfall region, the estimate of irrigation water requirement is made at two levels, average and high. Rajshahi, Dacca, and Barisal are taken to represent the low, medium, and high rainfall regions of the country. To meet the irrigation water requirements, water may be available from moisture stored in the soil at the beginning of the period, rainfall, and irrigation.[1] Since losses of water in the form of deep percolation, run-off, and loss in distribution channels continually occurs in the course of supplying water, the total amount of water to be supplied from these sources must be more than the amount of water required for only evapo-transpiration and land preparation. Water is provided through irrigation when the water requirement in any specified period exceeds the amount available from initial moisture and rainfall. A simple budget technique for monthly time periods[2] is employed to show the irrigation

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[1] Dew may be a source of supply of water. Since it supplies a negligible amount of moisture, it is ignored in this study.

[2] Fortnightly requirement is estimated at half the monthly requirement.

requirement of crops in a season. The irrigation water requirement of crops may be computed as:

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

where:

l_{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.

L_{s_i} = surface run-off loss of irrigation water 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.

In order to estimate the irrigation requirements, monthly data on rainfall and evapo-transpiration have been used. The irrigation requirement budget constructed on weekly basis could identify water supply constraints for short periods. However, the monthly data have been used because of the lack of weekly data.

The estimates of irrigation requirements in the medium rainfall region are presented in Tables 4.5 and 4.6. It appears that boro rice is the highest user of irrigation water, while the irrigation requirement for jute is the lowest. In case of average level of irrigation requirement, boro rice requires more than three times the irrigation water for aus rice and about five times the irrigation water for aman rice (Table 4.5). All the Boro season crops require consistently higher amounts of irrigation water than Aus or Aman season crops. The most important reason is obviously the much smaller amount of rainfall received in the Boro season compared to Aus or Aman season. The irrigation water requirements in the three seasons clearly indicate that in terms of capacity, a low-lift pump can provide water to a much larger area in Aus and Aman seasons than in Boro season.

Tables 4.5 and 4.6 also indicate that the variation in distribution of irrigation water requirement is quite wignificant within each season. In case of average level of irrigation requirement, Boro season crops require irrigation water in each month of the season, while the irrigation water is needed for shorter period of time for Aus and Aman seasons' crops. For the Aus season crops, irrigation water is crucially important at the planting time and it is not needed beyond May. However, the critical need of irrigation water for the Aman season crops (Aman rice) appears to be at the time of flowering and immediately after flowering. Such a pattern of irrigation water requirement during the Aus and Aman seasons might allow the annual repair, overhaul and servicing of the major portion of the low-lift pumps during June through September without reducing the area under the low-lift pump irrigation throughout the year. This means that with proper planning, only a small proportion of low-lift pumps may be necessary to keep in reserve if the low-lift pump irrigation is in fact, provided throughout the year.

Irrigation requirements in the low and high rainfall regions,in general,vary according to the amount of rainfall received in the respective regions (Table 4.8). However, the difference in irrigation requirements among the three rainfall regions is greater in Aus and Aman seasons than in Boro season. In the high rainfall region, the requirement of irrigation water is negligible at only 2 inches in the Aman season. Farmers in this region may therefore, tend to be indifferent to the necessity of irrigation in the Aman season.

Empirical Evidence and the Estimates of Irrigation Requirements

Data on irrigation requirements of crops based on empirical investigation are very limited in Bangladesh. Only some scattered efforts were made to determine the impact of irrigation on different crops. Experimental works at the Amla Experimental Station[1] represented one of those efforts. On the basis of these observations the total water requirement of boro rice is estimated to be between 40 and 50 inches in WAPDA's Master Plan (31). The irrigation requirement may

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[1]Amla station is government owned and located on the low rainfall region of the country. No detailed experimental results obtained in the Amla station are available with us for analysis.

Table 4.8. Estimated irrigation requirements per acre in the low and high rainfall regions, Bangladesh.

Months and Seasons	Low Rainfall Region at Average Level							High Rainfall Region at Average Level						
	Rice	Jute	Potato	Wheat	Mustard	Ground-nut	Pulses	Rice	Jute	Potato	Wheat	Mustard	Ground-nut	Pul-ses
						Inches of water								
Boro Season														
December (2nd half)	5.7		2.6	2.6	2.6	2.6	2.6	2.9						
January	5.9		1.1	0.9	1.1	0.9	1.3	6.1						
February	7.3		4.1	2.6	3.6	2.2	3.8	7.1		3.8	2.1	3.4	1.7	3.5
March	9.8		6.4	5.6	5.3	5.3	5.8	9.2		5.6	4.8	4.5	4.5	4.8
April (1st half)	5.1		3.8	7.6	--	6.9	2.8			2.1	4.1	--	3.4	1.0
Total	33.8		18.0	19.3	12.6	17.9	16.3	29.1		11.5	11.0	7.9	9.6	9.3
Aus Season														
April (2nd half)	7.6	3.4						6.3	1.7					
May	8.4	2.7						3.4						
June	1.6													
July														
August (1st half)														
Total	17.6	6.1						9.7	1.7					
Aman Season														
August (2nd half)	1.1													
September	1.6													
October	4.9													
November	7.5							1.0						
Dec. (1st half)	3.2							1.0						
Total	18.3							2.0						

thus, be estimated to range between 38 and 48 inches by deducting probable effective rainfall[1] from the water requirements. This irrigation requirement seems to be much higher than the irrigation water farmers used in the low-lift pump irrigated areas in 1969-70. According to the Report on the Evaluation of TIP in Bangladesh (69), a low-lift pump was operated an average of 504 hours during the Boro season to irrigate an area of 39.2 acres in 1969-70. Thus, the amount of irrigation water applied per acre is estimated to be about 26 inches.[2] These data are considered to be fairly reliable because these were collected on the basis of a sample survey of the use of irrigation water on the farmers' fields in the low-lift pump irrigated areas covering 25 thanas in Bangladesh.

Additional information on irrigation requirements are available from experiments conducted at Comilla during 1961-63 (70, p. 58). The results of the experiment show the irrigation water requirements of 27, 10, 8, and 15 inches for boro rice, t. aman rice, aus rice, and potato respectively.

The irrigation water requirements estimated for the purpose of this study (Tables 4.5 and 4.6) compare closely

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[1]Effective rainfall in the low rainfall region during the Boro season is estimated at 2.4 inches.

[2]A 2 cusec pump generally supplies 2 acre inches of water per hour of operation. Therefore, a total of 1004 acre inches was supplied for 39.2 acres (i,e., 26 inches per acre).

with empirical information obtained from the experiment at Comilla (70, p. 51) and the Report on the Evaluation of TIP in Bangladesh (69). The irrigation requirements for other crops like jute, pulses, and oil seeds could not be compared because of the nonavailability of empirical data.

In the absence of appropriate data, we are uncertain about whether the empirical data on irrigation water mentioned above represents the optimum use of water, that is, the use of water up to the point at which the marginal cost of water (MFC) equals its marginal value product (MVP). In order to determine the optimum use of water, we need accurate information on the variables affecting MVP and MFC. The data on the variable cost of low-lift pump irrigation water and prices of output are available. However, the data on the yield response of the application of different rates of irrigation water are mostly lacking. Since these yield response data are crucially important to determine the optimum use of irrigation water, empirical investigations of the yield response function of irrigation water is highly needed in Bangladesh.

CHAPTER V

IMPACT ON FARMS AND ON THE ECONOMY OF LOW-LIFT PUMP IRRIGATION POLICIES

This chapter examines the impact of low-lift pump irrigation policies on farms and on the economy under various alternatives. The impact of irrigation is measured by direct profitability expressed in monetary terms. Returns to irrigation are estimated for the medium rainfall region of the country. The alternatives to be examined in this chapter include: 1) use of pump irrigation (a) throughout the year, (b) in the Boro season only, and (c) in the Aus and Aman seasons; 2) rental levels; and 3) levels of command area per pump. The results obtained under the seasonal alternatives will then be subjected to sensitivity tests by varying yields, prices, irrigation requirements and interest cost.

Farm Level Impact

At first, the model results will be analyzed with respect to cropping pattern, cropping intensity, marginal value product of limiting resources, and net farm revenue for the 'typical' farm. Then the net return resulting from irrigation estimated on the basis of the model results will be examined.

Cropping Pattern

The allocation of land to various crops with year-round irrigation is presented in Table 5.1. One of the significant impacts of irrigation is the use of entire cultivated land of the 'typical' farm under irrigation during the Boro season as compared with less than 20 percent under unirrigated conditions. This result thus confirms the fact that the lack of soil moisture is a limiting constraint during the Boro season. Also, the full use of land with irrigation in the Boro season as compared with other seasons appears to be quite realistic because the Boro season crops are highest yielding and least risky. The use of higher proportion of land in the Aman season than in the Aus season seems justified because the traditional dominance of t. aman rice in the medium land in the Aman season is expected to continue so long as the yield of IRRI aus rice does not exceed the yield of IRRI aman rice. The relative competitiveness for land between the Aman and Aus seasons is, however, very close. The model result indicates Tks 856 and Tks 844 as the lower bound of the solution for IRRI t. aman and IRRI aus rice respectively as compared with their net revenue of Tks 858 and Tks 852 respectively used in the model. Thus, a small

Table 5.1. The basic result[a] of the linear programming model on the cropping pattern of a typical farm[b] with year-round irrigation at full development,[c] Bangladesh.

Crops	Boro Season	Aus Season	Aman Season
		Acres	
IRRI Boro Paddy	2.55		
IRRI Aus Paddy		1.00	
IRRI Aman Paddy			2.78
Local Boro Paddy			
Local T. Aman Paddy			
Local Aus Paddy			
Jute		0.72	
Potato	0.45		
Wheat			
Mustard			
Groundnut			
Pulses			

[a]It is based on basic sets of input-output coefficients, prices, and yields.

[b]The total size of the farm is 3.5 acres with a net cultivated area of 3 acres.

[c]Full development is reached at the fifth year.

relative change in their yields will lead to a shift in the allocation of land between the Aus and Aman seasons.[1]

Within the Aus season itself, aus rice and jute compete closely for land. The allocation of land to aus rice exceeds the minimum restriction put in the model with respect to the area under rice. This may be interpreted as the relative competitive strength of aus rice. The competitiveness between aus rice and jute, however, appears to be close. The IRRI aus rice already showed signs of yield potential higher than the yield (42 maunds per acre) assumed in the model. On the other hand, vigorous extension efforts will be necessary to attain the assumed jute yield (25 maunds per acre) in the absence of improvement in jute seed technology. However, no technological breakthrough in jute seed comparable to that in aus rice is in sight. This situation clearly indicates the vulnerability of jute to IRRI aus rice. The competitive edge of IRRI aus rice over jute in terms of potential productivity could be neutralized by increasing the price of jute. But the increase in the internal price of jute might have adverse impact on the competitiveness of jute in the export market. Policies affecting price and productivity of these two crops would be vitally important to the Bangladesh economy due to jute's dominant position in earning foreign exchange and the

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[1]Assuming that other things including prices remain constant.

importance of aus rice in increasing the supply of food grains. The impact of changes in price, yield, irrigation requirement, and interest rate on the competitiveness of aus rice and jute is explored later in this chapter. Because of the nature of importance, the question of competitiveness between jute and aus rice under various alternative conditions, however, deserves further comprehensive studies.[1]

If the model is run only for the Boro season with the assumption that low-lift pump irrigation is provided only in the Boro season, the land in that season is allocated entirely to boro rice. Whereas in case of year-round irrigation, land is allocated to both boro rice and potato (Table 5.1). This means that without the crop alternatives possible with year-round irrigation, boro rice emerges to be more profitable than potato in the Boro season.

The model result indicating the allocation of entire land to boro rice in case of only Boro season irrigation is also comparable with the empirical finding that most of the low-lift pump irrigated areas were under boro rice in 1969-70 (69).

If the model is run for the Aus and Aman seasons assuming that low-lift pump irrigation is provided only in

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[1]Rabbani (75, 76) and Ahmed (4) examined this issue at length in their studies.

these two seasons, the entire land is cropped in each of these seasons. In the Aus season, however, IRRI aus rice completely eliminates jute.

In case of providing low-lift pump irrigation throughout the year, 12 crop activities were included in the model. The model in its solution allocated land only to 5 crops indicating that irrigation under the specified conditions leads to substantial specialization of crops. This specialization occurs by way of shift in cropping away from local varieties of rice, oilseeds, and pulses to IRRI varieties of rice. This process may, therefore, contribute to the national goal of the attainment of self-sufficiency in food grains. But with the increase in the irrigated areas in the country, this process may lead to the fall in domestic production of oilseeds and pulses. As indicated in Chapter II, the area under pulses is already on the decline. Irrigation may, therefore, further accelerate this process.

The model results indicate that a reduction by 20 percent in yield or in price of rice and potato fails to make oilseeds and pulses competitive with IRRI rice or potato under irrigated conditions. This means that a substantial increase in the yield or in prices of oilseeds and pulses will be needed to make these crops competitive with IRRI rice and potato. This situation emphasizes the crucial importance of research efforts to evolve high yielding varieties of oilseeds and pulses.

Marginal Value Product of the Fixed Farm Resources

The marginal value products (MVP) or shadow price indicated by the programming results show the relative importance of the resource contraints affecting crop production activities of the 'typical' farmer. The MVP's of fixed resources at particular times provide a better understanding of specific production activities farmers undertake under a given physical and economic environment.

It will appear from Table 5.2 that with irrigation a farmer faces constraints of labor for 5 months. Of the 5 months, the MVP's of labor are the highest during April, August, and December when the sowing and harvesting of crops overlap. Without irrigation, however, a farmer experiences constraint of labor only in April and August. This relatively short period of labor constraint without irrigation is due to less intensity of cropping and the growing of crops like local varieties of rice, pulses, and oilseeds which require less labor than IRRI varieties of rice and potato.

The MVP's of Tks 3.5 per bullock-pair day during the second fortnights of each of the months of April, August, and December with irrigation indicate the constraint

Table 5.2. Marginal value product of the fixed farm resources of a 'typical' farm[a] for year-round irrigation, Bangladesh.

	With Irrigation						Without Irrigation					
	In a Year		In Boro Season		In Aus and Aman Seasons		In a Year		In Boro Season		In Aus and Aman Seasons	
	Month	MVP	Month	MVP	Month	MVP	Month	MVP	Month	MVP	Month	MVP
						Tks.						
Cropped Area (MVP per Cropped Acre)		640						404				
Labor (MVP Per Man-Day)	Apr. 1[b]	3.5	Apr. 1	3.5	Apr. 2[c]	3.5	Apr. 2	3.5			Aug. 2	3.5
	Apr. 2	3.5	Dec. 2	3.5	July	2.5	Aug. 2	3.5				
	July	0.4			Aug. 1	3.5						
	Aug. 1	3.4			Aug. 2	3.5						
	Aug. 2	3.5			Sept.	2.5						
	Nov.	0.4			Dec. 1	3.5						
	Dec. 1	3.5										
	Dec. 2	3.5										
Bullock Power (MVP Per Pair Day)	Apr. 2	3.5	Dec. 2	3.5	Apr. 2	3.5	Apr. 2	3.5			Apr. 2	3.5
	Aug. 2	3.5			Aug. 2	3.5	Aug. 2	3.5			Aug. 2	3.5
	Dec. 2	3.5										

[a]Total size of the farm is 3.5 acres with a net cultivated area of 3 acres.

[b]The number 1 following month indicates the first half of the month.

[c]The number 2 following month indicates the second half of the month.

of bullock power at the sowing time only. Compared to labor, bullock power constraint is, thus, concentrated.

High MVP's of labor during the months when harvesting and sowing overlap and the high MVP's of bullock power during the sowing periods demonstrate the possibility of greatly increased return for investment in labor and bullock power. This situation suggests the necessity of a suitable national policy to aid in handling these seasonal resource constraints in order to increase overall productivity from agriculture.

The MVP's per cropped acre are Tks 640 and 404 with and without irrigation respectively (Table 5.2). The higher MVP with irrigation reflects the higher cropping intensity than that without irrigation. The high MVP's clearly points out the great potential of increasing returns by increasing the cropping intensity. However, as the maturity period of crops is one of the important determinants of cropping intensity with irrigation, the high MVP of cropped area with irrigation thus suggests a high pay off for any research efforts to shorten the maturity period of crops, especially jute and high yielding IRRI varieties of rice. Since the most important limiting factor for cropping intensity without irrigation is the lack of soil moisture, the high MVP of cropped area without irrigation indicates the high potentials for profitability of irrigation.

Net Farm Revenue

Net farm revenue (gross revenue minus variable cost) accrues to the labor of the farmer and his family, farmer's bullock power, fixed capital, management, and risk taking. Table 5.3 presents the net farm revenue with and without irrigation at full development which is assumed to be reached at the fifth year. It will appear that the net farm revenue with irrigation is Tks 5718 for year-round irrigation followed by Tks 4325 for Aus and Aman season irrigation and Tks 2317 for Boro season irrigation. It may be noted that the net farm revenue with irrigation in Boro, Aus, and Aman seasons add up to higher than that in a year. This occurs mainly due to higher cropping intensity when irrigation is assumed to be provided separately for Boro, Aus, and Aman seasons. If irrigation is assumed to be provided separately, the cropping intensity becomes 300 percent in Boro, Aus and Aman seasons. But in case of year-round irrigation, cropping intensity is restricted to 250 percent in a year because of some physical limitations.[1]

Impact of Seasonal Alternatives in Irrigation

Farmers' return to irrigation is quite high under each of the three seasonal alternatives: year-round

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[1]The reasons for putting restriction on cropping intensity for the year-round irrigation is discussed in detail in Chapter III.

Table 5.3. Net revenue with and without irrigation to a 'typical' farm[a] at full development[b] from the model results, Bangladesh.

	Net Farm Revenue		
	Year-round Irrigation	Boro Season Irrigation	Aus and Aman Season Irrigation
	Tks.	Tks.	Tks.
With Irrigation	5718	2317	4325
Without Irrigation	2141	202	1960

[a]Total size of the farm is 3.5 acres with a net cultivated area of three acres.

[b]Full development is reached at the fifth year.

irrigation, Boro season irrigation, and Aus and Aman season irrigation (Table 5.4). As expected, the return to year-round irrigation is the highest. The return to year-round irrigation is higher than that to the Boro season irrigation by Tks 1770 (i.e., 67 percent). This high profitability shows that although the low-lift pump irrigation is mostly confined to Boro season at present, farmers can increase their income substantially by shifting to year-round irrigation. Another important element is that farmers start getting a considerable amount of net return to irrigation from the first year. This element is likely to further reinforce the farmers' incentive to use irrigation.

Farmers' return to irrigation in Aus and Aman seasons is Tks 2884 compared to Tks 2633 in the Boro season. This higher return to irrigation in Aus and Aman seasons is contrary to the widely held view in Bangladesh that the return to Boro season irrigation is higher than the return to irrigation in Aus and Aman seasons. This divergence may be due to the recent appearance of high yielding IRRI varieties of rice for both Aus and Aman seasons. This implies that farmers may now increase their income considerably by using low-lift pump irrigation in those areas where a surface water for supplemental irrigation is available only in Aus and Aman seasons but not in the Boro season.

Table 5.4. Return at the farm level: estimated return to irrigation per acre by seasons (basic result),[a] Bangladesh.

Irrigation by Season	Net Present Value (NPV)[b] in Tks.					
	1st Year	2nd Year	3rd Year	4th Year	Total of 5th to 8th Year	Total of 1st to 8th Year
Year-round Irrigation	353	448	522	579	2501	4403
Boro Season Irrigation	220	273	315	346	1479	2633
Aus and Aman Season Irrigation	217	285	339	380	1163	2884

[a]Based on existing rental of Tks. 250 per pump (i.e., Tks. 5 per acre) and the command area per pump of 50 acres, and basic sets of input-output coefficients, prices, and yields.

[b]In estimating NPV, discount rate is assumed at 10 percent.

Impact of Alternative Rental Levels for Low-Lift Pumps

At present, rental per pump is charged on a flat rate basis. That is, rental per pump is fixed irrespective of the length of the time period within a year (one or two or three seasons) during which a low-lift pump is used. Accordingly, rental rate in this study would be on a flat rate basis. The impact of three alternative rental levels have been examined. These three alternative rental levels include: (a) the existing rental charge of Tks 250 per pump (level 1); (b) the rental charge involving 50 percent subsidy (level 2); and (c) the rental charge without any subsidy (level 3).

The results show that if the rental level is increased from level 1 to level 2, the total NPV of return to irrigation per acre decreases by about Tks 245, i.e., by only 6 percent for year-round irrigation, 9 percent for Boro season irrigation and 8 percent for Aus and Aman season irrigation (Tables 5.4 and 5.5). If the rental charge is increased further to level 3 from level 1, the total NPV of return per acre decreased by Tks 517 or by 12, 20, and 18 percent for year-round, Boro season, and Aus and Aman season irrigations respectively (Tables 5.4 and 5.5). It thus appears that with the rental raised to level 3, farmers' return arising out of irrigation is affected only partly and that their returns to irrigation still remains

Table 5.5. Return at the farm level: estimated return to irrigation per acre with alternative rental levels,[a] Bangladesh.

Irrigation by Seasons	Net Present Value (NPV)[b] in Tks.											
	Rental Rate With 50 Percent Subsidy						Rental Rate With No Subsidy					
	1st Year	2nd Year	3rd Year	4th Year	Total of 5th to 8th Year	Total of 1st to 8th Year	1st Year	2nd Year	3rd Year	4th Year	Total of 5th to 8th Year	Total of 1st to 8th Year
Year-round Irrigation	312	409	488	548	2401	4158	265	368	449	513	2291	3886
Boro Season Irrigation	179	235	280	315	1379	2388	133	193	242	286	1269	2116
Aus and Aman Season Irrigation	175	247	304	342	1571	2639	129	205	266	314	1453	2367

[a] Assuming 50 acres as the command area per pump.

[b] In estimating NPV, discount rate is assumed at 10 percent.

very high. Moreover, the stream of NPV of return shows that under no combinations of rental rate and seasonal irrigation, farmers return decreases to zero. The NPV of return to irrigation remains positive at Tks 133 and Tks 129 per acre in the first year with the rental rate at level 3 for Boro season, and Aus and Aman seasons respectively (Table 5.5). This high rate of return to irrigation even with the full cost rental raises questions about the validity of the rate of subsidy as high as 95 percent as a means of continuing to provide financial incentive to farmers. The implicit assumption behind the existing subsidization policy of low-lift pump irrigation that heavy subsidy is needed to provide incentive for the expansion of low-lift pump irrigation, therefore, seems to have been overplayed. The results clearly indicate that a substantial reduction in subsidy, if not complete elimination, would still leave a considerable rate of return constituting strong incentive for farmers to use low-lift pump irrigation.

We find that farmers' return to year-round irrigation (Tks 3886) with the rental rate involving no subsidy is much higher than the return to Boro season irrigation (Tks 2633) with the existing heavily subsidized rental (Tables 5.4 and 5.5). This means that farmers would be financially better off with the year-round irrigation even if they are to pay unsubsidized rental.

Impact of Alternative Command Areas per Pump

The command areas per pump examined in this study are 40, 50, and 60 acres. The increase or decrease in the command area per pump decreases or increases proportionately the rental cost per acre because the rental is fixed per pump. Table 5.6 indicates that under the existing rental rate of Tks 250 per pump (level 1), the increase of command area from 40 to 60 acres per pump (i.e., by 50 percent) results in a negligible increase of less than 1 percent in the NPV of return to irrigation per acre. Given such a negligible effect on the farmers' return of a change in the command area per pump, it is economically quite rational for farmers not to be interested in expanding the command area under a pump. And this provides a valid explanation from the standpoint of monetary incentive for the low and declining command area per pump until 1970.[1]

It may be argued that the effect of a change in command area is small because of the existing low level of rental (level 1). However, under the assumption of increased rental to level 2 and level 3, an increase in command area from 40 to 60 acres per pump raises the NPV for year-round irrigation to only 2 and 5 percent respectively (Table 5.6). And the NPV for Boro season irrigation

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[1]Command area per pump is shown in Table 2.7.

Table 5.6. Return at the farm level: estimated return to irrigation per acre with alternative command areas per pump, Bangladesh.

Irrigation by Seasons	Net Present Value (NPV)[a] in Tks.								
	40 Acres Command Area			60 Acres Command Area			Percentage Increase in NPV for Change in Command Area From 40 to 60 Acres		
	Rental Rate at Level 1	Rental Rate at Level 2	Rental Rate at Level 3	Rental Rate at Level 1	Rental Rate at Level 2	Rental Rate at Level 3	Rental Rate at Level 1	Rental Rate at Level 2	Rental Rate at Level 3
Year-round Irrigation	4397	4131	3796	4409	4205	3983	neg.[b]	2	5
Boro Season Irrigation	2627	2324	1989	2639	2434	2211	neg.[b]	5	11
Aus and Aman Season Irrigation	2878	2576	2238	2890	2687	2462	neg.[b]	4	10

[a]In estimating NPV, discount rate is assumed at 10 percent.

[b]Means negligible and the change is negligible when it is less than 1 percent.

rises to the maximum of 5 and 11 percent respectively (Table 5.6). It is quite doubtful whether farmers will find the difficulties[1] involved in the considerable expansion of command area (from 40 to 60 acres) worth the additional return. With regard to the possibility of the expansion of command area, the assumption was that it will increase with the increase in rental. The Evaluation Committee on TIP in 1971 (21, p. 10) observed that increased rental charge will increase the command area "because lower coverage will result in distinctly higher cost. . . ." However, the relatively small effect of a big change in the command area as indicated above does not seem to confirm the belief that increasing rental charge will be a strong incentive for farmers to increase the command area under a pump.

Sensitivity Analysis

In this section, the effects of changes in yield, price, irrigation requirement, and interest cost on farmers' returns to irrigation under the three seasonal alternatives have been examined. The basic results as discussed in the foregoing sections are based on the average (most probable) yield rate (Table 3.11), price of output (Table 3.11),

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[1]Difficulties involve the problem of group formation, group coordination, conflict resolution, etc. of members forming a pump group.

irrigation requirement (Tables 4.5 and 4.6) and interest cost (Table 3.8). In order to determine the effects of changes in these variables on the farmers' return to irrigation, the changes in the levels of these variables are made as follows:

1. Two levels of yield per acre, high and low are assumed. High and low levels of yield are assumed to be 20 percent higher and 20 percent lower respectively than the average yield.
2. Similar to yield, price is also assumed at two levels, high and low. High and low levels of price are assumed to be 20 percent higher and 20 percent lower than average price.
3. In addition to the average level of irrigation, only the impact of high level of irrigation requirement per acre will be examined. Since the low-lift pump irrigation would be relatively recent to a vast number of farmers who are used to rainfed crop culture, a high level of efficiency in the use of irrigation cannot be expected on an average. Therefore, the higher irrigation requirement appears to be more likely than lower irrigation requirement. The assumptions underlying the estimate of high level of irrigation requirement are made in Chapter IV. The average

and high level of irrigation requirements are presented in Tables 4.5 and 4.6.

4. Given the small part of the total credit requirement met from the institutional sources and the problem of increasing the supply of credit from institutional sources, higher than average cost of credit may be expected. Therefore, only the impact of high level of interest cost is examined. The average and high level of interest cost and the bases of estimate are presented in Table 3.8.

Changes in the level of these variables were incorporated into the programming model and then the model was run separately for each change in order to determine the effect of these changes. This approach allows flexibility so that a profit maximizing farmer has the option of making suitable adjustments in maximizing his profit under the changed situations. The underlying assumption is that if a farmer, in fact, were faced with the changed levels of the variables, he would tend to make decisions in the light of the changed circumstances. Because of the flexibility allowed to farmers in making adjustments, the effects of changes in the variables have been moderated than would have been the case if they were not allowed to make any adjustments. In this sense, the results would represent the upper bound of longer term adjustments.

Table 5.7 presents the returns to irrigation with the changed levels of yield, price, irrigation requirement, and interest cost. Of these variables, the change in yield seems to have the most dominant impact on the rate of return to irrigation. With the high level of yield, the NPV of return per acre goes up to the highest of Tks 6428 and falls lowest to Tks 2438 in case of year-round irrigation (Table 5.7). The increase in the level of yield to high level results in the increase of NPV by 46, 40, and 54 percent respectively for irrigation in a year, Boro season and Aus and Aman seasons. The decrease in yield also results in similar decreases in the NPV. It appears that most drastic reduction in return occurs with the low level of yield in case of irrigation in Aus and Aman seasons. This result suggests that the expansion in the use of low-lift pump irrigation in the Aus and Aman seasons will be associated with the expansion in the use of high yielding IRRI varieties of rice.

Next in importance to yield in influencing the rate of return to irrigation is the price of output. The NPV for year-round irrigation increases by 31 percent with the high level of price and decreases by 27 percent with the low level of price.

A change from average to high level of irrigation requirement affects only slightly the farmers' return. The NPV of return of Tks 4403 with the average level of

Table 5.7. Return at the farm level: sensitivity of returns per acre to changes in the levels of important variables, Bangladesh.

Levels of Variables	Net Present Value (NPV)[a] in Tks.						
	1st Year	2nd Year	3rd Year	4th Year	Total of 5th to 8th Year	Total of 1st to 8th Year	Percentage Change from Basic Result
Year-round Irrigation							
Basic Result	353	448	522	579	2501	4403	
High Level of Yield	498	643	758	847	3682	6428	+46
Low Level of Yield	157	226	280	322	1453	2438	-45
High Level of Price	425	564	675	760	3338	5762	+31
Low Level of Price	244	318	378	423	1851	3214	-27
High Level of Irrigation Requirement	367	455	524	576	2463	4385	-1
High Level of Interest Cost	365	455	524	579	2477	4400	neg.[b]
Boro Season Irrigation							
Basic Result	220	273	315	346	1479	2633	
High Level of Yield	237	329	403	461	2059	3682	+40
Low Level of Yield	125	169	205	232	1026	1757	-33
High Level of Irrigation Requirement	218	270	312	343	1466	2609	-1
Aus and Aman Season Irrigation							
Basic Result	217	285	339	380	1663	2884	
High Level of Yield	385	469	533	581	2462	4430	+54
Low Level of Yield	49	102	144	177	860	1332	-54
High Level of Irrigation Requirement	208	277	330	371	1626	2812	-2

[a]In estimating NPV, discount rate is assumed at 10 percent.

[b]Means negligible and change is less than 1 percent.

irrigation requirement decreases by only 1 percent to Tks 4385 with the high level irrigation requirement in case of year-round irrigation (Tables 5.4 and 5.7). Similarly, the decrease in return is 1 percent for Boro season irrigation, and 2 percent for irrigation in Aus and Aman seasons. This negligible effect of a change in the level of irrigation requirements per acre shows that farmers might be less concerned with the improving of water management practices. Returns to irrigation for the low and high rainfall regions have not been estimated in this study. However, the difference in irrigation requirements per acre per crop between the average and high levels for the medium rainfall region is comparable with the difference in the irrigation requirements between the low and high rainfall regions (Tables 4.5, 4.6, and 4.8). The above result of a change in return to irrigation by 1-2 percent due to change in irrigation requirement between average and high level, therefore, suggests that the difference in return to irrigation due to varying amounts of rainfall received in the low and high rainfall regions, given other things, will be very small.

The impact of the high level of interest cost as compared with the average level appears to be negligible. The increase in interest cost to high level decreases the NPV by less than 1 percent for year-round irrigation. This situation occurs because with the high level of interest cost farmers make adjustments in the cropping pattern involving lower amount of credit. The irrigation seems to offer options which make it possible to neutralize greatly the effect of increase in interest cost as specified in Table 3.8.

Impact on the Economy

In case of farm level impact examined in the foregoing section, prices of inputs and outputs used are those which farmers paid or received under the given market conditions characterized by imperfections and government controls. Because of the market imperfections and government's control measures, these prices do not reflect the true scarcity values. However, the evaluation of economic impact involves the use of shadow price (real price) reflecting these scarcity values of the inputs and outputs. In this section, the shadow prices of inputs and outputs will first be estimated. Then, the impact from the point of view of the economy arising out of low-lift pump irrigation will be examined.

Shadow Prices of Inputs

Fertilizer.--Fertilizer is heavily subsidized. The rate of subsidy on fertilizer during 1965-70 was estimated at 57 percent (17). As this estimate was based on valuing foreign exchange at the official rate which was lower than free market rate, actual rate of subsidy was higher than 57 percent.

According to the target of production of fertilizers by 1969-70 (74), a greater portion of the urea would be available for domestic industries and most of the triple super phosphate (TSP) and muriate of potash (MP) would have to be imported. The shadow price of fertilizer is, therefore, estimated on the basis of ex-factory price of urea and CIF chittagong price for TSP and MP. The shadow prices[1] per seer (equivalent of 2.057 lbs.) of urea, TSP, and MP are estimated at Tk 0.72, Tk 0.69 and Tk 0.56 respectively.

<u>Plant Protection</u>.--Plant protection measures involve costs of pesticide chemicals, sprayers, and the labor used in applying the pesticides. Table 5.8 presents the shadow cost of plant protection. This cost is based on the imported price of pesticides and sprayers, and the shadow price of foreign exchange[2] and the average number of sprayings recommended by the Directorate of Agriculture.

<u>Low-Lift Pump</u>.--The estimated capital, operating and maintenance cost (shadow) of a low-lift pump of two cusec capacity is presented in Table 5.9. This estimate utilizes information available in the Low-Lift Pump Irrigation

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[1]Shadow price of foreign exchange is estimated at US $1 = Tks 9.5.

[2]*Ibid.*

Table 5.8. Estimated shadow price of plant protection per acre under irrigated and unirrigated conditions, Bangladesh.

	IRRI Boro Rice	IRRI Aman Rice	IRRI Aus Rice	Local Boro Rice	Local Aman Rice	Local Aus Rice	Jute	Potato	Wheat	Mus-tard	Ground-nut
					Tks						
Irrigated Crops	36	40	38	18	20	19	20	20	10	5	5
Unirrigated Crops					15	15	10		5	2	2

Table 5.9. Estimated annual cost of a 2 cusec Low-Lift Pump, Bangladesh.

Items	Local	Foreign[a]	Total	Average Annual Cost
			Tks	
Capital Cost				
Pump	50	1093	1143	
Pump Engine	560	4871	6431	
Spares	117	1168	1285	
Trolley	50	598	648	
Pipes	355	770	1125	
Bends	90	162	252	
Foot valve	70	180	250	
Sub-total	1292	9842	11,134	2087[b]
Tools, Equipment and Vehicles	175	1000	1175	191[c]
Buildings				120
Total Capital Cost				2398
Operating and Maintenance Cost				
ADC's staff				800
ADC's overhead				100
Pump Driver				1224
Pump Manager				400
Model Farmer				100
Contingencies				50
Total				2674
Grand Total for Capital, Operating and Maintenance Cost				5072

[a]Foreign exchange is valued at Tks 9.5 per US dollar.

[b]Estimate is based on the assumption of 8 years life, 10 percent rate of interest, and entire investments made in the first year.

[c]Estimate is based on the assumption of 10 years life, 10 percent rate of interest, and entire investment made in the first year.

chemes (16, 18), and the report of the 1967 Mission of the World Bank (49). The life of pump engine and accessories is assumed to be 8 years with zero salvage value. Other tools and equipment are assumed to have a life of 10 years with zero salvage values. The operating and maintenance costs are estimated within the framework of TIP institutional arrangements.

The diesel fuel is subject to various taxes. The shadow price of diesel is estimated at Tks 1.70 per gallon (imperial) by deducting all taxes and marketing charges from the C & F Chittagong price of diesel. Since fuel consumption is estimated to be 0.625 gallons (imperial) per hour for a 2 cusec low-lift pump, one hour of operation costs Tks 1.1 for diesel. The requirement of lubricating oil is estimated at 15 percent of the requirement of diesel. Therefore, one hour of operation costs Tks 1.27 for diesel and oil. Since a 2 cusec low-lift pump can normally lift 2 acre inches of water in an hour, the cost of an acre inch of water is Tk 0.635.

Labor.--The shadow price of agricultural labor in a less developed country with a largely agricultural economy has been a matter of great controversies among economists. Some are of the view that the economic cost of labor in these countries is zero because of zero marginal product of labor in agriculture (61, 65). Another group of economists contend that marginal product of labor is positive (88). Although the proponents of both the views have empirical findings to back up their respective positions, they have considerable differences over methodologies followed and definition of disguised unemployment. Kao, et al., (55) observed that "the existence of disguised unemployment is largely a matter of definition and the assumptions about the institutional forces involved." This issue of the extent of marginal product of agricultural labor is still unresolved. But it is generally accepted that shadow cost of labor will be somewhere between zero and market wage rate. However, what should be the appropriate economic cost of agricultural labor in Bangladesh is unknown.[1] Given this uncertain situation, we assume for the purpose of this study a shadow cost of agricultural labor at 50 percent of the market wage rate.

Shadow Prices of Outputs

Rice.--Bangladesh had to import an average of 1 million tons of rice a year during the decade of the sixties. The importation of rice is expected to continue in the near future. The shadow price of rice is, therefore, estimated on the basis of present and prospective CIF import price. The landed price of rice at Chittagong is estimated at Tks 38 per maund of medium quality rice in

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[1]Ahmed (4) included a fairly elaborate discussion on this issue in his study.

the mid-70s. By converting rice into paddy (1 unit of paddy = 0.666 unit of rice) and deducting Tks 4 for milling and transportation, the shadow price of paddy at the farm gate works out to Tks 21 per maund.[1]

Jute.--In contrast with price of rice, the shadow price of jute is based on F.O.B. export price because export is the relevant trading alternative for jute.

An important element in estimating international price of jute is the growing competition between jute and synthetics. As the synthetic fibre is a good substitute for jute, the elasticity of demand for jute in the international market has increased considerably. The international price of jute has been relatively stable since 1965 mainly because of high cross elasticity of demand between jute and synthetics.

The price of synthetic end products is on the decline because of technological improvement and an increasing efficiency in production. The price of synthetic end products will continue to decline (39). Repetto (81) projected 25 percent decline in the price of synthetic end products by 1975. If we assume that jute manufactures constitute 50 percent of the value of raw jute and 75 percent[2] of the fall in price is passed on to

[1]One maund equals 82.28 lbs.

[2]The remaining 25 percent will be absorbed in the processing margin of the domestic jute industry.

raw jute, a reduction of 37.5 percent in the price of jute would, therefore, be necessary to maintain its competitive position against the synthetics. Moreover, it is necessary to allow for the adverse effect of the dislocation in the world jute trade during 1971-1972 on the prospective price of jute. The synthetics made further inroads into the international jute market because of this dislocation. For the purpose of this study, it is assumed that 40 percent reduction in the price of raw jute will occur by 1975 and an additional 20 percent reduction will occur by 1980. In the light of the above discussion, the shadow price of raw jute per maund at farm gate is estimated at Tks 67, 42, and 29 in 1970, 1975, and 1980 respectively. In calculating the gross revenue from jute in this study, a shadow price of Tks 42 per maund of jute has been used.

Wheat, Mustard, Groundnut, Potato, and Pulses.--Of these products, most of the domestic supply of wheat and a considerable amount of oilseeds are imported. Based on CIF prices, projection of international price trend, and shadow price of foreign exchange, the shadow price per maund at the farm gate is estimated at Tks 24, 50, and 37 for wheat, mustard,and groundnut respectively by 1975. The domestic demand for potato and pulses are met from internal production. The average 1970 prices in the domestic market, therefore, serves as a basis for estimating the shadow price of these two crops. Accordingly, as in the case of farm level analysis, the shadow prices of potato and pulses per maund are estimated at Tks 13 and 18 respectively.

Seasonal Alternatives and Return to Irrigation

The return to investment in low-lift pump irrigation from the point of view of the economy is highly profitable in Bangladesh (Table 5.10). The existing practice of using the low-lift pump only in the Boro season shows a high IRR of 57 percent. This high rate of return confirms the earlier findings by the World Bank of a high return to Boro season irrigation (49). The high return for the Boro season irrigation might also be regarded as a strong explanatory variable for the all out efforts by the government to expand the low-lift pump irrigation even though it was mostly confined to the Boro season. However, we find that the estimated rate of return increases considerably to 92 percent if low-lift pumps are used throughout the year instead of only in the Boro season (Table 5.10). The substantial increase in return from year-round irrigation suggests that a considerable amount of additional output to the nation can result from the investment already made and that nonutilization of low-lift pumps in other than Boro season represents a considerable loss to the economy.

Table 5.10. Economic return: estimated return to irrigation per acre by seasons, Bangladesh.

Irrigation in Different Seasons	NPV (Tks)	B/C Ratio	IRR (percent)
Year-round Irrigation	2558	1.60	92
Boro Season Irrigation	1209	1.45	57
Aus-Aman Season Irrigation	1222	1.38	54

The rate of return arising from the use of low-lift pump irrigation in Aus and Aman seasons is almost as high as the return to Boro season irrigation. The high IRR of 54 percent for Aus and Aman season irrigation indicates that the public investment in the low-lift pumps would be economically feasible even if the pumps are used only in the Aus and Aman seasons.

Under the existing practice of confining the use of low-lift pumps in the Boro season, these pumps have to remain idle in the Aus and Aman seasons. Thus, based on the opportunity cost principle, the economic (real) cost of using these pumps in Aus and Aman seasons will be quite small because otherwise the alternative is to keep them idle during this period. The cost involved is only due to some additional repair and maintenance required to use these pumps during this period. For the purpose of calculation, an increase of 25 percent in additional repair and maintenance has been assumed. Under the changed conditions specified above, the return to the economy for irrigation in Aus and Aman seasons increases considerably. The NPV, B/C ratio, and IRR are estimated at Tks 1519, 1.52, and beyond 400 percent respectively (Table 5.11).

Table 5.11 Economic return: estimated return to Aus and Aman season irrigation based on the assumption of low opportunity cost of low-lift pumps, Bangladesh.

	NPV	B/C Ratio	IRR (percentage)
Basic Result	1519	1.52	Exceeding 400

Alternative Command Areas per Pump and Return to Irrigation

The basic result as analyzed in the above section is based on the command area of 50 acres per low-lift pump. In this section, the impact of high (60 acres) and low (40 acres) levels of command area per pump on the rate of return has been examined. Since a larger command area involves longer hours of operation of a low-lift pump, there will be higher rates of wear and tear and breakdown if not properly maintained. The reverse would be the case in case of lower command area. To account for these elements, cost for repair and maintenance has been changed proportionately to the change in the command area. A change in the command area per pump results in a substantial increase in the rate of return to irrigation. An increase in command area from low to high level increases the IRR per pump from 168 percent to 225 percent and the NPV per pump by Tks 56, 686 in case of year-round irrigation (Table 5.12). This increase in command area also raises the IRR per pump from 103 to 134 percent for Boro season irrigation and from 94 to 120 percent for irrigation in Aus and Aman seasons (Table 5.12). This high profitability arising out of an increase in the command area from the point of view of the economy stands in sharp contrast with the small increase in profitability at the farm level (Table 5.6).

Sensitivity Analysis

The levels of yields and prices assumed for this study are discussed earlier in this chapter. Table 5.13 presents the return to the economy from irrigation with high and low levels of yields and prices. In case of year-round irrigation, the IRR rises to 164 percent with high level of yield and falls drastically to 40 percent with the low level of yield. On the other hand, high level of price increases the IRR to 148 percent and low level of price decreases the IRR to 69 percent for the year-round

Table 5.12. Economic return: estimated return to irrigation per pump with alternative command areas, Bangladesh.

Alternative Command Areas and Seasons	NPV	B/C Ratio	IRR
	Tks		Percent
Year-round Irrigation			
High Command Area	166,199	1.68	225
Low Command Area	109,513	1.67	168
Boro Season Irrigation			
High Command Area	85,301	1.58	134
Low Command Area	55,580	1.56	103
Aus and Aman Season Irrigation			
High Command Area	102,201	1.62	120
Low Command Area	56,105	1.46	94

Table 5.13. Economic return: estimated return to irrigation per acre with high and low levels of yields and prices, Bangladesh.

Levels of Yield and Price	Year-round			Boro Season			Aus and Aman Seasons		
	NPV	B/C Ratio	IRR	NPV	B/C Ratio	IRR	NPV	B/C Ratio	IRR
	Tks		Percent	Tks		Percent	Tks		Percent
High Yield	4935	1.95	164	3042	1.87	115	2629	1.82	103
Low Yield	887	1.22	40	417	1.16	28	-186	0.94	2
High Price	4479	1.87	148						
Low Price	1772	1.45	69						

irrigation (Table 5.13). The relative effect of variations in yield and price levels clearly demonstrates that the yield has higher impact on the returns to irrigation than price.

Because of the dominant influence of variation in yield in case of year-round irrigation, we further trace through the impact of changes in yield in case of Boro season irrigation, and Aus and Aman season irrigation.[1] We find that low level of yield drastically reduces the return to irrigation. It is interesting to note that with the low level of yield for Aus and Aman seasons, irrigation becomes unprofitable with negative NPV and B/C ratio less than one (Table 5.13). Before 1970, no high yielding IRRI varieties of rice were available for the Aus and Aman seasons and the yield per acre of local varieties of rice in these seasons was lower than the low level of yield assumed for this analysis. The negative NPV and the B/C ratio of less than one for Aus and Aman seasons irrigation explain the lack of enthusiasm until 1970 on the part of the government to expand the use of low-lift pump irrigation in the Aus and Aman seasons. The result thus indicates the vital importance of high yielding IRRI varieties

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[1]The effect of variation in price for Boro season, and Aus and Aman seasons is not shown separately because the effect will be similar differing proportionately in magnitude.

of rice for the profitability of low-lift pump irrigation in Aus and Aman seasons.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

Summary

Low-lift pump irrigation is the major form of irrigation in Bangladesh. The government has placed a high priority on further rapid expansion of the low-lift pump irrigation throughout the country. Under the existing arrangements, the government owns the low-lift pumps and rents them out to pump groups at a fixed rental charge. The low-lift pump irrigation program is characterized by the use of low-lift pumps mostly in one season (Boro), a heavy subsidy by the government and a relatively small command area per pump.

The objective of this study was to evaluate the economics of alternative low-lift pump irrigation policies from the point of view of farmers and the economy. The alternatives considered in this study were:

1. The use of low-lift pump irrigation in (a) the Boro season alone (b) the Aus and Aman seasons, and (c) the whole year, that is, in the Boro, Aus and Aman seasons.

2. Three levels of rental charge per pump.
3. Three levels of command area per pump.

In order to analyze the impact of alternative policies in low-lift pump irrigation, a theoretical framework was developed to show how farmers would adjust in response to the alternative policies and how their benefits and costs would be affected. Estimates for a 'typical' farm were developed by providing data on input-output relationships, prices of inputs and outputs, and fixed farm resources. In the absence of empirical data on irrigation requirements, the modified Penman formula was used to estimate the irrigation requirements for the crops considered in this study. Linear programming techniques were employed to determine returns to fixed farm resources, the optimum cropping pattern, and the amount of hired labor, and bullock power required for a 'typical' farm. The coefficients of the linear programming tableau were then suitably adjusted to measure the changes in the impact due to changes in yield rate, price of output, irrigation requirements, and interest cost. In evaluating the impact on farms, the net present value (NPV) was estimated. The internal rate of return (IRR), the benefit/cost ratio (B/C ratio), and the NPV were computed to evaluate the impact on the economy.

Limitation of the Analytical Procedures

Recognition of the following limitations is required for the proper interpretation of the conclusions of this study.

1. The return exclusively attributable to the low-lift pump irrigation was determined by deducting the net return without irrigation from the net return with irrigation. It was assumed that IRRI varieties of rice would be grown only with irrigation. Since the latest indication is that IRRI varieties of rice can be grown without irrigation in the Aus and Aman seasons in several parts of Bangladesh, the return to irrigation as estimated in this study includes additionally the return from the high yielding IRRI varieties of seed in case of Aus and Aman seasons. The return to irrigation may, therefore, be interpreted accordingly.
2. Since the 'typical' farm is assumed to be located topographically on the medium land, the results of the study are specifically applicable to farms on these lands. In order to make the results apply to farms located on the high and low lands, some adjustments in cost and output would be necessary.
3. The 'typical' farm was developed to represent average production situations with respect to

resource ownership positions, input-output relationships and so on. The 'typical' farm, thus, cannot be taken to represent all variations of farms located on the medium lands. In addition, the estimates for a 'typical' farm had to be made by synthesizing secondary data available from diverse sources.

4. The return to low-lift pump irrigation estimated in this study applies to the medium rainfall region of the country. In estimating the irrigation requirements in the medium rainfall region, the data on monthly rainfall in Dacca were used. The use of weekly rainfall data instead of monthly data might result in slight modification of the irrigation requirements and the net return to irrigation.

5. As the cost could not be calculated for government research efforts for the development of HYV's of seed or for the part of the cost of the government extension efforts to expand the HYV's and low-lift pump irrigation, the net return to the economy of low-lift pump irrigation used with the HYV's tends to have some upward bias. The net return shown in this study may, thus, be considered to be an upper limit.

Conclusions

Crop Enterprise Combinations and Marginal Value Products

1. Low-lift pump irrigation results in a considerable specialization of crops. With year-round irrigation, out of 12 crops considered, only 5 crops appeared in the solution. Most of the shift in cropping was toward the IRRI varieties of rice. This result thus confirms the validity of the top priority given to low-lift pump irrigation as one of the important strategies to attain self-sufficiency in food grains in Bangladesh.
2. With the year-round irrigation, the entire farm land is cropped in the Boro season. But 93 and 57 percent are cropped in the Aman and Aus seasons respectively. The relative competitiveness for land between the Aman and Aus seasons appeared to be very close. A small increase in the yield of IRRI aus rice will lead to an increased allocation of land to Aus season crops relative to the IR-20 variety of rice in the Aman season.
3. The IR-8 variety of rice seems to have a competitive edge over potato in the Boro season. Although 0.45 acres were allocated to potato in the case of year-round irrigation, the IR-8 completely eliminated potato in case of irrigation only in the Boro season.

4. There would be an intense competition for land between IRRI aus rice and jute in the Aus season under irrigated conditions. Without considerable increase in yield of jute, IRRI aus rice is likely to replace substantially the jute crop under irrigated conditions.
5. With irrigation, the competitiveness of traditional pulses and oilseeds relative to IRRI boro rice and potato decreases substantially. Pulses and oilseeds cannot compete with IRRI boro rice and potato, even when the yield per acre or price per maund of IRRI boro rice and potato are reduced by 20 percent.
6. Under irrigated conditions, the marginal value product (MVP) of labor is the highest at Tks 3.5 per man day for the three months of December, April, and August when the harvesting and sowing overlap. But the MVP of bullock power rises to Tks 3.5 per bullock-pair day during the sowing time (second fortnights of April, August, and December) only.
7. The MVP of cropped acreage rises to as high as Tks 640 per acre with year-round irrigation. Such a high MVP indicates the great potential of increasing returns by increasing cropping intensity.

Impact of Alternative Low-Lift Pump Irrigation Policies on Farms

1. Farmers' return to irrigation using HYV's of seed appears to be high under each of the three seasonal alternatives. Of the three seasonal alternatives, return to year-round irrigation was the highest. However, contrary to the popular belief, the return to irrigation in the Aus and Aman seasons together was found to be higher than in the Boro season under the relationships used in this analysis (Table 5.4).

2. Increases in the rental charge for low-lift pumps affects farmers' profitability of irrigation only marginally. An increase in rental charge from the existing level of Tks 250 per pump to a higher level involving only a 50 percent subsidy decreased the NPV by only 6 percent for the year-round irrigation, 9 percent for the Boro season irrigation and 8 percent for irrigation in the Aus and Aman seasons (Tables 5.4 and 5.5). With the rental charge increased to the level involving no subsidy the NPV of return decreased only by 12, 20, and 18 percent for the year-round, Boro season, and Aus and Aman season irrigation respectively (Tables 5.4 and 5.5). Under all the three levels of rental,

farmers obtain net returns from irrigation starting in the first year.

3. A change in the command area per pump has very small impact on the profitability of irrigation to farmers. Under the existing rental level of Tks 250 per pump, the increase of command area from 40 to 60 acres per pump increased the NPV of return to irrigation by less than 1 percent (Table 5.6). With the rental level increased to the level involving no subsidy, an increase of command area from 40 to 60 acres increased the NPV of return by a maximum of only 11 percent (Table 5.6).

4. A change in the yield rate per acre seems to have the most dominant impact on the farmers' return to irrigation. A change of 20 percent in yield rate per acre resulted in a change of NPV of return by 45-46 percent (Table 5.7). The second in importance in affecting the NPV of return to irrigation was the price of output. A change of price by 20 percent changed the NPV by 33-40 percent (Table 5.7).

5. Variations in the irrigation water requirements per acre and interest cost per acre appear to have negligible effect on the farmers' return to irrigation (Table 5.7).

Impact of Alternative Low-Lift Pump Irrigation Policies on the Economy

1. From the point of view of the economy, low-lift pump irrigation appears to be highly profitable for each of the seasonal alternatives. The IRR was estimated at 92 percent for the year-round irrigation, 57 percent for the Boro season irrigation, and 54 percent for irrigation in the Aus and Aman seasons (Table 5.10). With the assumption of a low opportunity cost for the use of low-lift pumps in the Aus and Aman seasons,[1] the return to irrigation in Aus and Aman seasons increased substantially. The IRR and NPV for Aus and Aman season irrigation rose to over 400 percent and Tks 1519 respectively (Table 5.11).

2. A change in the command area per pump affects considerably the return to the economy from irrigation. With the increase in command area per pump from low to high level (from 40 to 60 acres), the IRR per pump increased from 168 to 225 percent for year-round irrigation, from 103 to 134 for the Boro season irrigation, and from 94 to 120 percent for Aus and Aman season irrigation (Table 5.12). The

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[1]For discussion of the assumption, see pp. 158,159.

above change in command area increased the NPV by Tks 56, 686 per pump for year-round irrigation.

3. The impact of a change in yield on return to the economy from irrigation appears to be substantially high. In case of year-round irrigation, the high level (20 percent higher than average) of yield increased the IRR to 164 percent and the low level (20 percent lower than average) of yield decreased the IRR to 40 percent (Table 5.13). Similarly, the IRR for the Boro season irrigation was 115 and 28 percent for high and low levels of yields respectively (Table 5.13). However, the low level of yields made irrigation in the Aus and Aman seasons unprofitable with negative NPV and B/C ratio less than one.

4. A change in price considerably influences the return to irrigation. However, price had lower impact on return to irrigation than yield. In case of year-round irrigation, the high level (20 percent higher than average) of price increased the IRR to 148 percent and the low level (20 percent lower than average) of price reduced the IRR to 69 percent (Table 5.13).

Implications

The conclusions of this study have implications for individual farmers, government policy makers, and other researchers.

Farmers

1. Farmers should be aware that they have the opportunity of substantially increasing their income by using low-lift pump irrigation throughout the year, if surface water is available. Since low-lift pump irrigation is profitable under each of the three seasonal alternatives, farmers in those areas having surface water available in one season only can also increase their income considerably by using low-lift pumps.
2. The higher profitability of irrigation in the Aus and Aman seasons indicates that farmers should rethink about the age-old tradition of exclusively depending on rainfall for cropping in the Aus and Aman seasons. As the surface water in the Aus and Aman seasons would be available in wider areas than it is in the Boro season, farmers could capture the benefit of low-lift pump irrigation in extensive areas throughout the country.

3. The present level of rental is very low. Even if the level of rental is increased considerably, farmers should be aware and well-advised that their profitability is affected only marginally.

Government Policy Makers

1. As the rate of return to the economy from irrigation appears to increase substantially by extending the low-lift pump irrigation throughout the year instead of in the Boro season alone, top priority should be given to considering implementation of a year-round pump irrigation program. The finding that farmers' profitability also increases significantly as a result of year-round irrigation reinforces the possibility of success of any government policy to encourage year-round irrigation. As the existing policies with respect to formation of pump groups, supply of pumps, repair and maintenance of pumps, and supply of input packages are mainly geared to the Boro season irrigation, a shift in priority to year-round irrigation will necessitate the reorientation of these policies.
2. Since the rate of return to irrigation in the Aus and Aman seasons from the national standpoint is estimated to be almost equally as high as for Boro season irrigation, government policy makers should

consider the low-lift pump irrigation program in those areas where surface water for pump irrigation is available only in the Aus and Aman seasons (and not in the Boro season). With farmers' strong financial incentive because of high profitability of irrigation in the Aus and Aman seasons, suitable governmental policies are likely to expand rapidly the irrigation in the areas having surface water in the Aus and Aman seasons only.

3. There is scope for substantial reduction in subsidy involved in the low-lift pump irrigation program without any significant adverse effect on farmers' incentive.

4. Efforts on the part of the government to increase the command area per pump will have high pay off in terms of increasing national gain from the use of available pump capacities. Since under the existing arrangements, farmers have very little incentive to increase command area per pump, public policy measures might include the formulation of rental structure favoring the pump groups having a larger command area under a pump. The impact of change in rental charge on farmers' profitability is not high enough to make an effective policy based on the variation in rental arrangements alone. Therefore, other auxiliary policies like the

preferential treatment in granting credit, supply of pumps, and other input packages to pump groups having larger command area per pump will be necessary.

5. Although the effectiveness of extension activities are not specifically analyzed in this study, it appears that extension services have to be sufficiently improved and strengthened in order to realize the potential gains from irrigation indicated in this study. Vigorous extension efforts will contribute to the attainment of several objectives like 1) expansion of the year-round irrigation instead of the Boro season irrigation only, 2) expansion of irrigation in the Aus and Aman seasons in those areas where surface water is available only in this period, 3) increase in the command area per pump, 4) increase in the use of high yielding varieties of crops, and 5) improvement in the water management practices.

6. The breakthrough in seed technology for aus rice has increased considerably the competitive strength of aus rice relative to jute. With the high yield potential of IRRI aus rice, the jute acreage may decline greatly unless the relative price of jute and aus rice changes in favour of jute. As the scope for increase in the price of jute is limited

because of probable adverse effect on jute export, a viable alternative lies in increasing the productivity of jute.

7. The acreage under oilseeds would decline rapidly in the irrigated areas because of high profitability of IRRI boro rice and potato. Unless the loss in irrigated area for oilseeds is fully neutralized by the expansion in unirrigated areas, production of oilseeds will decrease. The short-run implication for a decrease in the production of oilseeds in the irrigated areas might be a rise in price or increased import or a decrease in the area under closely competitive crops like pulses. From the long-run point of view, the feasible policy alternative is to bring about an increase in productivity through varietal improvement in seed.

8. Irrigation will accelerate the decline of acreage under pulses. Since pulses are the important source of protein, this process will further deteriorate protein deficiency in Bangladesh. Thus, either a search for alternative sources of protein or a vigorous public policy to encourage the development of high yielding varieties of pulses would be required.

9. A change in the rate of interest had a negligible effect on the profitability of irrigation under the

conditions specified in this study. This implies that there is a considerable scope for increasing the rate of interest on institutional credit without adversely affecting the incentive of farmers using low-lift pump irrigation.

Future Research

1. It is highly important that adequate research efforts be directed toward bringing about yield-increasing innovations in jute, oilseeds, and pulses. Since the yield potential of the existing local varieties of oilseeds and pulses even with irrigation is very limited, a breakthrough in seed technology for these crops seems most important.
2. The relative competitiveness of jute and IRRI aus rice should be a topic of comprehensive study for evolving appropriate price and other policies for jute and IRRI aus rice.
3. The estimate of irrigation requirements for various crops as developed in this study should be tested on the farmers' fields. Therefore, micro level studies in various parts of Bangladesh would be necessary to determine the water response function and the optimum water requirements for various crops. Such studies would enable the verification

of the irrigation water requirements and output responses used in this study.

4. A restriction on the maximum cropping intensity that may be attained with irrigation was imposed. The main reason for this restriction is the length of maturity period of various crops. The programming solution indicated the MVP of Tks 640 per cropped acre in case of year-round irrigation. This implies a high profitability of the increase in cropping intensity. This suggests that research efforts to shorten the maturity period of crops especially IRRI varieties of rice and jute will have a high payoff.

5. A series of sample studies in various parts of Bangladesh would be necessary to improve the estimates of input-output relationships used in this study. Such improved estimates could be used in a linear programming model as used in this study to verify these conclusions. In particular, the performance of IRRI varieties of rice in the Aus and Aman seasons with and without irrigation should be thoroughly analyzed to obtain improved estimates of returns to farmers and the economy.

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