ECONOMIC ANALYSIS OF TUBEWELL IRRIGATION IN BANGLADESH

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ABSTRACT

ECONOMIC ANALYSIS OF TUBEWELL IRRIGATION
IN BANGLADESH

By

Rais Uddin Ahmed

The study was undertaken with three main objectives: 1) to investigate the monetary profitability of investment in tubewell irrigation in Bangladesh, 2) to investigate the relative merit, measured in monetary terms, of various technical alternatives available in the installation and operation of tubewells for irrigation in Bangladesh, 3) to investigate the impact of tubewell irrigation on employment generation. Some policy implications involved in the process of adjustment from non-irrigated to irrigated farming were also indicated.

A linear programming model with appropriate constraints was employed to project cropping pattern under irrigation. The net effect of irrigation was measured by deducting the net monetary benefits of non-irrigated farming from the net monetary benefits of irrigated farming. This net effect of irrigation was measured by the criteria of the benefit-cost ratio, the internal rate of return, and the net present value for comparing the technical alternatives available in

tubewell installation. For similar comparison of these technical alternatives from the point of view of employment generation, marginal employment-investment ratios were constructed. The change in the level of employment in agriculture due to irrigation was measured. Demand functions for labor under irrigated conditions were also estimated. Sensitivity tests were conducted to investigate the variations in the results for various values of important parameters.

The results of the programming model indicated that, with the existing relative prices of jute and rice, jute production might not be undertaken by the farmers in the irrigated areas. Considering the position of jute with its synthetic competitors in the world market, a cost-minimizing technological breakthrough in jute production is essential. Farmers' working capital requirement for irrigated cropping was found to have important effects on cropping intensity; availability of working capital at or below Rs. 400 per season, particularly in the Boro season, might restrict cropping intensity below 234 percent in the irrigated areas. The net income to individual farmers from crop production under irrigated conditions was estimated to go up by more than 108 percent over the present income from farming.

The internal rates of returns for various technical alternatives available in the installation of tubewells were found to vary from 24.6 to 40.1 percent. Drilling technique and type of engines had higher influence on the rates of returns compared to other elements in the technical alternatives. However, with a range of low and high values of important parameters, the range of the rate of returns was found to widen substantially. It ranged from a negative internal rate of return to as high as 95 percent. The yield rates of crops, prices, the rate of utilization of a well, and the time lag in reaching full development were found to be the factors to which the results were most sensitive.

The ranking of the technical alternatives available in the installation of tubewells in Bangladesh showed the same pattern from the points of view of both income and employment generation. Low cost wells were generally found superior to high cost wells both in income and in employment creation. It was estimated that one tubewell generated an additional 139,765 mandays of work for unskilled workers and 9.900 mandays of work for skilled workers over a 20 years period. This is equivalent to a permanent job creation for 21.2 unskilled workers and 1.5 skilled workers. About 93 percent of the total additional employment created was found to originate in crop production activities. The per acre demand for all labor was estimated to go up by 112 percent due to a shift from a low-yielding local variety to a high-yielding new variety of rice. The per acre demand for hired labor was estimated to go up by 149 percent for a similar shift. The wage elasticity of demand for all labor per acre was estimated to be -0.46, and that of hired labor,

-1.55. The per acre demand for all labor was found to be negatively related with farm size and the per acre demand for hired labor was found to be positively related with farm size.

The incremental labor requirement for an irrigated cropping pattern was estimated to be 109 percent over that for a non-irrigated cropping pattern. Assuming static wage rates and farm sizes, about 62 percent of the increased labor requirement could be attributed to the new high-yielding varieties. The remaining 38 percent was attributable to the increased cropping intensity made possible by irrigation.

The important policy implications of the results of the study relate mainly to resource allocation. Various measures constructed in the study to evaluate income and employment generations from various types of tubewells will provide guidelines for sectoral and sub-sectoral allocation of investments. Impact of irrigation programs on regional imbalance in income and agricultural employment and the implication of such programs for marketing, agricultural extension and research were also indicated.

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Dedicated to

My Parents

Without their sacrifice, inspiration, and groundwork I would not have been at this stage of my education.

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CHAPTER I

INTRODUCTION

The General Level of Economic Activity

Before the recent war with Pakistan, the population of Bangladesh was estimated to be 75 million in 1970 with an annual growth rate of about 3.0 percent.[1] Against this population estimate, the total cultivated area in Bangladesh is only 24 million acres, the per capita land resource being only 0.32 acres. There is little scope for further extension of the cultivated land area. Per capita income, as calculated by a Commission on National Income was only Rs. 315 in 1965.[2] The war caused large scale destruction to the economic infra-structures and the means of production, so that the per capita income in the years just following the war is expected to go down further.

Agriculture is the largest sector in the economy. During the past few years, little structural change has occurred in the economy with the resulting contribution of

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[1]East Pakistan (now Bangladesh), Bureau of Statistics, Statistical Digest, 1966, (Dacca Secretariat Buildings, 1966), p. 11.

[2]Government of Pakistan, National Income Commission, Final Report of the National Income Commission, (Karachi, CSO, 1965), p. 41.

agriculture to the Gross Domestic Product falling from about 61 percent in 1959/60 to only 56 percent in 1967/68.[3] However, after the war, the economy may have reverted to the structural status of the early fifties due to the destructive impact of the war on industrial units, institutions for trade and commerce, communications, ports, and skilled labor force. Agriculture will naturally continue as a dominant sector for a long period in the economy of Bangladesh.

Role of Agriculture in Economic Development

The importance of agriculture in the economic development of Bangladesh will be apparent upon consideration of the following factors:

a. Approximately 85 percent of the civilian labor force was employed in agriculture in 1961.[4] Comparison with the 1951 Census figures indicates that the growth of agricultural labor force during the decade of the fifties was 33.79 percent as compared to 16.17 percent growth in the non-agricultural labor force. Essentially the same growth rate characterizes the decade of the sixties. Any program for providing increased welfare to majority of the people in the country must stress priority on agriculture.

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[3] East Pakistan (now Bangladesh), Planning Department, Economic Survey 1967-68, (Dacca, Government Press, 1968), p. 2.

[4] Pakistan, Bureau of Census, 1961 Population Census, (Karachi, Government Press, 1963).

b. Agriculture is the largest source of foreign exchange earnings for the country; during the period from 1960/61 to 1965/66, the export of Jute products alone accounted for an average of approximately 84 percent of the total value of exports from the country. In the initial stage of development it will remain in that position. Lack of foreign exchange constrains the exchange of domestic savings for physical equipment and other productive inputs from abroad.

c. Food products from agriculture are the major wage goods in the economy. If agriculture fails to provide an adequate and relatively cheap supply of food to other sectors, higher wage demand and concomitant labor unrest may choke the process of increasing production and employment in non-agricultural sectors. Agriculture may, in turn, be adversely affected, thus, becoming unable to supply cheap food and adequate raw materials to industry.

d. Rising agricultural income is necessary for providing market outlets for the bulk of the industrial products, acting as an indirect stimulant to industrial growth.

e. Agriculture being the largest sector, the burden of capital accumulation will have to be borne substantially by this sector during the initial phase of development.

Importance of Irrigation in Agricultural Development

Growth of agriculture has been slow in the past. Rice accounts for about 85 percent of the value of all crops. Taking the growth rates of rice as an indicator, the average annual growth rate of agriculture during the decade of the sixties is only 2.1 percent. Rates of increase in the production of rice fell far short of the rates of increase in the domestic demand during this period, mainly due to higher growth rate of population. As a result, the import requirement went up sharply. Though part of the increased demand for rice was offset by higher prices, increased imports represented about 8 percent of the total consumption in the five year period from 1960 to 1965 and about 10 percent during the following three years.[5] More menacing is the annual fluctuations in production arising mainly from natural factors. Crop production is heavily dependent on rainfall which is often untimely and inadequate. Only about 5 percent of the total cropped area was under any kind of artificial irrigation by 1968. Excessive rainfall may cause flood and inadequate rainfall may cause drought, both with substantial damage to crops. Absence of rainfall in the winter season has led to a cropping pattern in which cultivation is

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[5] East Pakistan (Bangladesh), Planning Department, *Programme for Attainment of Self-Sufficiency in Food Production by 1970*, (Dacca, Government Press, 1968), p. 2.

concentrated in the rainy season. In winter, about 75 percent of the cultivated land remains fallow. Without controlled water supply, investment in agriculture becomes risky. Provision of a controlled water supply through irrigation projects is likely to achieve the following major results:

1. It will facilitate the use of most of the land presently lying fallow in the winter season.

2. It will increase production not only by reducing damage from drought, but also by providing suitable conditions for introduction of new high yielding varieties and heavier fertilizer application.

3. It will reduce violent fluctuations in production and provide a healthy environment for investment in agriculture.

Important Planning Questions

Irrigation is important in improving productivity in agriculture; however, the agricultural planners are beseiged with questions in the process of planning such irrigation programs. First, any big program of irrigation within a short or medium run plan will require some external financing, the main source in the past being the World Bank. Such external lenders make a point of assuring, before providing funds, that the investment is socially profitable. Even if domestic savings are used in financing such projects, it is desirable to determine the expected rate of return so that the planning process can insure the allocation of limited investible funds to the best alternatives.

Second, from the global point of view, provision of irrigation poses a number of alternatives: irrigation by tubewells using underground water, irrigation by small low-lift pumps without major construction, and irrigation by large pumps involving large construction. Some of these alternatives may be location specific, i.e., the economic advantages of one over the other may appear obvious from their technical advantages in relation to the location. But even in such a situation, the rate of return from various alternatives will provide some guidelines in setting priority among these various alternatives.

Third, various alternatives can be adjusted internally, in various ways; for example, tubewells can be drilled either manually or by machine. Similarly, electric power or diesel engines can be used to pump the wells. The economic implications of these various methods are not well understood.

Fourth, with introduction of irrigation, the new seed-fertilizer technology will tilt the comparative advantage of one crop against the other because of the differential success in the evolution of high yielding varieties of various crops. These effects are likely to cause reallocations of resources to various enterprises and readjustments in the relative price structures.

Fifth, the generation of employment will perhaps be one of the major social objectives of the national plans.

To fulfill this objective the planners must consider the employment effects of investment alternatives.

Last, in the appraisal of irrigation projects imperfect knowledge of the future stands out as a challenging problem. Future costs and returns and their determining factors are uncertain and difficult to forecast. Sensitivity analysis is, therefore, necessary to identify the important but uncertain parameters which have a relatively higher influence on the outcome. It is desirable to indicate the variations in the outcome within the probable range of variations in such parameters.

Objectives of the Study

In the previous section we have listed a number of questions generally encountered in the process of planning irrigation programs. Appropriate information on all of the questions can not be generated in one study with limited resources and time available. The present study is, therefore, undertaken with a modest set of objectives, that of seeking solutions to some of the important questions. Specifically, the objectives are as follows:

1. Determination of the monetary profitability of investment in tubewell irrigation from society's point of view (with a limited attention to private profitability), in one area of Bangladesh.

2. Investigation of the relative merit, measured mainly in monetary terms, of various technical alternatives available in the installation and operation of tubewells for irrigation.

3. Investigation of the impact of tubewell irrigation on employment generation.

Efforts are also made to bring out possible major policy implications, which might arise in the process of adjustment from a non-irrigated to an irrigated cropping pattern. Attempts are also made to investigate the variability of monetary profit due to variations in the value of different parameters which are of uncertain nature, thereby identifying the important areas for further intensive studies.

Evaluation of the effects of irrigation on the future pattern of income distribution in the study area will not be attempted. This is not to say that the income distribution is an unimportant issue. The main reason for the exclusion of any treatment of the issue of income distribution is the lack of appropriate data, and the limited time and resources available to the author. Moreover, the objectives of income distribution and employment are closely related. Generally, the unemployed people are the poorer group in the distribution of income. Thus, the impact of any public program on the employment generation will indirectly measure the impact of such programs on the pattern of income distribution.

However, the present pattern of the distribution of agricultural income (excluding the landless laborers) in Bangladesh is considered relatively uniform. The following evidence is cited to support this hypothesis of uniform distribution of agricultural income in Bangladesh:

1. Farm sizes are relatively uniform. About 70 percent of the farms in 1960 were within the size group of 2.5 to 7.5 acres; about 7 percent within 7.5 to 12.5 acres; less than one percent of the farms were above 25 acres; and about 22 percent of the farms were under 2.5 acres.[6]

2. Farm sizes are positively correlated with the family sizes.[7] Thus, whatever absolute income differential may arise due to the differences in farm size, will tend to further even out on a per capita basis.

3. Different farm management studies in Bangladesh indicate that with the existing technology smaller farms are more productive (product per acre) than the large ones.[8]

However, the present uniform pattern of agricultural income distribution does not guarantee a continuation of the

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[6] Government of Pakistan, Bureau of Census, Agricultural Census 1960, (Karachi, Government Press, 1962), p. 15.

[7] Ibid., pp. 83-86.

[8] M. Habibullah, Large Agricultural Farms in East Pakistan: Do They Serve National Objectives? (Paper presented in the Annual Meeting of the Economics Association, Karachi, 1968.) For further information see reference at the end of the paper.

same pattern in the future under a different set of technological conditions of production. The future pattern will depend on government policy towards new technology as a vehicle of agricultural development. Discussion on such policies can be found elsewhere.[9] The independence of Bangladesh was obtained through a tremendous sacrifice and the aspirations of people were heightened with independence. Any policy which will create income polarization will, perhaps, cause political turmoil.

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[9]F. Johnston and John Cownie, "The Seed Fertilizer Revolution and Labor Force Absorption", American Economic Review, 59 (September, 1969). Also see: Walter P. Falcon, "Green Revolution: Second-Generation Problems", American Journal of Agricultural Economics, Vol. 25 (December, 1970).

CHAPTER II

MAIN FEATURES OF AGRICULTURE IN BANGLADESH AND THE STUDY AREA

Bangladesh is located between 20^{o}-30' and 26^{o}-45' of North Latitude and 88^{o} and 90^{o}-56' East Longitude and has a total area of 55,126 square miles. It is a vast delta in the Bangal Basin served by three major river systems--the Ganges, the Brahmaputra, and the Meghna. Its climate, demography, hydrography and soil have combined to influence the evolution of Bangladesh's present agriculture.

Climate

The climate of Bangladesh may be described as 'tropical monsoon' with warm and wet summer and a cooler dry winter. The monsoons bring very heavy rainfall for five months, from the end of May to mid-October. The sky remains cloudy and the average total rainfall in these months varies from 48.11" at Rajshahi, and 58.34" at Narayangani, to 127.37" at Cox's Bazar and over 200" in the northern parts of Sylhet[1]

[1] Harouner Rashid, East Pakistan, A Systematic Regional Geography and Its Development Planning Aspects, (Karachi, Ghulam Ali and Sons, 1967), p. 59.

(See Appendix I). The timing of the arrival of the monsoon rains is very important to the agriculture of the country. Heavy early rains can destroy the Aus rice crop. Heavy late rains are even worse; they may destroy both the Aman rice and the jute crops. Inadequate and untimely rainfall may delay planting or cause serious inhibitions to crop growth. The average temperature varies from 69°F to 89°F. The temperature starts falling in October; January is the coldest month. From the beginning of February, temperature gradually rises. The night temperature goes down to about 47°F in January in Srimangal, the coldest place in Bangladesh. In the same place, the day temperature in January remains at about 80°F. In most other parts of the country the ranges of maximum and minimum temperatures are between 53°F to 78°F in winter and 78°F to 90°F in summer. Such a distribution of temperatures generally favors year round crop production without serious problems of photosynthesis.

Relative humidity is quite high throughout the year, it being everywhere over 80 percent during the months from June to September.[2] The northern part is relatively less humid than the rest of the country. March and April are the least humid months. Fogs and mist which are a common feature of the weather from November to March, do not pose any crop production problem.

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[2] *Ibid.*, p. 64.

Soil

There has been no systematic and detailed work on soil classification in Bangladesh. The Ministry of Agriculture classifies the soils in Bangladesh into seven types based on geological origin and physio-chemical properties such as color, texture, composition, size of particles, PH, etc. Consistent with these soil types the following soil tracts are identified:[3]

a. Madhupur tract
b. Barind tract
c. Gangetic alluvium
d. Teesta Silt
e. Brahmaputra alluvium
f. Coastal Saline tract
g. Chittagong Hill tracts

Rashid classified land in Bangladesh into twenty regions with fifty-seven sub-regions on the basis of physical features and drainage patterns.[4] Land classification by the Ministry of Agriculture and that by Rashid appear to be complementary to each other while the former stressed mainly qualitative aspects of soil, the latter concentrated on topography and drainage aspects. However, both classifications are broad and have many limitations for agricultural project planning. Recently, under the U. N. Soil Survey Program, some comprehensive works have been conducted. These studies have

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[3]M. A. Islam, Fertilizer Use In East Pakistan, (Dacca, Agriculture Ministry, 1966).

[4]Rashid, A Systematic Regional Geography, op. cit., p. 8.

combined considerations of qualitative aspects of soils, topography, drainage patterns, strata formations and some indications of soil capabilities for production. Information on strata formation would provide some indirect indication of potential underground water availability, essential for planning tubewell irrigation programs.

Farm Size and Tenure

Farm size, defined as the area of land under one operator , is small in Bangladesh. The average farm size, as found in the 1960 Census, is 3.50 acres;[5] out of this about 3.12 acres are under cultivation. Distribution of the number of farms under various size groups indicates that more than 50% of the farms are of the size 2.5 acres and below (Appendix II). The modal size is about 3.0 acres. There are considerable variations in farm size among various districts. While the Comilla and Noakhali districts have the smallest farms, averaging 1.8 and 2.0 acres respectively, Kushtia and Denajpur have the largest, averaging 5.8 and 5.5 acres, respectively.

Farm sizes in various districts are strongly correlated with population density. Increased density of population coupled with the law of inheritance, which entitles each child of a family to a portion of the land, is considered

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[5] _Agricultural Census 1960_, _Op. cit_., p. 108.

responsible for the gradual diminution of average farm size. The average size was 5.21 acres in 1931 and 4.36 acres in 1960.[6] However, this downward trend may flatten out with the acceleration of development in industry, business and commerce.

Another aspect of the farms in Bangladesh is that they are not only small but also fragmented. One average farm normally consists of 6 to 10 fragmented plots. The 1960 Census figures indicate that the number of fragments increases as the size of farm increases.

Farms classified on the basis of tenure indicate a larger proportion of owner operated farms. Sixty one percent of the farms are purely owner operated tilling 52 percent of the total cultivated land, 37 percent are owner-cum-tenant operated tilling 47 percent of the total cultivated land, and only two percent are purely tenant operated tilling only one percent of the total cultivated land. Eighty two percent of the total cultivated area is owner operated and 18 percent tenant operated.[7]

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[6]Kalim Uddin Ahmed, Agriculture in East Pakistan, (Dacca, Ahmed Brothers Publications, 1965), p. 60.

[7]Agriculture Census 1960, Op. cit., p. 49.

Cropping Pattern and Intensity

If the number of crops grown is the basic consideration in the definition of diversification, the cropping pattern of Bangladesh is diversified both from the national as well as from the individual farm's point of view. However, if the proportion of cultivated area devoted to crops is the main criterion, agriculture in Bangladesh is mainly a rice growing farming system. On the average 74 percent of the total cropped area is planted in rice (see Appendix III). The second important crop is jute occupying about 6.2 percent of the cropped area. Jute is the largest cash crop for most of the farmers and the most important export product in the economy. Pulses and oilseeds come next, both in terms of the areas devoted to them and their importance in the household consumption. If all crops grown are classified as food and non-food crops, the proportion of area (average of five years ending 1964/65) allocated to food crops is 93.5 percent, jute being the main non-food crop, and rice the main food crop.

The regional distribution of crops indicates some degree of specialization dictated by the comparative advantage of areas in the production of different crops. The origin of such comparative advantage may generally be traced to the differences in climate, soil class, drainage pattern, and special market facilities. The degree of such regional specialization, however, seems to be rather small.

Consideration for subsistence appears to have a great influence on the pattern of cropping. Rice is the main food crop and is grown in all parts of the country. Jute is mainly concentrated in the districts of Mymensingh, Rangpur, Comilla, Dacca and Faridpur. About 72 percent of the total area under jute is located within these five districts accounting for a little over 73 percent of the total jute production (average of 1960/61-1964/65). Virtually no jute is grown in Chittagong and Chittagong Hill tract; jute is also not grown in the saline tracts of Barisal and Khulna. Cotton is mainly grown in Chittagong Hill tract, and to a small extent in Mymensingh. Sugarcane production has main concentrations in the Rajshahi, Denajpur, Rangpur, and Kushtia districts and the Kishonganj sub-division of the Memensingh district. Market outlets to sugar factories are considered to be the main factors for such concentration. Rape and Mustard are the largest oil crops and the districts of Mymensingh, Dinajpur, Rangpur and Faridpur have relatively larger acreage under these crops, although the crops are grown in almost all other districts in substantial areas. From 1955 to 1965, trends in land allocations reflect the increased demand for rice. Even allowing for annual fluctuations, there is a visible increasing trend in the acreage under all the three rice crops.[8] Comparing the averages of

[8]Explaining trend on the basis of averages might be hazardous; variability might be too high so that such trends might be misleading. However, looking at the annual fluctuations, one could project which trends, on the basis of averages, are relatively steady and safer for approximation.

the period 1955/56 to 1959/60 to those of 1960/61 to 1964/65, the acreage under Aus rice has gone up by 8.2 percent, Aman rice, by 7.7 percent, and Boro rice, by 31.6 percent. In absolute terms, however, the increase in acreage under the Aman rice would be higher than the Aus rice, and that of Aus higher than the Boro rice. The area under jute between the two periods shows also an increase of 18.2 percent. However, the annual variability in jute acreage is so high that the conclusion would be misleading. Sugarcane and potato have shown steady growth in acreage during the period under consideration. But these two crops still occupy a small proportion of the total cropped area, 0.01 percent by sugarcane and 0.005 percent by potato. Thus, an increase in acreage under these two crops will have insignificant influence on the change in the total cropped area.

Crops showing declining trends are pulses, vegetables, seasonal fruit crops and some minor food and non-food crops. The acreage under pulses declined by 19.1 percent; vegetables, 38.3 percent; and seasonal fruits, about 65 percent. Comparison of the average total cropped area in the latter half of fifties and that in the first half of sixties indicates an increase in the total cropped area of 5.1 percent; this increase has come about partly through a shift of acreage from pulses, vegetables, seasonal fruits and other minor food and non-food crops to rice, and partly through an increased use of rice land. Vegetables and fruits are important protective foods, and pulse is one important source of protein to rural people in Bangladesh. This shift of acreage from crops of higher income elasticity to crops of lower income elasticity would, perhaps, indicate a hypothesis of declining per capita income level in rural Bangladesh during the period; however, before arriving at such a conclusion, foreign trade has to be taken into consideration. Even then, the relatively larger import of rice and the absence of any import of vegetables and fruits will further reinforce the hypothesis.

Cropping intensity[9] is a useful indicator of the extent of utilization of the existing land resources. According to the Agricultural Census of 1960, the cropping intensity in Bangladesh was 148 in 1959/60.[10] In the Agricultural Census, the total cultivated area was found to be 19.4 million acres in 1959-60. But the Agriculture Department assumes the cultivated area to be 22 million acres which is based on the extrapolation of the 1944 complete plot by plot survey.[11] Cropping intensities calculated with three alternative levels of cultivated areas are shown in Appendix III. For the purpose of calculation of cropping intensity total cultivated area may be assumed constant, as the extent of

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[9] Cropping intensity $= \frac{\text{total cropped area}}{\text{total cultivated area}} \times 100.$

[10] Agriculture Census 1960, Op. cit., p. 148.

[11] Ibid., p. 8.

cultivable waste land in the country is very small.[12] From the Appendix III, it will appear that cropping intensity is showing a steady, though modestly increasing trend. The highest intensity, with the assumption of lowest cultivated area, is 149.1 in 1964/65. The increase in intensity is more pronounced in the first five years of sixties than the five years of latter fifties. In fact a decreasing trend is observed during the first four years starting from 1955/56. This may be attributable to the repeated natural calamaties in this period.

The crop statistics in the country, for the 1960/61 to 1964/65 period, were adjusted a little upward to bring the statistics in conformity with the National Survey results; the adjustments being limited to rice crops only.[13] As the adjustment in rice was only about 400,000 acres in five years (which is only 0.01 percent of the total rice area), the general validity of the observations made so far in this section is not changed.

Water Resources

There are, generally, two main sources of water in any country--surface sources including rain, and underground

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[12] *Ibid.*, p. 108.

[13] Haroun-er Rashid, Rice Production in East Pakistan in the Second Plan Period (1960-65) (Dacca, Planning Depth, 1966, mimeo), p.15.

sources. Development and utilization of these two main water resources have far reaching consequences on the economic development of Bangladesh.

Surface water.--Three main rivers--the Ganges, the Brahmaputra and the Meghna--along with their numerous tributaries and a few other small rivers--comprise a vast and complicated system of surface water resource in Bangladesh. A large number of small lakes (locally called '*beels*' and '*haors*') also hold some water; the proportion of such sources of surface water is relatively small. All the main rivers originate in the Himalayas. With the melting of snows in the Himalayas water levels in the rivers begin to rise. Simultaneous heavy monsoon rainfall increases the flow in the rivers so much that the water spills over the banks causing extensive damage, in some years, to crops and property. On the other hand, water discharge during the months of March, April and May is small. Comprehensive study of the hydrology of Bangladesh has yet to come. Based on limited recordings of discharges, Thijsse estimated the average minimum flow in the main three rivers at about 240,000 cfs.[14] Industrial and household use of surface water is not known but is considered to be low.[15] But

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[14] J. Th. Thijsse, *Report on Hydrology of East Pakistan*, 1964, p. 21. (n.p., Available with the Bangladesh WAPDA).

[15] *Ibid.*, p. 18.

these uses will increase in the future. Thijsse estimated that if water were drawn from the rivers for irrigating 2.5 million acres in the Boro season, it would reduce the minimum flow in the rivers to between 160,000 to 170,000 cfs. Such a reduction in the minimum flow might involve an ingression of saline water from the sea by about 10 miles and hamper navigation and fisheries.[16] Though Thijsse's estimates are no better than an expert guess due to the lack of any hydrological statistics, this gives some indication of the problem. Use of surface water for irrigation has limits. Already about 1.2 million acres are being irrigated by surface water. Rapid and large scale expansion of irrigation will necessarily call for the exploration of other water sources.

Underground water resources.--Though no comprehensive studies on ground water resources have yet been conducted, scattered test borings, the performances of existing wells, and inferences from studies on soil formations and structures indicate the existence of considerable underground water of good quality in many parts of Bangladesh. For planning irrigation projects utilizing underground water, information on the quantum of underground water, static water level, permeability of soil stratas, extent and quality of the water-bearing strata, horizontal and vertical recharge

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[16] *Ibid.*, pp. 21-22.

rates, time-lag between the drawing up of water and the recharge, and the relationship between underground water and surface water are necessary technical ingredients. Detailed survey on underground water has been conducted on only 7741 square miles so far.[17] Conclusions of the studies are only indicative.

Peterson, in his study based on field reconnaissance, indicated six probable areas for tubewell irrigation. He observed, "The presence of extensive ground water in East Pakistan (Bangladesh) can be attributed to two principal factors: (1) relatively high rainfall and (2) favourable geology. With minimum average rainfall of 40-50 inches in the Western part--increasing to 200 inches or more in the Eastern part, the importance of rainfall in recharging the ground water is obvious. In addition, the generally flat terrain coupled with the large areas of relatively pervious soils and permeable underlying sediments, is favourable for the rapid percolation of the rain."[18] From a geo-electrical resistivity survey in the districts of Rajshahi and Bogra and the southern parts of the districts of Denajpur and Rangpur, experts concluded, "It may be taken for established fact that in wide parts of the region coherent groundwater

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[17] Shaziruddin K. Ahmed, Review of Ground Water in East Pakistan, (Dacca, Agricultural Development Corporation, 1970), p. 2.

[18] H. V. Peterson, Report of Groundwater in East Pakistan, (San Francisco, International Engineering Co., 1963-64).

tables exist in the underground."[19] The Hydrology Directorate of the Water and Power Development Authority (WAPDA) carried out ground water investigations in the country during the years 1964-67. In their reports it is stated, "The evidence from bore hole logs and numerous domestic wells and observation wells makes it obvious that practically the entire East Pakistan (Bangladesh) is underlain by a body of ground water at varying depth below land surface depending on location and seasons of the year. The total volume of the underground water in storage is enormous because the thickness of alluvium probably is in the range of thousands of feet."[20] Most of the studies give impressive indications about the extent of underground water. But statistics in regards to important aspects of possible behavior of underground water tables relative to the horizontal and vertical recharge rates and the relationships of underground water with the surface water are not so detailed. For a comprehensive tubewell irrigation program with a large coverage such information is important. For a modest tubewell program in Bangladesh, the existing groundwater hydrological information is considered adequate.[21] However, alongside a modest program it is

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[19] K. Deppermann and J. Thiele, Geoelectrical Resistivity Survey for East Pakistan 1968, (Dacca, WAPDA, 1968), p. 2.

[20] East Pakistan (Bangladesh), WAPDA, Groundwater Investigation in East Pakistan, Vol. I, (Dacca, WAPDA, 1968), p. 14.

[21] IBRD, Tubewell Project in East Pakistan, Report No. PA-49a (Washington, D.C., 1970), p. 4.

essential that the groundwater hydrological studies be continued so that the planning of larger tubewell irrigation programs in the future will not be handicapped. The exploitation of underground water for household and irrigation purposes has been very limited (Appendix IV) so far. By 1969, only 2807 cusecs of underground water were being used for both agricultural and household uses. Household use of underground water was entirely limited to urban areas and accounted for only about 13 percent of the total underground water use. However, there are several thousand hand-operated tubewells and an unknown number of indigenous shallow wells used mainly for rural household use. Estimates of groundwater from these wells are not available.

Experience With Irrigated Agriculture in Bangladesh

Irrigation Programs.--Indigenous manual methods of irrigation have been commonly practiced in Bangladesh through the ages. In 1959/60, according to the 1960 Agricultural Census, about 1.3 million acres were irrigated, mostly by manual methods, out of which about 920 thousand acres were under irrigated Boro crop.[22] Manual methods have many disadvantages. If the water level is not within two to three feet of the discharge point, such methods become unsuitable

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[22] *Agricultural Census, 1960*, *Op. cit.*, p. 144.

for using surface water. Moreover, control of water use, consistent with the irrigation requirements of crops, is difficult to achieve by manual methods. Further, the volume of water that can be lifted by a worker is quite small; eight hours' work by a man can hardly lift a half acre-inch of water.

Public sector investment in irrigation utilizing surface water started with the initiation of the Ganges-Kabodak (G.K.) project in 1955. The project provides for a gravity canal system of irrigation fed by large pumping installations on the river Ganges to supply water to about 330 thousand acres in the Kushtia District.[23] The project suffered from serious planning and designing errors and had to be revised several times, with the cost estimates going up every time. By 1968, work on field water distribution system was still going on. However, the utilization of the installed capacity was still very low; by 1968 water was being used only on 62,000 acres, which was somewhat less than 50 percent of the then available capacity.[24]

Unsatisfactory experience with the G. K. project coupled with the need for meeting the regional demand for

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[23]Ghulam Mohammad, "Development of Irrigated Agriculture in East Pakistan: Some Basic Considerations", <u>Pakistan Development Review</u>, Vol. VI, 1966, No. 3. (Karachi, Pakistan, Institute of Development Economics), p. 323.

[24]East Pakistan (Bangladesh), <u>Food Self-Sufficiency Program</u>, <u>Op. cit.</u>, p. 14.

irrigation led the government to shift priority to low-lift pumps and tubewells for supplying irrigation water. In 1962 WAPDA initiated work on the North Bangal Tubewell and Power Pump Irrigation Project in the Denajpur District of Bangladesh. Under this project 380 electric powered tubewells, averaging 3 cusec capacity, 60 electric-driven low-lift pumps, and 800 diesel-driven low-lift pumps were installed to irrigate 186,000 acres.[25] Irrigation in the tubewell project area started in May, 1965. About 4000 acres were irrigated from 116 tubewells during the summer of 1965, and about 400 acres during the winter of 1965-66.[26] By 1969 an area of 66,360 acres were covered by 362 tubewells. Out of 380 tubewells, 365 wells were successful and 362 were available for irrigation; the remaining three were being used for powerhouse cooling.[27] By April, 1969 about 76 percent (87,800 acres) of the total command area was irrigated. The main obstacles to full capacity utilization are: (1) lack of adequate and timely supply of electric power, (2) incomplete construction of the main channels, and (3) ineffective organization of farmers for effective water use.[28]

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[25] Ghulam Mohammad, Development of Irrigated Agriculture, Op. cit., p. 340.

[26] Ibid., p. 343.

[27] Harold Rinnan, Review of Irrigation Well Development in East Pakistan, (Dacca, USAID, 1969 , Mimeo), p. 5.

[28] Ibid., p. 6.

While the WAPDA was sinking tubewells in the Northern area of Bangladesh, the Academy for Rural Development at Comilla was experimenting in tubewell irrigation with the particular objectives of (1) finding efficient ways of installing and managing wells, and (2) evolving a suitable organization, within a broad administrative framework for rural development, to ensure proper utilization of installed well capacity. By 1969, only 160 tubewells have been installed by the Comilla Academy, the capacity of each well varying from 1.0 to 1.5 cusecs. The wells were drilled by hand rigs with emphasis on the use of locally manufactured materials as far as possible.[29]

The Agricultural Development Corporation (ADC) started its operations in supplying irrigation water to farmers in 1961/62 by transportable low-lift pumps, mainly in the winter season. Before 1961/62, the Agriculture Department had a small program consisting of 1367 low-lift pumps of a total capacity of 1743 cusecs. These pumps were taken over by the A.D.C. when it started operation in 1961/62. The supply of low-lift pumps for winter irrigation gradually expanded under the control and management of A.D.C. By 1968/69 about 10,850

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[29] *Ibid.*, p. 9.

pumps having a total capacity of 22,245 cusecs, were put in operation by this organization.[30] In 1968/69, the ADC also embarked on a tubewell irrigation program.

As of September, 1969, 421 tubewells of two cusec capacity each have been constructed under this program. It proposes to install 21,000 such tubewells during the period 1970.71 to 1974/75.[31] However, the proposal was prepared before the war and conditions after the war may have thrown the proposal into uncertainty.

Organization for Management and Utilization

While the WAPDA and the ADC were the main two public organizations for creating irrigation capacities in the country, the Academy for Rural Development at Comilla was conducting experiments to evolve a suitable irrigation system. WAPDA's irrigation projects had no farm-level organizations which could organize and train farmers in water utilization. General agricultural extension personnel worked at individual farmers. Absence of such organizations was reflected in the very slow utilization rates of irrigation facilities even though the water was being offered as a free input to the farmers. ADC's low-lift pump project also

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[30] Harold Rinnan, Thinking About Irrigation with Small Scale System, (Dacca, USAID, 1970, mimeo), p. 2-4.

[31] East Pakistan (Bangladesh), ADC, Fourth Plan Tubewell Irrigation Schemes, P.C.I. form, (Dacca, ADC, 1970).

lacked any field level special organization for organizing, training and helping the farmers in raising irrigated crops. The ADC, however, allocated the pumps in the field through self-organized groups of farmers, occasionally helped by the agricultural extension workers. Farmers had to pay for the supply of water at a fixed rate, per acre, per season. Basically there were no differences between the ADC and the WAPDA so far as the provisions of field level organizations in the respective projects are concerned. But the performance of ADC measured in terms of the ratio of capacity utilized to capacity installed, was considered relatively better. This was mainly due to the fact that the low-lift pumps are transportable and as such offer flexibility to adjust the allocations of pumps to locational and seasonal demand. Even with such flexibility, the rate of capacity utilization in the low-lift pump program fell sharply with the substantial increase in number of pumps. The area irrigated per cusec pump capacity fell gradually from 38 acres in 1962/63 to only 23 acres in 1967/68.[32] There was an initial need for rapid acceleration of irrigation facilities in the country. This need was sharply accentuated by the complementary nature of the high-yielding rice varieties and irrigation water. We had an apparently inconsistent situation where an increasing need for irrigation existed

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[32] *Ibid.*, p. 2.

side by side with a decreasing capacity utilization. Organizational constraints were considered to be the main reasons for the inconsistent situation. The Comilla Rural Development Academy was conducting research on this problem. The results of the experiments with irrigation at the Rural Development Academy at Comilla were, in the meantime, further tried on a pilot-scale to determine the adaptability of the findings in the whole country.[33] These evaluations and analysis of the results ultimately led to the formulation of the Thana Irrigation Plan covering almost the whole country.

The main features of the new system can be summarized as follows:

a. The tubewell and the low-lift irrigation programs will be a part of the integrated rural development program, with farmers and field level officers of various departments of the government involved in the planning, implementation and operation of irrigation projects.

b. The initial groups of farmers willing to use irrigation water will gradually form into village cooperatives. The group will indicate locations of the irrigation installations. Thereafter, the ADC will install the irrigation facilities as an agent of the village cooperative which will bear the operation costs and also pay the replacement costs

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[33] Academy for Rural Development, Evaluation of the Thana Irrigation Program in East Pakistan, (Comilla, November, 1969), p. 9.

of the engines in four installments starting from the 7th year. However, in the initial stage, there will be a substantial amount of subsidies in such payments through some other schemes.

c. The village level cooperatives will not only manage the irrigation facilities but will also undertake other activities in the supply of farm inputs considered essential for reaping a higher return from irrigated farming.

d. The village cooperatives will be helped by the Thana Cooperative and Thana Development Councils consisting of the Thana level officers and representatives from the cooperatives. Training of farmers, workshop and repair facilities, and other external assistance needed by the farmers will be provided by these Thana organizations. They will guide the village cooperatives in the effective use of water in particular and rural development in general.

e. The Rural Development Academy prepared a detail manual for guidance of the Thana Development Councils.[34]

How far the new system will succeed when it spreads throughout the country is still a matter of the future. But the concerned experts and proponents of the system appear to be confident of a higher rate of utilization of installed

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[34]East Pakistan (Bangladesh), Manual on Thana Irrigation Programme, (Dacca, B.D. and L.G. Department, 1968).

irrigation capacity. The adoption of the system in the WAPDA's North Bangal tubewell irrigation areas has already showed a sharp increase in the area under irrigation in 1968/69.

Irrigated Crops

The low-lift irrigation has so far been limited mainly to rice areas in the Boro season. In many areas, the indigenous method of irrigation has been replaced by pump irrigation in raising Boro rice. In the low-lying areas of Dacca, Faridpur and Pabna Districts, where risk of crop damages by flood is high, the broadcast Aman rice has partially been replaced by the relatively high-yielding and risk-free Boro rice using low-lift irrigation.[35] In the North Bangal tubewell irrigation areas, the predominant irrigated crop is rice though the soil is considered not so suitable for rice and the project was initially conceived for irrigating sugarcane. In the Comilla area some potatoes and watermelons were grown in 1966-67 under irrigated conditions, though rice was still the dominant irrigated crop. Watermelon is not a major food crop and its demand provides only limited scope for expansion. Potatoes are a more important food crop than watermelon and their demand is higher than for

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[35]Rais Uddin Ahmed, Growing Boro Paddy by Low-Lift Pumps in Dacca District, (Dacca, Planning Department, 1968, mimeo).

watermelon. But in comparison to rice, potatoes still occupy a small insignificant position. Population density and the present low level of income, without any prospect of spectacular rise in income level, coupled with the consumption habits of the people, will dictate a predominantly rice farming irrigated agriculture in Bangladesh for long time to come.

Study Area

Locations.--The ADC has proposed to implement a tubewell program of 21,000 wells of 2 cusec capacity each during the 1970/71 to 1974/75 period. This program includes projects for installation of 1604 and 1016 tubewells in the Mymensingh and Tangail districts respectively.[36] The tubewell areas are located in the flat, medium, and high lands around the west, south and northern edges of the Madhupur jungle tract and also on the northern side of the old Brahmaputra river. The area is not generally affected by flood. Two main considerations have influenced the author to select the area. First, the Mymensingh District[37] has important typical attributes of agriculture in Bangladesh.

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[36]East Pakistan (Bangladesh), Fourth Plan Tubewell Irrigation Schemes, Op. cit., p. 13.

[37]Mymensingh District included Tangail subdivision till 1969 in which year Tangail was separated from Mymensingh and formed an independent district.

The average farm size, percentages of cropped area under different crops in different size groups of farms, and the tenure system very closely approximate countrywide averages.[38] There is no extreme diversity or specialization in cropping. As such, the findings of the study, if cautiously interpreted, may be considered as approximations for many parts of the country. Second, the author has an intimate knowledge of the agriculture of the area through a long period of residence and agricultural extension work.

Soil.--In the soil capability classification map, the area is identified by the units red 4, 5, and partially red 3a, 3b, and 3c in the central region.[39] Provision of irrigation and use of fertilizers and improved varieties of crops are the major means of rapid realization of development potential of agriculture in these units of soil classes. Soil characteristics of the area represent those of alluvium mainly old alluviums of Brahmaputra. Soil structure is loamy to clay-loamy. The divergence is not great. Soils nearer to the Madhupur tract have some influence of the

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[38]Agricultural Census, 1960, Op. cit., pp. 26, 46, 108, 173. Also see appendices V and VI in the present study.

[39]The author studied the map personally. Due to reluctance of the authority to release the map before clearance from the IBRD and the Bangladesh government, the map cannot be presented here. It is expected, however, that by the time the present study is available for use, the maps will also be available, at least to concerned circles, for examination and reference.

clay soil of the Madhupur tract and as such clay-loamy in nature. The soils away from the Madhupur tract are generally loamy.

Farm Size and Tenure.--The average cultivated area per agricultural farm in the Mymensingh district is 3.06 acres (Appendix V). Preliminary data from the Master Survey (7th round) collected by the Bureau of Statistics in 1967-68 indicate a close similarity in the farm size with the census data of 1959-60. A farm management study conducted by the WAPDA's consulting engineers in the north Mymensingh area shows the modal farm size at 3.0 acres.[40] Most of the farms are owner-operated farms. About 55 percent are purely owner-operated, 37 percent owner-cum-tenant operated, and only two percent are purely tenant operated. In terms of area, 83 percent of the total cultivated area is owner-operated, and 17 percent tenant-operated (Appendix V). Most of the tenant operated area is limited to the sharecropping system.

Cropping Pattern.--The cropping pattern practiced in the study area, as identified in the soil capability classification reports, is one of Aus rice and jute in the Aus season, Aman rice in the Aman season, and various rabi crops in the following rabi season. Rabi crops have to be

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[40] East Pakistan (Bangladesh), WAPDA, Feasibility Report of North Mymensingh Tubewell Area, (Dacca, WAPDA, 1967).

grown with the retained soil moisture; hence land use in the rabi season is limited to about 16 percent of the available land resources.[41] The major rabi crops are various kinds of vegetables, potato, pulses, minor cereals, and spices. Most of the vegetables and spices are grown on lands around the homestead. The average cropping intensity in the area is about 160.

The Agricultural Census relating to the 1959-60 crop year does not show much variation in the allocations of land to various crops in various size-groups of farms (Appendix VI) in the Mymensingh district as a whole. This is particularly true in the case of rice. Farms below 0.5 acres in size allocate about 58 percent of their cropped area to rice. Except this size-group, allocation of area to rice in all other groups ranges from 73 to 78 percent without any discernible pattern. However, the allocation of land to jute shows the smaller farms allocating a larger percent of the cropped area to jute, a cash crop. In the case of jute, however, if we exclude the farms below 0.5 acres in size, the variation is small among the remaining size group. In fact, there is no variation at all among the size-groups ranging from 2.5 acres to 24.0 acres. All the size groups within this range allocate nine percent of their cropped area to jute.

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[41] East Pakistan (Bangladesh), Soil Survey Project: Reconnaissance Soil Survey of Netrokona, Jamalpur, Tangail, and Sadar North, Mymensingh District, (Dacca, Directorate of Soil Survey, 1968/69).

Some Concluding Observations

The main purpose of the chapter was to present some facts about agriculture and its production environment in Bangladesh in general, and in the study area in particular. It was pointed out that some of the typical attributes of agriculture in the study area very closely approximate the country wide averages. As such, the results of the present study, if cautiously interpreted, could well be valid for large areas of the country. With this observation, we will list here a few major conclusions from the chapter.

a. For providing winter irrigation, ground water exploration will be essential. Though limited information on ground water statistics indicate no immediate problem for a modest tubewell program, any large program will require more elaborate ground water exploration.

b. If the number of crops grown is the criterion of diversification, the cropping pattern in Bangladesh is very much diversified. If the extent of area under a crop is the criterion of diversification, the agriculture of Bangladesh is mainly a rice farming system. This will continue to be so in the foreseeable future. During the second half of the last decade there has been a sharp shift in allocations of land from seasonal fruits, vegetables, and pulses to rice. Cropping intensity, particularly that of rice land, has been showing a slow increasing trend.

c. Considerable experience has been gained with the irrigated agriculture in Bangladesh. The experiences with types of irrigation, organization, and management will provide useful insight for successful future programs.

CHAPTER III

METHODOLOGY

The methods of analysis for achieving the objectives of the study are presented in this chapter. However, a brief discussion of fundamental research problems and a review of literature on techniques of project evaluation are also presented as introductory materials for the discussion on the methods of analysis employed in the study.

Three Fundamental Problems in Designing a Research Problem

In any problem solving research three fundamental difficulties are generally encountered. First, in the absence of an interpersonally valid common denominator, multiple objectives can not be easily handled. If a project objective includes both an increase in the production of goods and services and an adjustment in the distribution of income, and if the alternatives under study are found to be conflicting in terms of their relative contribution to the achievement of the twin objectives, it becomes necessary to compare the trade-off between the objectives in the process of decision making. Such a comparison of trade-offs naturally involves interpersonal comparison of the utility of income.

Economists generally tend to avoid such comparisons of interpersonal utility of income. In the problem solving research of the real world, however, such comparisons can hardly be avoided. A pragmatic approach to this problem would be to resort to systematic interactions among the researchers, politicians, administrators, and all other people involved in the solution of the problem.[1] Such interactions may help provide a common basis for determining how much of an objective has to be sacrificed for how much of a gain in another conflicting objective. For example, we assume a situation where growth rates in income and employment are conflicting and interactions among the researchers, administrators, and the political system indicate the extent to which the growth rate in income should be sacrificed for additional employment. Then the value of the sacrificed income should measure, as a social opportunity cost, the value of the marginal employment generation. This is commonly known to economists as a weighting system of the objective function. The process of interactions may provide a basis for selecting the weights. However, arriving at a common basis through the process of interaction is not always so easy. Diverse groups with diverse interests may not come to a common measure of

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[1]Glenn L. Johnson and L. K. Zerby, <u>What Economists Do About Values: Case Studies of and Answers to Questions They Don't Dare Ask</u>, (East Lansing, Michigan State University, 1972).

good and bad. For this reason, in empirical studies we often find separate treatments of the objectives leaving the questions of trade-offs to the decision makers.

The second fundamental difficulty in solving practical development problems is determining the optimum order in which projects should be executed within a program, the order in which programs should be executed within a policy, or the order in which various policies should be executed in a developing economy. The optimum order conditions may be defined as follows. Development activities in an economy are interrelated. Some of the interrelationships are direct and their effects immediate; while other relationships are indirect and their effects not so obvious. The order in which these activities are carried out makes substantial differences in the final results, generally measured by the flow of income. There is generally more than one possible sequence of implementing these development activities in an economy. Every sequence has a total outcome which may be different from that of the others. If all possible sequences of activities are arranged in the order of decreasing benefits per unit of incurred costs, then the one with the maximum net benefit represents the optimum order conditions. Hirschman stressed the importance of the order conditions in the evaluation of development programs in less developed countries.[2] He viewed the appraisal of development projects

[2]Albert O. Hirschman, The Strategy of Economic Development, (New Haven, Yale University Press, 1967), pp. 76-82.

in piece meal as leading to sub-optimization. Even such sub-optimization, he observed, would not make much sense if the development activities in any particular economy were sequenced with 'maximum disorderliness'. When projects, programs, and policies involve technological and institutional change as well as change in human agents, as so many do, there is no guarantee that an optimum order condition will automatically prevail. In the case of an irrigation project, the order conditions may imply appropriate sequences of activities like agricultural extension services, marketing and transportation facilities, supplies of inputs and credits, and necessary rural organizations. For example, an irrigation project following the establishment of infrastructures like power plants and roads will have different cost structures than the irrigation project before such social overheads. This relationship of projects with the environment and other projects should not be confused with the externalities we know in economics. The effects of appropriate ordering arise exclusively out of the differences in sequencing the various activities whereas the externalities--both technological and pecuniary--arise out of the influence of one on another either through the supply or the demand sides. The problem of ordering conditions is difficult to handle. In empirical studies, particularly in project appraisals, it is often assumed that the optimum order conditions among various activities exist. Such studies do not yield optimum solutions, though they are very often claimed to do so.

The third fundamental problem is the problem of determining which decision making rules are best in prescribing the superior alternatives. The choice of an appropriate decision making rule depends mainly on the attitudes of decision makers. The decision makers may want to maximize the average future net returns or they may want to minimize loss. Imperfect knowledge of future outcomes imposes further difficulties in selecting an appropriate decision rule. The use of apriori probabilities of outcomes, when such probabilities are available, is very often helpful in handling the cases of imperfect knowledge of the future.

Before we discuss how we propose to handle these three fundamental problems in the present study, we need to elaborate the meanings of problem solving research. By problem solving research we mean those categories of research in social sciences which produce evidences indicating the best courses of actions for decision makers in any problem. It relates to final decision making. Another category of research in social sciences generates information on certain aspects of a total problem. These informations are necessary but they themselves may not be sufficient for final decision making. The present study falls in the second category. It generates information on monetary profit derivable to the economy of Bangladesh from investment in tubewell irrigation. It also provides information on creation of additional employment by tubewell irrigation. Given these limited purposes of the study, the three fundamental problems of problem solving research are assumed to be not critical in generating the desired information in the present study. The impact on employment generation is treated separately in the study. In respect to the order conditions, it is assumed that the present and future orderings of development activities are optimum or nearly so. Effects towards an irrigated agriculture in Bangladesh have gone through considerable trials during the past few years. As such, the likelyhood of a serious ordering problem is considered small. The questions of decision rules will be apparent upon consideration of the discussion in a subsequent section on the model of the study. Before we go to discuss the methods of analysis employed in the study, a brief review of literature on the subject is considered helpful.

Brief Review of Techniques

The application of the economic principles of resource allocation in the public sector has been getting increasing attention with the increasing role of public expenditures in national incomes. In the United States water resource development was one of the largest public sector programs, involving many agencies. Concern for appropriate investment policies in the public sector led to the formulation of evaluation guiding rules for river basin projects as documented in the "Green Book" prepared by a Federal Inter Agency Committee in 1950.[3] The attempts in the Green Book were more for bringing uniformity among various agencies in the process of project appraisal, in defining objectives, concepts of costs and benefits, etc., rather than any improvement in the analytical techniques per se. Eckstein undertook a detailed study of the existing methods used by various water development agencies in the evaluation of projects.[4] He attempted to establish the existing methods on firmer economic grounds. His analysis of the criteria of benefit-cost ratio, internal rates of return and the net present value with respect to their effectiveness in choice making, particularly when various constraints and assumptions are treated in various manners, is a landmark in benefit-cost analysis.

With the adoption of the planning programming budgeting system (PPBS) in public expenditure in the U.S., and with the large inroad of operations research techniques in the analysis of investment programs, there has been considerable improvement in the analytical techniques in the

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[3] U.S., Interagency Committee on Water Resources, Proposed Practices for Economic Analysis of River Basin Projects (Revised). The Green Book (Washington, D.C., 1958).

[4] Otto Eckstein, Water Resource Development: The Economics of Project Evaluation (Cambridge, Harvard University Press, 1958).

evaluation of public programs in the U.S.A. However, in developing countries economic analyses of public programs were almost absent till the end of the fifties. The increasing role of foreign assistance in the development efforts of developing countries, particularly the participation of the World Bank in such efforts, has tremendously influenced developing countries to subject their public investment programs to tests of effectiveness through economic analysis.

The general technique in public program evaluation has been to compute the values of streams of benefits and costs and express the results in terms of the benefit-cost ratio or the internal rates of return or the net present value of the project outcomes. Initially, this technique had some major limitations. First, the results were mostly deterministic and considered not effective in handling consequences of uncertainty. Second, the results were only relevant from the point of maximization in income. In case of multiple objectives, e.g. employment generation, income distribution and balance of trade accounts, there were complex difficulties in modifying the technique. Third, employment of the technique proceeded mostly within the partial equilibrium setting, assuming interaction with the related sectors of the economy negligible or absent. Attempts to overcome the first limitation of the technique have been made by incorporating the technique of sensitivity test in the analysis. With computer facilities available, large number of runs can be arranged taking various values of the factors of uncertain nature to test the variations of the results. Recently, probability theories in statistics are being applied in project evaluation.[5] Following this technique, the results--the internal rates of returns, the net present values or the benefit-cost ratios--are obtained in the form of probability distributions. The probability distribution of outcomes is based on some probability distribution of the uncertain factors. The calculation of the probabilities of the outcome from the probability distribution of basic variables involves aggregation. This is done mainly by (1) simulated sample or (2) application of mathematical calculus of probability theories.

The problems of multiple objectives, particularly the cases of employment and income distribution, are generally handled in the analysis through adoption of multiple criteria and the separate treatment of these objectives in the analysis. However, if the objectives do not pose any valuation problems, they can be evaluated through a single criterion. As for example, Chenery[6] suggests the criterion of social marginal productivity of investment which incorporates consideration of the balance of payment effects of

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[5]Shlomo Reutlinger, Techniques for Project Appraisal Under Uncertainty, (IBRD, Washington, D.C., 1970).

[6]Hollis B. Chenery, "The Application of Investment Criteria", Quart. J. Econ. 67: Feb. 1953, pp. 76-96.

projects. This is necessary when the objectives of national planning are not only an increased growth rate of the national product but also a desirable balance between the country's exports and imports. The social marginal productivity (SMP) is a modified version of the traditional benefit-cost ratio. It is defined as follows:

$$SMP = \frac{V-C}{K} + \gamma \frac{B}{K}$$

where V is the present value of the domestic value added, composed of gross output less imported material costs, and C is the present value of operating costs, made up of labor and domestic material costs. The present value of project investment costs is denoted by K, while γ is the proportion by which the shadow exchange rate exceeds the official rate, i.e., the extent of overvaluation of the exchange rate. The term B is the present value of the total balance of payment effects computed to include the direct and indirect effects of project investment, the direct operating effects, and the indirect operating effects.[7]

The main difference between the benefit-cost ratio and the SMP is that the latter includes the indirect effects on the balance of payments. The effect on the balance of payments of a project's investment and operation is measured by the last component of the SMP equation, i.e., by B/K. A

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[7]Chenery describes in detail the balance of payment effects in his article.

final judgement as to whether the benefit-cost ratio or the SMP should be used depends on the indirect balance of payments effect.

The third limitation of project evaluation in the partial equilibrium setting has been partially overcome by broadening the scope of analysis. As for example, Zusman and Hoch adopt an approach based on general equilibrium analysis in which water resource development programs are embedded in a more general economic development plan.[8] Their model is essentially a dynamic linear programming problem in which existing capital capacities and available primary resources serve as constraints. The first is expanded through investment activities; the latter vary exogenously. In this model, the state's economic activity is represented by 32 principal sectors and four sectors related to water supply and irrigation activities. This is essentially a macro-model designed to estimate the optimum level of investment on aggregate water supply for irrigation along with investment in other sectors. The extensive nature of the analysis is not costless, and the authors of the study agree that the relevant information concerning important micro features of the water system must be

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[8] Pinhas Zusman and Irving Hoch, "An Efficient Program of Water Resource Development in the Framework of Growth and Trade", American Journal of Agricultural Economics, Vol. 50, No. 5, 1968.

sacrificed to insure consistency. In fact, project evaluation in the partial equilibrium setting, which might be called as micro project analysis, and that in the general equilibrium setting, which might be called macro project analysis, are not substitutes, but complementary. Both are necessary--the former provides the scope for detailed analysis of components and the latter provides the overall planning framework for maintaining consistency within which the micro project analysis should proceed.

Another approach, less global but considerably aggregated is the sectoral framework for project evaluation. This framework is designed for sectoral planning. In water resource planning, for example, following this approach the demands for water for irrigation, recreation, household and industrial use, navigation and fisheries are considered simultaneously along with their various supply sources. Attempts are then made to allocate water to various demands so that efficient utilization of the water resource system is obtained. Various mathematical programming and simulation techniques have been used in this approach. The Harvard Water Program, under the guidance of a large number of skilled professionals in various fields including economics, made extensive studies in water resource planning. They evolved and tested large numbers of techniques for planning

water resource systems.[9] Most of these techniques are essentially applications of simulation, including mathematical programming, to the evaluation of water resource programs.

Model

The main feature of the model to be used for the present study is the tracing and measurement of the direct cost and benefit streams of activities, through time, of a farming system under two alternate conditions--one with irrigation and the other without irrigation. The differences in effects of these two systems are attributed to irrigation. The differential effect will be measured through different criteria for different objectives. For measuring the impact on the income objective, the criteria of (1) the internal rates of return (IRR), (2) the net present values (NPV), and (3) the benefit-cost ratio (B-C ratio) will be constructed. For the employment objective, which will be evaluated separately, the ratio of marginal employment to investment on irrigation will be calculated. The exact mathematical formulation of these constructs are shown in each case in the course of their detailed elaboration.

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[9] Arthur Maass _et al._, _Design of Water Resource Systems_, (Cambridge, Harvard University Press, 1966).

Net Present Value Criterion (NPV).--Since multiperiod investment proposals can not be evaluated in terms of the results of one year, the NPV criterion calls for the consideration of monetary costs and gains over the entire economic life of the proposed project. But the streams of incomes and expenditures cannot be added unless the individual annual sums are expressed in equivalent terms in relation to time. This is accomplished by discounting the streams of inputs and outputs to the present time, given the rate of discount and time horizon. These discounted values are the present worth of the streams of future costs and benefits. The decision rule of this criterion is to accept the alternative with the maximum NPV subject to the condition that NPV $\geq$ 0. The net present value is obtained by deducting the present worth of cost streams from the present worth of benefit streams. The mathematical formula for the NPV is as follows:

$$NPV = \left(\frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} + \ldots . + \frac{b_n + s}{(1+i)^n}\right) - \left(\frac{c_1}{(1+i)} + \frac{c_2}{(1+i)^2} + \ldots . + \frac{c_n}{(1+i)^n}\right) \quad \ldots . (1)$$

where:

$b_1, b_2 \ldots . b_n$ = series of prospective benefits in years

1, 2, ...n;

$c_1, c_2 \ldots . c_n$ = series in prospective costs in years

1, 2, ...n;

S = Scrap value if any

i = appropriate discount rate

Sometimes a different form of the formula is also found in many studies.

$$NPV = \left(\frac{b_1 - 0_1}{(1+i)^1} + \frac{b_2 - 0_2}{(1+i)^2} + \ldots + \frac{b_n + S - 0_n}{(1+i)^n} \right) - K \qquad (2)$$

where: 0 = operating costs in years 1, 2, ...n

K = initial capital costs

In this form, the underlying assumption is that the entire capital cost is incurred in the beginning of the initial year of the project and that discounting does not make any difference in the capital cost.

One major objection to this criterion is that it fails to recognize the fact that a larger investment project would, in absolute terms, yield a larger net value than a smaller investment proposal. Thus, a project with larger size is apt to win over its smaller-sized competitors. However, this deficiency could be overcome if it would be possible to add together a number of smaller projects before comparison is made with a big project. Another alternative would be to compute a ratio of the NPV to the present value of project investment or total costs. This will then be a modified form of the B-C ratio. With the NPV, comparison of projects will be valid if the scale of investment is the same.

Internal Rate of Return (IRR).--The internal rate of return may be defined as the rate of discount which will make the net present worth of the project zero. It is the prospective rate of profit. In the absence of computer facilities, it is calculated by a trial and error process. The streams of costs and benefits are discounted by several rates of interest and every time the net present worth is recorded. The rate of interest at which net present worth is zero is the internal rate of return. When one ends up with two successive net present worths, one positive and the other negative with none zero, then the true rate is computed by interpolating these two net present worths. The decision rule following this criteria is to accept the alternative with highest IRR subject to the condition that the IRR $\geq$ a given rate.

The mathematical formulation of the IRR is given below.

$$\left(\frac{b_1-c_1}{(1+r)} + \frac{b_2-c_2}{(1+r)^2} + \ldots . + \frac{b_n+S-C_n}{(1+r)^n}\right) = 0 \quad \ldots . \quad (3)$$

where:

r = internal rate of return

b_1 and c_1 have the same meanings as in (1)

Another form of the IRR formulation sometimes found in literature is:

$$K = \frac{b_1 - 0_1}{(1+r)} + \frac{b_2 - 0_2}{(1+r)^2} + \ldots + \frac{b_n + S - 0_n}{(1+r)^n} \quad \ldots . \ (4)$$

Symbols in this equation have the same meanings as in (2).

This also assumes that the capital cost K is incurred in the beginning of the initial year and its present value does not change by discounting. This form of the IRR is equivalent to Keynes's formula for marginal efficiency of capital.

One of the major weaknesses of the IRR is that, like the benefit-cost ratio, it is also a ratio. Ratios do not say anything about absolute magnitudes of the gains and costs. One has to be concerned about the scale. Maximization of the net gains from a given budget will be obtained following this criterion if the projects are ranked according to their IRR and then the selection of the projects with the higher IRRs exactly exhausts the budget.

One assumption involved in the IRR is that the net receipts generated by the project are perpetually re-invested at the same rate of return. This means that the future investment opportunities are identical to the current situation. This condition is violated if the investment function is not continuous over the relevant time horizon. However, in the less developed countries the investment opportunities are generally of the expanding nature. As such this limitation of the IRR criterion is only of academic interest.

The arethmatic of the IRR stipulates the condition that investment costs should be incurred in the initial years and must thereafter be followed by positive net receipts until the last year of project's life. This means that net receipts must not become negative after they become positive. If they do so, it may not be possible to find any unique IRR. In an irrigation project such a situation might arise due to uncertain natural and political conditions. The effects of such uncertainty are generally handled by spreading them over the project life, and thus, in such cases, the particular problem of more than one IRR may be ignored.

Benefit-Cost Ratio (B-C ratio).--The B-C ratio is a simple device very often used in project evaluation by government planning agencies. Total benefits are related to total costs so that an index of solvency is obtained. The B-C ratio is arrived at by dividing the discounted streams (present worths) of benefits by the discounted streams of costs. Like the IRR it does not give any indication of the absolute magnitude of the gains and losses. There are two general forms of the B-C ratio. In one, the operation costs are deducted from the gross benefits before such benefits are discounted. In the other, they are added to the capital costs. In other words, in the first case operation costs are treated as negative benefits and go to numerator; in the second case they are treated as simple costs and go to the denominator.

Mathematical expression of the two forms is as follows:

$$\text{B-C Ratio} = \left(\frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} + \dots\dots + \frac{b_n+S}{(1+i)^n}\right)$$

$$\left(\frac{C_1}{(1+i)} + \frac{C_2}{(1+i)^2} + \dots\dots + \frac{C_n}{(1+i)^n}\right)^{-1} \quad \dots\dots (5)$$

$$\text{B-C Ratio} = \left(\frac{b_1-0_1}{(1+i)} + \frac{b_2-0_2}{(1+i)^2} + \dots\dots + \frac{b_n+S-0_n}{(1+i)^n}\right) K^{-1} \dots\dots (6)$$

Symbols represent the same meanings as in previous equations.

The decision rule, following this criterion, is to select the alternative with the highest B-C ratio subject to the condition that the B-C ratio is equal to or greater than 1.

Computation of the B-C ratios following the two methods and using the same information would give different results. A simple example will illustrate this point. Suppose the discounted gross benefits from a project are Rs. 30 million. The present worths of capital and operating costs are Rs. 10 and Rs. 5 million, respectively. When the operating costs are deducted from gross benefits, the B-C ratio is [(30-5)/10] = 2.5. But when the operating costs are added to the capital costs, the B-C ratio is [30/(10+5)] = 2. In absence of any standard classification of costs and benefits, there is a lack of uniformity of treating specific items as either costs or negative benefits. A moment's reflection would show that an alternative treatment of an item would alter the ratio, making the decision maker wonder which ratio to accept as an index of profitability. So when the B-C ratio is used as the criterion for ranking projects, care should be taken to treat the costs uniformly in all the projects. Moreover, when the ratios of capital costs to operation costs differ widely among projects, this criterion should not be used for ranking purposes.

The three decision rules coincide only at the margin where (1) the B-C ratio is one, (2) the IRR equals the opportunity cost of capital or market rate of interest (when market rate is assumed as opportunity cost and used as the discount rate), and (3) the NPV is zero. The above values provide the minimum floor for acceptance, or the feasible region.

It is apparent by now that the different measures may result in contradictory decisions. The question of which criterion to use now emerges. Project analysis can be viewed as divisible in to two stages: (i) the feasibility test or the test for the minimum floor of acceptance or rejection; (ii) the economic efficiency test or the test for maximizing the objective, e.g., contribution to GNP. For the feasibility test, the decision rules are to accept projects if the B-C ratio is greater than one, or the IRR is greater than the opportunity cost of capital, or the NPV is greater than zero. This test does not involve any problem of criteria because all the three criteria will give the same decision. Problems arise in the second test which is, in fact, the crucial phase of project evaluation. Which criteria should be selected to insure economic efficiency? Given the objectives it depends on the nature of alternatives, the size and limitations of the budget, and any other constraints in a particular situation.

At this stage, it is appropriate to present a brief discussion on the link between the three criteria and the optimizing formula in the theory of resource allocation. A note on the theoritical basis of benefit-cost analysis is presented in Appendix VII. Some important points from the note are elaborated here to highlight the link.

In micro-economic theory, optimum level of utilization of a resource is obtained when the marginal value product (MVP) from the resource is equal to the marginal resource or factor cost (MFC). We can consider benefits and costs of an investment in a project in terms of a production function where benefits represent output and costs an input. The optimum level of factor use in this function will be indicated by the point where the difference between the benefit and cost curves is maximum. It is precisely the point where MVP=MFC or MVP/MFC = 1. If we assume a project as a marginal one, a B/C ratio of 1 will indicate that an optimum level of investment in the project has been achieved. When the resource under consideration is specific to one use or fixed, its opportunity cost is zero. Then the total factor-cost function will be zero. In this case we will maximize the benefit i.e., we shall use specific resource up to the point where the total benefit is maximum. In reality, a project cost includes both specific and non-specific resources. Total factor cost of all resources should reflect the appropriate opportunity costs of both specific and non-specific resources.

We have so far assumed no budget constraints in production process. If a budget is limited to expand production to the point where the MVP equals MFC or B/C ratio equals 1, the optimum level of resource use will be indicated by the B/C ratio of 1 plus a factor, say v, reflecting the tightness of the budget. A measure of the tightness of a budget may be obtained from the additional cost involved in raising additional capital. Sometime the marginal taxation rate or the cost of borrowing external finance provides an estimate of tightness of a budget. If the marginal taxation rate is 0.05, the B/C ratio for optimum resource allocation would be 1.05.

Comparing projects by the B/C ratio merely means a comparison of the respective benefit and cost function. For a given budget, selection of a project with a higher B/C ratio will imply maximization of net benefit from the budget.

So far we have not mentioned anything about time. Generally, an investment in a project generates revenues over a number of years. In terms of a production function this means that values at every point in the curve or production surface represent the present values. The present value is obtained by discounting streams of outputs and inputs by an appropriate discount rate. The same principles of optimum resource use are still valid. With an unlimited budget the optimum level of resource use will be where MVP=MFC (discounted) and B/C ratio is equal to 1. At this point the NPV is maximum from the given resource use. However, the IRR measure will indicate the same optimum level of resource use only if it is equal to the discount rate.

With a limited budget we generally can not reach to the optimum level. In fact we look for new optima--optima subject to budget constraints. In these situations we should have B/C ratios greater than one and IRRs greater than the discount rate. Within the context of limited budgets comparison of alternatives becomes extremely meaningful. The pitfalls of such comparisons using the IRR, B/C ratio, and NPV have already been discussed. The main objective of such comparisons is to maximize net benefits from a given budget.

In the context of the present study, any one of the three criteria, the IRR, the NPV, and the B-C ratio, would evaluate the alternatives to be compared vis-a-vis the income objective without any conflict in ranking. But the result of the study may be useful in making comparisons with other irrigation projects or projects in the agricultural sector. In making such comparisons, conflict may arise in ranking due to the different natures of constraints and costs. These would not be known at this stage. For this reason, the results in the present study are presented in tables in the form of all the three criteria, though discussions are made using only one or two of the criteria in the text. For evaluating the first two objectives of the study, i.e., to investigate the monetary profitability of investment on tubewell irrigation and the relative merits of various technical alternatives, the three criteria discussed so far in general terms are used. The general equations are now stated with the specific meaning of the terms for the present study:

$$NPV = \left(\frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} + \dots + \frac{b_n+S}{(1+i)^n}\right) - \left(\frac{C_1}{(1+i)} + \frac{C_2}{(1+i)^2} + \dots + \frac{C_n}{(1+i)^n}\right) \quad \dots\dots (7)$$

$$\left(\frac{b_1-C_1}{(1+r)} + \frac{b_2-C_2}{(1+r)^2} + \dots + \frac{b_n+S-C_n}{(1+r)^n}\right) = 0 \quad \dots\dots (8)$$

$$\text{B-C Ratio} = \left(\frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} + \dots + \frac{b_n+S}{(1+i)^n}\right)\left(\frac{C_1}{(1+i)} + \frac{C_2}{(1+i)^2} + \dots + \frac{C_n}{(1+i)^n}\right)^{-1} \quad \dots\dots (9)$$

Where:

b_n = (value of crops in year n under irrigated conditions --cost of production of crops in year n under irrigated conditions)--(value of crops in year n under non-irrigated conditions--costs of production of crops in year n under non-irrigated conditions)

$n = 0, 1, \ldots. n$ years

C_n = sum of capital, operation, maintenance and replecement costs and costs on agricultural services in the year n.

i = appropriate discount rate

r = IRR (internal rate of return)

S = salvage value if any

<u>Criteria for Employment Objective</u>.--During the last decade, many developing countries initiated consciously planned policies and programs to achieve faster economic development (measured in terms of growth rates of GNP). By the end of the decade, however, many of these countries were appalled to see that although they were able to achieve a respectable growth rate by historical standard, the growth of unemployment and consequent poverty in the economy had accelerated. This trend has alarmed development economists and politicians who in the process of reappraisal of their strategies and theories have increasingly stressed employment generation as a primary objective in their economic

plans. This has called for the development of appropriate criteria for measuring the change in development at the macro level and for project evaluation at the micro level. Gustav Ranis suggests, "the criteria of success in the development effort may be stated as a rate of industrial labor absorption in excess of the rate of population growth."[10] He views this criterion as effective in insuring policy orientations favorable for the growth of both GNP and employment in an initially labor surplus economy.

In the context of project evaluation the criteria used to measure the effectiveness of a project in employment generation have direct relevance to the present study. Measurement of the effect of a project on employment generation has been attempted by the valuation process of labor input. In a recent report to the Water Resource Council of the United States of America, a Task Force recommended that the benefit of employment generation from a project should be measured by the inclusion of such labor costs (type of labor employment generated) in the benefits.[11] This inclusion of the labor costs once in the benefit and again in the cost side is equivalent to the proposition of valuing the labor

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[10] Gustav Ranis, "Allocation Criteria and Population Growth", _The American Economic Review_, Vol. LIII, no. 2, May, 1963, p. 623.

[11] U.S.A., WRC, _Report to the WRC by the Special Task Force: Procedures for Evaluation of Water and Related Land Resource Projects_ (Washington, D.C., WRC, 1969), p. 69.

input at zero price. This approach combines the effects on both income and employment generation in one criterion. Another approach, however, which has empirical application to developing countries involves a separate criterion for employment creation objectives. Following this approach McGaughey and Thorbecke evaluated a series of irrigation projects in Peru.[12] They constructed employment-investment ratios of projects to indicate the relative employment creation capacities of projects.

Following the procedure used by McGaughey and Thorbecke in their appraisals of the Peruvian irrigation projects, the employment-investment ratio will be constructed in the present study for the measurement of the impact on employment of irrigation projects. The employment-investment ratio (henceforth called E/K ratio), is defined as the present discounted value of the unskilled labor input per unit value of the project investment cost. Hence,

$$E/K = \sum_{o}^{n} \left[E_n/(1+i)^n \right] \bigg/ \sum_{o}^{n} \left[K_n/(1+i)^n \right]$$

Where:

E = sum of the present values of labor costs,
K = sum of the present values of capital costs,
E_n = values of labor costs in year n,

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[12] Stephen E. McGaughey and Erick Thorbecke, "Project Selection and Macro-Economic Objectives: A Methodology Applied to Peruvian Irrigation Project", American Journal of Agr. Econ., Vol. 54, February, 1972, pp. 33-37.

K_n = values of capital costs in year n,
n = 0,1,2, ... n years,
i = discount rate.

In addition to the E/K ratios, the employment generated in terms of man-days, attributable to investment on the irrigation project, is also calculated in the study. This is done by taking the difference in total man-days of labor required with irrigation and without irrigation. The distinction between skilled and unskilled labor is made by defining all laborers without any formal education or taining as unskilled. Thus all agricultural labor is considered unskilled. The "peons", "darwans", guards, helpers, and "barkandazs", in the category of fourth class employees in the Tubewell Irrigation Project (the Fourth Plan Project), are treated as unskilled, while the truck drivers, operators and other technical and non-technical employees in the project are classified as skilled labor. The question of whether the value of unskilled labor and not all labor should be included in the numerator of the E/K ratio has to be decided from the supply and demand situation of such labor in the country concerned. If both skilled and unskilled labor are surplus in the country, E will include both. If the unemployment problem is limited mainly to surplus unskilled labor, as is usually the case in less developed countries, then only the value of unskilled labor should be included in constructing the E/K ratio.[13] In Bangladesh the unemployment problem is severe primarily in the unskilled labor force. Some structural unemployment of skilled manpower is expected by 1985. This is expected to derive mainly from the imbalances in the skills currently produced and those for which demand is likely to be created by developmental activities undertaken by that time.[14] However, a deficit of skilled manpower is expected during the next decade or so, particularly in the context of the new situation, for several reasons. First, part of the skilled manpower in the country was formerly supplied by non-Bangalees which will not occur in the future. Second, independent Bangladesh will be in a better position to undertake a large development program creating a large demand for skilled manpower. Third, some skilled manpower was lost during the war. Considering these factors the inclusion of only unskilled labor in the E/K ratio, implying the existence of a surplus labor problem only in the unskilled category, appears to be justified.

The second consideration which influenced the selection of E/K ratio for evaluating projects from the point of view of the employment objective is its existing use in

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[13]The author discussed the issue with Dudley Seers when he visited the Michigan State University from May 30 to June 2, 1972 for a series of lectures on unemployment problems.

[14]East Pakistan (Bangladesh), Ministry of Planning, Manpower Planning In East Pakistan; Medium Term Projections, Problems and Policies; (Dacca, Planning Department, 1969).

planning in Bangladesh. For example, the employment-investment ratio was used as one method in projecting the demand for manpower in Bangladesh.[15]

Concluding Observations.--The chapter may be concluded with a few observations. First, the three fundamental problems in conducting a problem solving research need constant attention of researchers. In absence of any absolute measure of utility, money has been serving as the common denominator for multiple objectives. Interactions among researchers and the people involved in research problems may help partially overcome the problem of common denominator. The problem of order conditions is very difficult to handle. Nevertheless, it deserves attention of researchers while designing a study. Selection of an appropriate decision rule depends mainly on the attitudes of decision makers, various constraints in implementing the decision, and the extent of knowledge about future outcomes. Because of inadequate solutions to these three fundamental problems, many of the empirical studies generate partial information for decision makers. Final decision making can not, therefore, be based completely on the findings of such studies. The present study also falls in this cateogry.

Second, analytical techniques for evaluation of public investment programs have been steadily improving over

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[15] Ibid., p. 37.

time. But the status of techniques still deserves further improvement. Application of probability theories and simulation, including various programming techniques, are the recent tools of sophisticated analyses. These tools have been efficient in insuring consistency among related factors in aggregative models. But the micro aspects of many factors have to be sacrificed in largely aggregative models. Both macro and micro analyses are important and they should be considered complementary rather than substitutes to each other.

Third, the present study is conducted in a partial equilibrium setting. The study is designed to evaluate the net effects of investment in irrigation on income and employment. For evaluation of the effects on income, the measures of IRR, NPV, and B-C ratio are constructed. For evaluation of employment effects, the E/K ratio is employed. Mathematical formulations of these measures have been presented in this chapter. Various pitfalls in using these measures while making a choice among alternatives have been indicated. Attempts have also been made to elaborate the theoretical basis of use of the measures of IRR, NPV, and B-C ratio in evaluation of public investments.

CHAPTER IV

PROJECTION OF CROPPING PATTERN UNDER TUBEWELL IRRIGATION

One important step in the evaluation of any irrigation project is to project the most probable cropping pattern under irrigated conditions of farming. In the present chapter, a future cropping pattern for the study area will be projected. This projected cropping pattern will form the basis for the calculation of the project benefits from irrigation in the subsequent chapters.

Projection Problems

The first problem in the projection of a future cropping pattern is to identify the determining factors. What are the rationales behind the decision of a farmer in allocating various amounts of land resources to various crops? For commercial agriculture, it is agreed that the relative monetary profitability of an enterprise is the major determinant in allocating resources. In subsistence agriculture, the role of money income in resource allocation has been a long debated issue. To understand the issue, one must realize that, in the real world, very few farms are perfectly commercial or perfectly subsistence types. There is a continuum of two dimensions--the proportion of production consumed by family in one dimension and that of family labor employed on the farm in another. The differences between the commercial and the subsistence farms lie in the differences in degree of these two dimensions associated with different farming systems.

The question of the economic behavior of subsistence farmers has drawn the attention of economists and other social scientists. Schultz emphasized the role of profit as the most important consideration in farm resource allocation.[1]

On the other extreme, some institutionally oriented economists and social scientists tend to argue that the prevailing institutions and non-monetary considerations play the dominant role in resource allocations in subsistence farming. Intensive studies on the issue indicate that the fact is probably in between the two extremes.[2] Farmers in subsistence agriculture are responsive to economic incentives in adjusting their resource commitment to various enterprises, but the intensity of such responsiveness is constrained mostly by the need for security, the production conditions,

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[1]T. W. Schultz, Transforming Traditional Agriculture (London and New Haven, Conn.: Yale University Press, 1964).

[2]See for elaborate literatures in: Clifton R. Wharton (ed.), Subsistence Agriculture and Economic Development (Chicago, Aldine Publishing Co., 1965), pp. 165-243.

and to a lesser degree, by their customs and value system. However, the degree of responsiveness varies from crop to crop as well as between individual farmers and the agriculture sector as a whole. Cash crops and seasonal crops are more responsive to monetary incentives than perennial crops and subsistence food crops. The responsiveness of individual farmers in the reallocation of resources to various crops due to changes in the relative prices of these crops is generally more pronounced than the response of aggregate production in the agriculture sector to the changes in the price levels of agricultural and industrial products. The fact that subsistence food crops are less responsive than cash crops is, perhaps, a reflection of the farmers' concern for security. Farmers want to ensure that they get a certain level of food supply from their own farms. Rabbani working on jute and rice concludes that the allocation of land to rice and jute in the Aus season in Bangladesh is largely explained by the relative prices of these two crops.[3] With an increased productivity in agriculture arising out of new inputs, particularly the seed-fertilizer revolution, the role of the profit motive in resource allocation is likely to be more pronounced in Bangladesh as well as elsewhere.

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[3]Ghulam A. K. M. Rabbani, "Economic Determinants of Jute Production in India and Pakistan", (Karachi: The Pakistan Development Review, Summer, 1965), p. 50.

A second problem in the projection of a future cropping pattern is the uncertainty about which new crops will be introduced once irrigation water becomes available. Yield rates for these crops and the future price levels of outputs and inputs will also be a problem. Traditional crops grown in a traditional setting may not be the ones grown in a new setting of technological conditions. The raising of new crops, which were previously constrained by the lack of soil moisture, becomes possible with irrigation water. However, the major factor influencing the selection of crops is the demand level for the product. This factor alone will have the most dominant influence in Bangladesh. Therefore, rice will continue to be the major crop. However, new varieties of rice will most probably replace the low yielding existing varieties.

The yield rates of new varieties in the future can be estimated either by extrapolating the results of production trials within the country or by using the results obtained in other countries which have similar conditions. The latter source is considered to be very unreliable since there may be a host of factors which might not allow a high level of yield to be achieved in one country, although it was possible in some other apparently similar country. Estimates of yield rates based on the results of production trials should take into consideration the effects:

a. of a large scale expansion, possibly on gradually inferior soil, on the future average yield;

b. of a loss of vigor of many varieties in the process of adaptation over a long period; and

c. of the continued and accumulated experience of farmers in growing the new varieties with the resulting impact of a better husbandry affecting the yield rates.

Intorduction of the new high yielding varieties in Bangladesh started with the introduction of 303 rice varieties from the International Rice Research Institute, Philippines, in 1965.[4] These varieties were tried on the experimental farms in that year and the average yields of the best varieties (IRR-8) ranged from 62-87 maunds of paddy per acre.[5] In 1966-67, the varieties were released to farmers on about 2,000 acres. The estimated area under these new varieties in Bangladesh in 1967/68 and 1968/69 was about 160,000 acres and 200,000 acres respectively.[6] Scattered evidence on the yield rates obtained by these farmers using the new varieties is available. The Agriculture Department, in the food

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[4] A. Alim, et. al., Progress Report On: Accelerated Rice Research Program of East Pakistan, January-August, 1966. (Dacca, Agriculture Department, 1966), p. 5.

[5] Ibid., p. 7, (one maund = 82.29 lbs.).

[6] Joseph W. Willet, Spring Review of New Cereal Varieties, May, 1969. (Washington, USAID, 1969), p. 10.

self-sufficiency program assumed a yield rate of 51.4 maunds of cleaned rice per acre.[7] This was based mainly on the results of crop-cuttings from the demonstration plots of farmers. In terms of paddy, it worked out to be 74.4 maunds per acre which is undoubtedly very high for projection purposes. The author conducted a survey in the 1968 Boro season collecting data from 60 farmers in the Dacca, Chittagong, and Mymensingh districts. The average yield of the IRR-8 varieties in terms of paddy in this survey was found to be 52.20 maunds per acre. Underwood found the average yield of the IRR-8 varieties, grown in the Boro season in the Gumaibil area of the Chittagong district, to be 63.6 maunds per acre.[8]

The IRR-8 varieties were mainly meant for the Aus and the Boro seasons. For the Aman season, the IRR-20 was recommended by the Department of Agriculture.[9] This variety was grown in the 1970 Aman season on about 150,000 acres. The performance of this variety was evaluated through a survey conducted by the Department of Agriculture with the

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[7]East Pakistan (Bangladesh), Agriculture Department, Food Self-Sufficiency Program, op. cit., p. 10.

[8]Sharif M. Masud and F. L. Underwood, Gumaibil Boro Paddy: Profits and Losses, 1967-68 (Mymensing, Agricultural University, 1969), p. 13.

[9]Refugio I. Rochin, Farmer's Experiences with IR-20 Rice Variety and Complementary Production Inputs: East Pakistan, Aman 1970 (Dacca, Ford Foundation, 1971), p. 3.

help of economists from the Ford Foundation, the Agricultural University, Mymensingh, and the Pakistan Institute of Development Economics. The average yield of paddy was found to be only 33.64 maunds per acre in this survey. There was considerable variation; average yield ranged from 23 maunds in Denajpur to 47 maunds in Bogra. In some places, the yield was exceptionally high while in others it was very low. The results were considered inconclusive. In 1970, a severe natural calamity damaged the crops and hampered pollination. Moreover, the efforts in the first year had many limitations; seeds arrived late with a resulting planting delay in many places. In those areas where normal climatic conditions prevailed and recommended practices followed, IRR-20 yielded 40 to 50 percent higher production than the local varieties.[10] One outstanding finding was that the IRR-20 did relatively well even in those areas which did not have supplemental irrigation. However, this finding is not conclusive since it is based on a limited survey of one year only.

There are many other uncertainties, and price uncertainty is one of the most important ones. There is no single method by which the estimates of the most probable future relative price structures can be obtained. Projection of future supply and demand functions along with the likely future policies related to the relative prices of products

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[10] Ibid., p. 12.

is one way often referred to in the literature. Estimates of the long run supply and demand functions of agricultural crops in Bangladesh are not available. For the purpose of projection of the cropping pattern in the present study, ranges of relative prices have been used.

Review of Techniques for Projection of Cropping Pattern

In the developed western economies, agricultural economists and farmers have been working out enterprise combinations through various techniques. In the earlier periods of technological upsurge in agriculture, the main technique was budgeting. Complete and partial budgeting techniques used to be extensively employed. With the advent of operation research methods, new techniques like linear programming, dynamic programming, integer programming, recursive programming, simulation, etc. are being used more frequently with a declining reliance on budgeting techniques. Hutton[11] has summarized applications of these operation research techniques in farm planning and decisions. In the developed countries, application of these techniques was mainly meant for determination of profit maximizing cropping patterns or profit maximizing enterprise combinations. In contrast to the

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[11] Robert F. Hutton, "Operations Research Techniques in Farm Management: Survey and Appraisal," American Journal of Farm Economics, Vol. 47, No. 5, December, 1965.

developed economies, the developing countries have been using these techniques only recently and on a limited scale, to investigate the impact of new technologies and development programs on cropping patterns, supply responses, price relationships, etc. Gotsch[12] uses a linear programming model to investigate the optimal resource allocations for West Pakistan agriculture under the new technological conditions. He attempts to identify the changed role of price policies in the adjustment of resource allocation in agriculture and the distributional imbalance in income. Martin, Burdak and Young use a linear programming model to determine an optimum cropping pattern consistent with the declining water table.[13] Mann, Moore, and Johl examine shifts in the cropping patterns in Punjab, India under various technological conditions.[14] They use a linear programming model with resource restraints on land, irrigation water, family and hired labor, and liquid capital.

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[12]C. H. Gotsch, Technological Change and Price Policy in West Pakistan Agriculture: Some Observations on the Green Revolution (Cambridge, U.S.A., Harvard Development Advisory Service, 1971).

[13]W. E. Martin, T. G. Burdak and R. A. Young, "Projecting Hydrologic and Economic Interrelationships in Ground Water Basin Management", presented at the International Conference on Arid Lands in a Changing World, AAAS, Tuscon, June, 1969.

[14]K. S. Mann, S. S. Johl and C. V. Moore, "Projection of Shifts in Cropping Pattern of Punjab", The Indian Journal of Agricultural Economics, Vol. XXIII, No. 2, April-June, 1968.

<u>Model</u>

A programming model is used in the present study to determine the cropping pattern at the terminal year of the development of irrigated agriculture. Initially, only budgeting and linear programming techniques were considered for projection purposes. Basically there is no difference between the two techniques. But the linear programming technique offers some advantages which are not possible in the budgeting method. Projection of cropping patterns involves allocation of land resources generally under a set of constraints. If the number of constraints are more than one, it is hardly possible to maximize or minimize some objective (profit or cost) in the budgeting technique while simultaneously satisfying all the constraints. For this reason the programming technique is adopted. A representative farm with 3.0 acres of irrigated land is taken for analysis, and the overall cropping pattern for the area under a tubewell irrigation is obtained through aggregation. In this analysis the objective function is shown in equation 1.

$$ZO = \sum_{j=1}^{n} C_j X_j - \sum_{j=1}^{T} W_j L_j$$

Where the parameters are defined as follows:

C_j = per acre net income obtained from the jth crop production activity for sale or consumption, each crop in each season is considered a separate crop. (Gross revenue minus variable material input costs.)

W_j = the wage associated with hiring a unit of human labor for the jth crop.

The decision variables are:

X_j = the level (units of acres) of the jth crop production activity for sale or consumption

$X_j \geq 0$

L_j = the level (man-days) of hired labor in the jth crop.

$(j = 1, \ldots T)$

$L_j \geq 0$

Equation 1 is maximized subject to the constraints of the following forms:

<u>Land Constraints</u>

$$\sum_{j=1}^{n} a_{ij}X_j \leq b_i$$

$(j = 1, \ldots n)$

$(i = 1, \ldots m)$

Where:

a_{ij} = the exchange coefficient of the jth crop variable in the ith season

b_i = land available in the ith season

<u>Labor Constraint</u>

$$\sum_{j=1}^{n} \lambda_{ij}X_j \leq F_i + L_i$$

Where:

λ_{ij} = per acre labor requirement for the jth crop production activity in the ith period

F_i = family labor supply in the ith period

L_i = hired labor used in the ith period

<u>Subsistence Constraint</u>

$$\sum^{n} \delta_j X_j \geq R$$

Where:

δ_j = per acre production of the jth rice crop

X_j = the level (units of acres) of the jth rice crop production activity for consumption

R = consumption requirement of crops (rice) which the farm family insures from farm production

<u>Working Capital Constraint</u>

$$\sum_{j=1}^{n} S_{ij} X_j \leq M_i$$

$$(j = 1, \ldots n)$$

$$(i = 1, \ldots m)$$

Where:

S_{ij} = per acre requirement of cash in the ith season for the jth activity

M_i = cash available in the ith season and

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The specific activities and constraints in the rows and columns of the programming matrix are shown in Appendix VIII.

Land available in the three crop seasons, the Aus, Aman and Boro seasons, will not be the entire three acre irrigated area of a farm. If so, this will imply a cropping intensity of 300 percent which is considered impossible to attain in Bangladesh within the foreseeable future. Even if we assume that there will not be any controllable constraints, for example, partial mechanization for rapid land preparation, the growing period of rice crops will preclude the planting of all available land in any given season. Though research findings claim success in evolving short-period rice varieties, there have been no spectacular results.

Experience with the new rice varieties in Bangladesh indicates that, although the IRR-20 in the Aman season comes to maturity in a relatively shorter period of time than the local varieties, the IRR-8 varieties take about 120 days.[15] It is expected that the research in evolving short maturity varieties may be successful. Yet, projection of cropping intensity with this expectation does not seem appropriate with the present state of knowledge. For the present study, the maximum cropping intensity assumed is about 234 percent --about 83 percent in the Aus season, 74 percent in the Aman

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[15]A. Alim _et al._, _Progress Report of Accelerated Rice Research Program_, _op. cit._, p. 7.

season and 77 percent in the Boro season. The study of the cropping intensity under irrigated conditions in the Comilla area supports this assumption. In two villages of Comilla, the cropping intensity was 129 before irrigation was introduced (1963). After the introduction of irrigation, the cropping intensity went up to 231 in 1967.[16] The Master Plan of WAPDA assumed a future cropping intensity under irrigated conditions to range from 250 to 285 percent. This appears to be quite high and was considered unrealistic by the Planning Department.[17]

Data for the Programming

Data for the model were generated through a synthetic process. The main sources of primary data are as follows:

a. The author collected data during the 1968 Boro and Aus seasons from 20 farmers in Dacca, 25 farmers in Mymensingh and 15 farmers in Chittagong. The major objectives of this survey were to calculate the returns from improved rice varieties for comparison with local varieties and to investigate the problems of introduction of these varieties to farmers.

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[16] Nurul Islam, Impact of Irrigation on Cropping Pattern and Production Practices in Two Villages under Comilla Kotwali Thana (Mymensingh, Agricultural University, unpublished M.S. Thesis, 1967), p. 34.

[17] East Pakistan (Bangladesh), Review of WAPDA Master Plant Irrigation Projects (Dacca, Planning Department, 1965), p. 10.

b. Farm management studies conducted by the Comilla Academy for Rural Development were consulted. In addition to the two cost and return studies[18] by the Academy, data from 176 farmers in 1970 crop season were collected by the Academy to evaluate performance of their irrigation program. The master-sheet of this survey was available to the author.

c. Other survey reports were also used. For example, one by the Jute Research Institute[19] one by the agriculture department in 1970,[20] survey reports of the WAPDA's consulting firms,[21] World Bank evaluations of irrigation proposals,[22] farm management investigations in Gumaibil areas by Masud and Underwood,[23] and some other secondary sources were explored.

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[18]Mahmoodur Rahman, Costs and Returns: Economics of Winter Irrigated Crops in Comilla, 1965-66 (Comilla, Academy for Rural Development, 1967), (another study by the same author in 1965).

[19]S. D. Choudhury and Md. Ashraf Ali, Report on Survey of Cost of Production of Jute and Aus (Dacca, Central Jute Committee, 1962).

[20]R. I. Rochin, Farmer's Experience with IR-20, Op. cit.

[21]East Pakistan (Bangladesh), Farm Survey Reports by Ledshill, Deleuw Engineers (Dacca, WAPDA, 1968).

[22]IBRD and IDA, Tubewell Project, East Pakistan (now Bangladesh) (Washington, Agri. Project Division, 1970).

[23]S. M. Masud and F. L. Underwood, Gumaibil Boro Paddy: Profits and Losses, op.cit.

When the data source is so diverse, the necessity of synthesis is obvious. For example, while some of the studies were meant only for rice, others were for jute and some others covered two or three crops. The concept of costs and the coverage of different cost items varied in the different studies. Those studies which took place at different times and in different sample areas had different price estimates of inputs and outputs which very often confused the comparison of cost and production values among these studies. Moreover, the purpose of the present study concerns the future production pattern under irrigated conditions in one area of Bangladesh. Therefore, the present synthesis was considered essential. The process of synthesis involved identifying the items and the quantities of physical inputs and outputs in detail and then selecting the items relevant to the region and purpose under study. The costs of production of crops and the other data necessary for programming purposes which were developed through this synthetic process are shown in Appendices IX to XIV.

Analysis of the Programming Results, Cropping Pattern and Net Income

The acreage under different crops in the three acre irrigated area which came in the optimum solution is shown in Table 1.

Table 1. Results of the model: allocation of land in a modal farm with a given set of prices and yields, after irrigation development, study area, Bangladesh.

Crops	Area in Aus Season	Area in Aman Season	Area in Boro Season	Assumptions: Price Per Maund	Assumptions: Yield Per Acre
	(Acres)	(Acres)	(Acres)	(Rs.)	(Maunds)
Aus (IRRI) Paddy	1.59			18.0	40.0
Aus (Deshi) Paddy	0.0			18.0	25.0
Jute	0.91			25.0	25.0
Aman (IRRI) Paddy		2.20		19.0	40.0
Aman (Deshi) Paddy		0.0		19.0	25.0
Boro (IRRI) Paddy			1.79	19.0	45.0
Potato			0.51	14.0	90.0
Wheat			0.00	12.0	30.0

The net income, defined as the gross revenue minus variable costs (material input costs and costs on hired labor) from the three acres of irrigated land with the cropping pattern in Table 1 is Rs. 2707.53. This net income corresponds to the objective function (equation 1) in the programming model. However, the variable costs do not include water charges. The supply of irrigation water in Bangladesh has so far been priced at a lump-sum for the whole year or at a flat rate per acre without any consideration of the different irrigation water requirements for different crops. As such, this cost was considered as a fixed cost which did not vary with output. In addition to this, the net income does not include the net returns from 0.67 acres of land allocated to meet consumption requirement of the farm family. This is equal to Rs. 485.00. Including this amount the net income works out to be Rs. 3192.53. The per acre cost of irrigation, assuming a tubewell covers 60 acres a year, was calculated to be Rs. 94.0 by the ADC.[24] Although there are many shortcomings and conceptual deficiencies in the above calculation, this figure is accepted as an approximation for the time being. Including the water costs in the total variable costs, and including the net returns from the land allocated to meet the consumption requirement of the

[24]ADC, PCI Form of the 4th Plan, Tubewell Irrigation Project, op. cit., p. 18.

farm family in the total revenue, the net income works out to be Rs. 2910.53 per year. This net income may be called the return to family labor, fixed capital and land. For the particular cropping pattern in Table 1, 303.8 man days of family labor were utilized in the farm production activity during the whole year.

The cropping pattern and the return to family labor, land and capital as shown above are, however, subject to change with changes in cost functions, productivity and prices. The productivity and cost estimates assumed in the calculation of results described here are considered to be the most probable at the present time. Future prices are more uncertain. The cropping pattern and net farm income with various price and productivity assumptions are shown in Appendix XV.

A comparison of income originating from an irrigated cropping pattern, with the estimated income from the crops grown presently, is provided in the Appendix XVI and Appendix XVII. The present net income is estimated to be Rs. 1026.00 compared to the net income of Rs. 2910.53 under irrigated conditions. So the farmers' income is expected to rise by about 184 percent. However, the income from the present cropping pattern has been computed by assuming the same product prices as are expected to prevail with production under irrigated conditions. This has been done to make the comparison in real terms. If an approximate estimate of the existing farm gate prices of paddy is used in the computation of present income, the present net income works out to be Rs. 1398.00 from a 3-acre area. With this estimate, the farm income is expected to increase by about 108 percent by the supply of irrigation water.

Crops in Aus Season

Two important crops, Aus rice and jute, are grown in the Aus season. Aus rice is the second largest rice crop and jute is the largest foreign exchange product for the economy. In the high and medium lands with loamy and clay loamy soils, both crops compete for land in the same season. The price ratio of these two crops has been playing a significant role in the allocation of lands to these crops.[25] With the recent technological advances in rice crop production, the relative profitability of jute production has fallen far behind. The present normal yield rate of jute is about 15 maunds per acre.[26] Available research findings and the results of demonstration plots on farmers' fields with improved varieties of jute and more productive cultural practices indicate that there is considerable room for improving the yield rate of jute. Experimental results for

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[25] A. K. M. Rabbani, Economic Determinants of Jute Production, op. cit., p. 54.

[26] East Pakistan (Bangladesh), Agricultural Production Levels (1947-1965), (Dacca, Directorate of Agriculture, 1966), p. 15.

a few years in the Brahmaputra alluvium (which includes the study area) show an average yield rate of 34.5 maunds per acre, which is about 70 percent higher than that of the controlled area.[27] Demonstrations on farmers' fields show similarly encouraging results.

The Jute Association had been operating with the objective of teaching the farmers modern practices of jute cultivation. Average yield in the demonstration plots guided by the Jute Association was about 35 maunds per acre.[28]

Assuming an improved yield rate of jute to be 25 maunds per acre (with associated cost increase) and that of Aus rice to be 40 maunds of rice per acre, the influence of relative prices of jute and rice on the allocation of land is shown in Table 2.

It will be observed from the table that no land is allocated to jute when the ratio of jute to rice prices is 1.110. With the increase of the ratio to 1.250, only 0.91 acres come under jute, and it remains at the same level when the ratio is raised to 1.389. This reveals one interesting aspect of the interactions of constraints in the programming technique. Interaction of family labor constraints and working capital constraints in the present model forces

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[27]Ghulam A. K. M. Rabbani and Rais U. Ahmed, Long Term Jute Policy and a Program for Increasing Jute Production (Dacca, Planning Department, 1968), p. 42.

[28]*Ibid.*, p. 43.

Table 2. Estimated relationship between the ratios of jute to rice prices and the allocation of land to jute and rice crops after irrigation development, study area, Bangladesh.

Jute/Rice Price Ratio	Area Under Jute	Area Under Aus Rice (IRRI)
	(Acres)	(Acres)
1.110	0.0	2.50
1.250	0.91	1.59
1.389	0.91	1.59
1.500	2.50	0.0
1.563	2.50	0.0

Note: Compiled from the results of the model.

some acreage to be allocated to Jute when the ratios are 1.25 and 1.389, and the net profit per acre of jute falls below that of rice. However, when the jute to rice price ratio goes up to 1.5, no acreage is allocated to rice.

The interpretation of the above analysis should be done cautiously. The underlying assumptions of yield rates and costs should not be forgotten in any extrapolation or interpretation of the above relationships. It would have been desirable to work out the relationship of allocation of land for Aus rice and jute with their relative net revenues. This was purposely avoided. The statistical reporting system in Bangladesh does not generate any annual net revenue figures for crops as is the case with prices and yield rates. Policy makers are more conversant with the yield rates and prices of these two crops; prices tend to get more consideration in policy formulations. Costs and yield rates are generally assumed constant in policy formulations, which is considered realistic in the short run. Given this situation, the ratio of relative prices was purposely selected to analyze the influence of prices on land allocations to crops in the Aus season.

Crops in Aman Season

Only two kinds of rice, Aman (IRRI) and Aman (deshi) compete for land in the Aman season. Amsn (IRRI) has obvious economic advantage over the Aman (deshi) and came into solution in all the runs. However, the consumption requirement constraint interacting with the working capital constraint forced Aman (deshi) to come partially, in some solutions (Appendix XV).

Crops in Boro Season

Boro (IRRI) rice, potato and wheat are considered competing for land in Boro season. Potato may be considered as a proxy for some other vegetable crops in the season in terms of relative profitability. Assuming constant yield rates of Boro at 45 maunds per acre, of potato 90 maunds per acre, and of wheat 30 maunds per acre, the acreage allocations to these crops at various relative prices are interesting to note. When the rice (unhusked) price is Rs. 27

per maund, potato price Rs. 14.0 per maund, and wheat price Rs. 18.0 per maund (almost the recent relations), land in Boro season is allocated only to Boro (IRRI). When the price of Boro falls to Rs. 21 per maund, price of potato and wheat remaining constant, only a very small area (0.02 acres) comes under potato and the rest of the area goes to Boro (IRRI). The small land allocation to potato, however, appears due to the credit constraint. With an increase in the working capital available, and with the same sets of prices and yield rates, the acreage under potato goes up to 0.67 acres and the Boro (IRRI) area is reduced by the corresponding amount. When the rice price further falls to Rs. 17.0 per maund, other prices remaining constant, about 78 percent of the land goes to wheat and 22 percent to potato. However, when rice prices fall, wheat prices cannot remain constant. Because rice and wheat are close substitutes in consumption. Prices of these two substitutes maintain a difference of about Rs. 7 to 9 per maund. Assuming rice prices at Rs. 19, potato at Rs. 14, and wheat at Rs. 12.0, no wheat comes to solution; 78 percent of land goes to Boro (IRRI) and 22 percent to potato. With the same sets of prices except the potato price falling to Rs. 12.00, only Boro (IRRI) is cultivated in Boro season. Considering the interdependence of prices of wheat and rice, the most probable situation in the future is likely to be the one of rice (unhusked) prices at Rs. 19, wheat prices at Rs. 12, and potato prices at Rs. 14.0 per maund when about 78 percent of land in the Boro season goes to Boro (IRRI) and 22 percent to potato.

Implications of Working Capital Constraint

The important implication of this constraint is its limiting influence on the cropping intensity. If the availability of working capital is Rs. 1200.0 per year or Rs. 400.0 per season, the cropping intensity is reduced by 10 percent in the Boro season. However, this effect of the constraint is overcome by an interaction of this constraint with the constraint of consumption requirement. When the prices of rice fall with the same working capital constraint, consumption requirement is met by a shift from Aus (deshi) to Boro (IRRI) and thus, a full utilization of land is achieved. However, even if the working capital is increased to Rs. 1800 per year or Rs. 600 per season, working capital is completely exhausted in the Boro season though there is about 25 percent of the working capital remaining idle in the Aman season and 18 percent in the Aus season.

Policy Implications

a. The major policy implication emerging from the results of the model is that of competitive positions of rice crops vis-a-vis other crops in the allocation of land.

With a rapid expansion of decreasing cost seed-fertilizer technologies in rice production, other crops competing with rice for land will be thrown into a relatively disadvantageous position. Jute is the second most important crop after rice in Bangladesh. There has not been any comparable technological breakthrough in the production of jute. With a rapid expansion in rice production rice prices will come down. But it is not likely to come down sufficiently (below world price) to prevent a shift of land from jute to rice. Bangladesh will require exportation of jute in an increasing volume to finance its development programs. For achieving an increased production of jute or even for maintaining the present level of the production of jute in competition with the new rice varieties, two policy options are available. The first option is a new technological breakthrough in jute, like the one in rice. The second option is to maintain prices of jute sufficiently high so that its competitive position with rice does not deteriorate. The second option may not be a feasible one. It will conflict with the important consideration of keeping jute competitive with the synthetic substitutes of jute products in the world market. This consideration demands that Bangladesh, the major jute supplier in the world market, should take steps to lower the export prices of jute. One recent study by the F.A.O. indicates the magnitude of such a reduction in the present export prices of jute by between 35 and 50 percent by 1975.[29] There may be disagreements about this magnitude, but the fact of a substantial reduction in the jute prices in the next decade is inescapable.

So the consideration of a lower jute price further accentuates the need for a vigorous policy which will cause a substantial improvement in productivity in jute production. This is possible through a technological revolution in the jute production comparable to the one in rice production. The biological innovations in rice varieties were possible through international efforts of scientists. Unlike rice, jute cultivation is mainly limited to a few countries, Bangladesh being the largest one. So international efforts are not likely to come forward in substantial extent to evolve new high yielding varieties of jute. Bangladesh will, therefore, have to concentrate on its own scientists. This will imply special attentions to the research institutions for jute in the country.

b. The second policy implication is related to the factors which will be involved in the process of adjustment from a traditional farming system to an improved one under irrigated conditions. The Boro rice crop in tubewell areas will be a new rice crop in the winter season. Similarly, some other new crops may be introduced in the winter season with the avilability of controlled water supply. Farmers

[29] F.A.O., Impact of Synthetics on Jute and Allied Fibers (Rome, F.A.O., 1969), p. 5.

will have to be taught the techniques of growing these new crops. The Agricultural Extension Service will, therefore, have to be oriented to meet these requirements.

c. Another important factor involved in the process of adjustment is the supply of working capital for farming. Before we proceed further to indicate the implication of this constraint, it will, however, be wise to clarify the distinction between the need for working capital and credit. Working capital, as defined in this analysis, is the total cash demand for purchased inputs and services in the operation of farm business. The requirement of working capital may be met either by external borrowing (credit) or from internal sources of farm business or by both. We can not say anything from the results of the present analysis about the precise magnitude of credit need. However, some indications can be derived from the study. The working capital requirement under the irrigated farming system is estimated to be about 105 percent higher than that under the present system. This is mainly because of new varieties and increased cropping intensity. The proportion of working capital usually met by external borrowing by farmers in Bangladesh is not known. If we assume that the proportion of working capital supplied from external sources (whatever it is) remains the same, the absolute requirement of credit will go up considerably under the irrigated farming, particularly during the initial phase of irrigated cropping.

The results of the model indicate that a working capital of Rs. 400.00 in the Boro season (instead of Rs. 600.00) reduces the cropping intensity by 10 percent (1st run in Appendix XV). The demand for working capital will be higher in the irrigated system of farming, because of a higher proportion of purchased inputs in the cultivation of new rice varieties and intensive cropping. However, the supply of working capital originating in farm business may also go up because of a likely higher marketable surplus from a larger production. The point is that any program for an external supply of farm credit should be preceeded by evaluations of these elements of supply of and demand for working capital. Unfortunately, with conditions as in Bangladesh, it has been very difficult to separate out the demand for working capital for productive purposes from the demand for cash for consumption purposes. Households and production units are inseparable in a subsistence agriculture; thus, external assistances for productive purposes have very often been found to be actually utilized for consumption purposes. This was one of the main reasons why some of the agricultural credits for production purposes in the past were provided to the farmers in the form of physical inputs rather than in cash. The purpose in this section is not to formulate a credit program for the irrigated farming system, but to point out the need for such a program. Another important element which should get consideration in such a credit program is that of a changing seasonal demand for working capital. In the existing system of farming, the demand for working capital is largest in the Aus season. This demand will be largest in the Boro season under the irrigated farming system, particularly, where potato or similar crops will be included in the crop rotation.

CHAPTER V

RETURNS TO INVESTMENT IN IRRIGATION

In conducting an economic analysis of public investment in irrigation programs, the question invariably raised is that of which costs and benefits are relevant to the analysis. The literature on public investment analysis is replete with controversy about the issue.[1] Most of the controversy relates to secondary benefits and costs, particularly external economies and diseconomies arising from the investment in any project or program. The complexities of these indirect influences and externalities become particularly intense when a project analysis is conducted in a partial equilibrium setting, as is attempted in the present study. Full discussion of each of these controversies might legitimate each as an independent research topic. Therefore, it is hoped that the relevance of the benefits and costs assumed in this study will become apparent from the discussion on the categories of benefits and costs presented in the subsequent sections of the chapter.

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[1] A. R. Prest and R. Turvey, "Cost Benefit Analysis: A Survey", The Economic Journal, December, 1965, (See for more references, the bibliography at the end of the article).

One important point, however, has to be clarified at this stage, before we go to the discussions on costs and benefits. In Chapter I indications were given that the provision of controlled water supply for crop production would create favorable conditions for investment in agriculture. A discussion of how this may be expected to occur is necessary before we begin estimation of benefits from the project under study. A controlled water supply for irrigation will have two major influences on the farming system:

a. It will increase cropping intensity and per-acre yields of crops. The latter effects are expected to be caused mainly by the introduction of high-yielding varieties whose use is made possible by irrigation.

b. It will eliminate the risk of crop-damage due to drought. The elimination of this important risk factor will influence the farmers' decisions on investments. When farmers realize that the risk of loss of crops from drought is absent or very small, they will tend to make higher investments in production activities. Application of fertilizer will increase and intercultural operations, and other cultural practices will be performed more intensively. A farmer who can not plow his land effectively because he does not own a strong pair of bullocks will hesitate, under the existing conditions, to borrow money for buying a good pair of bullocks. He is not certain of a good harvest which will enable him to repay at least a part of the loan. Under these conditions creditors are also reluctant to lend money; if they do, they charge a high rate of interest. These situations will be changed to a considerable extent by the provision of irrigation water and concomitant reduction of uncertainty and risk.

In the present study, the effects of the first factor (increase in cropping intensity and yield) will be taken into consideration in estimating the project benefits. Any likely effects of the second factor will not be included in the estimations of benefits and costs unless explicitly mentioned otherwise in specific cases. The main reason for ignoring these effects is the lack of appropriate data. Most of these effects will be of the nature of potential gains in benefits. Therefore, the results of the study will be conservative to the extent that such effects are excluded from consideration.

Input Analysis

Capital Costs.--The capital cost for a tubewell irrigation project is defined to include all costs of installation of the well up to the point where it is ready to deliver water to the field.

The capital cost of a tubewell may be stated as a function of the well design, technique of drilling, type of power sources to operate the well, type of pump, and the quality of materials involved. Well design, in turn, is influenced by the nature of underground water and the environment within which the well will be utilized.

Design.--Under the conditions of Bangladesh, the relationship between capital costs and the variable elements in the well design are shown in the following cost equation:[2]

$$CC = a + b_1D + b_2D_F + b_3H + b_4L + b_5Lg + 75\ h\ (.15Q + .7)$$

where CC = capital costs

D = depth of drilling

D_F = fixtures generally equal to D

L = screen length of a given diameter

H = pump housing length

L_g = length of gravel pack generally equal to L

h = horsepower of engine

Q = discharge of water in cusec (cubic feet per second)

a = constant cost elements

$b_1, \ldots b_5$ = cost per unit of the respective variables

The design parameter to which the costs of the well are most sensitive is the length of the well screen. This is not only because the screen material itself is expensive, but because costs of other items such as drilling, gravel packing, pump and pump housing are directly related to the length of the screen, and because a high proportion of the

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[2]Adapted from the data on capital costs provided by IBRD: IBRD, Tubewell Project--East Pakistan, Washington, June, 1970.

other items in the total cost equation are relatively constant over the probable range of design decisions.[3] As the well screen is such an important element in capital cost, it is necessary to determine the optimum length of the screen as well as the type of material used in its manufacture. Combining the empirical relationships which exist between the physical characteristics of a well, the various elements of capital cost, and the present value of future operating costs, the IBRD derived an equation for the most economical length of well screen as follows:[4]

$$L = \sqrt{\frac{PQ}{129}\,(233.12 + 14.1Q + 0.0275Qtf)}$$

where: L = optimum length of screen in feet

P = a permeability factor

Q = discharge in cusec

t = hours of operation per year

f = discounting factor for future operating costs

Assuming the expected values of various parameters in the equation above under the conditions in Bangladesh as: P = 510, Q = 2.0, t = 1,200 and f = 0.085, the L was found to be 80.6 feet. The Agricultural Development Corporation of Bangladesh, however, apparently did not agree and proposed a screen length of at least 120 feet.[5]

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[3] *Ibid.*, p. 2, annex 5.

[4] *Ibid.*, p. 3, annex 5.

[5] East Pakistan (Now Bangladesh), ADC, *P.C. 1 Form for Tubewell Irrigation Project, Fourth Plan* (Dacca, ADC, 1970), p. 24.

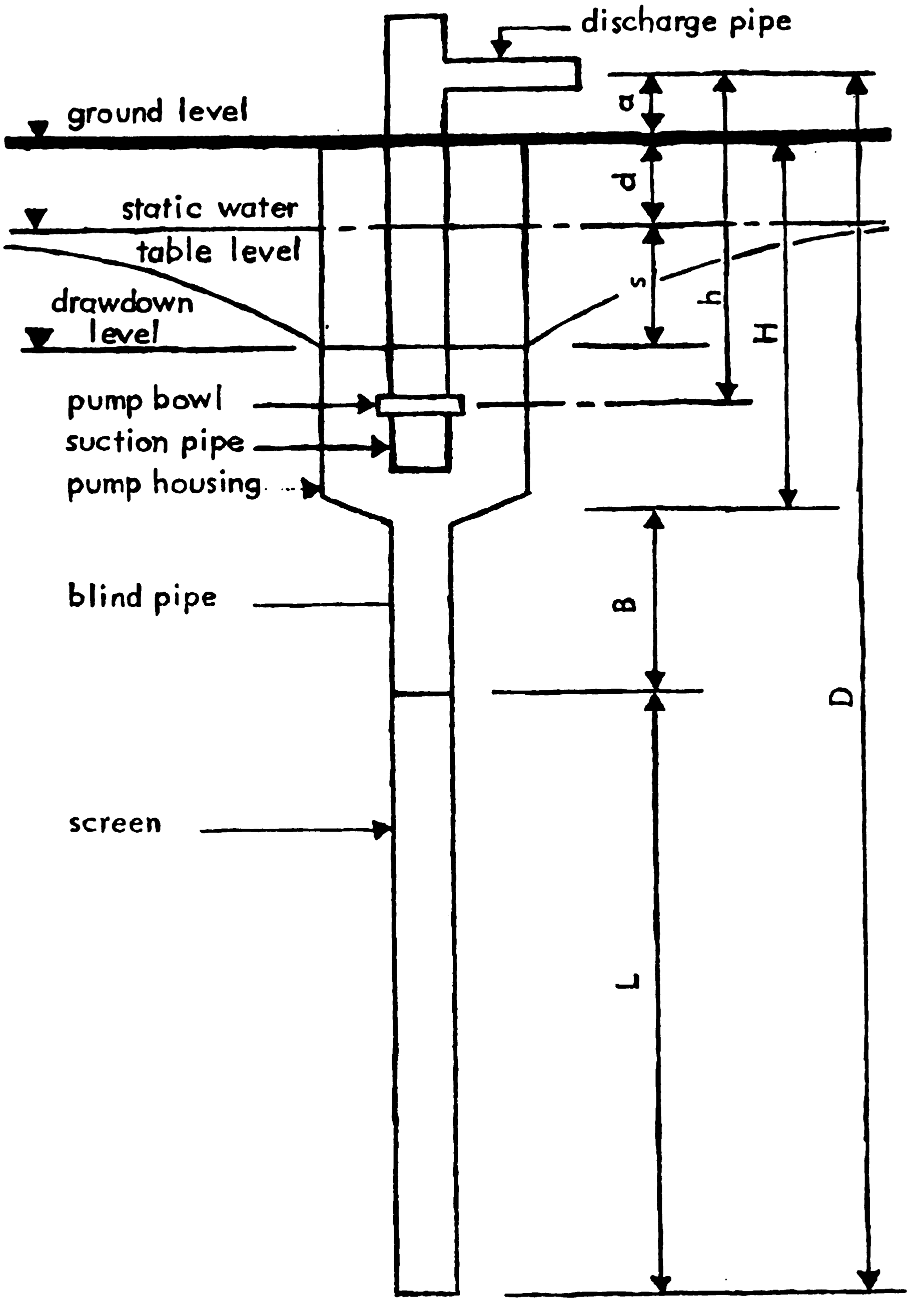

Figure 1. Diagramatic View of a Tubewell Lay out.

The changes in screen length affect both capital costs and operating costs. An increase in capital costs through longer screen length is almost offset by a simultaneous reduction in operating costs so that there is very little change in the present value of total costs (capital cost plus operating costs). However, the coice between two screen lengths does have policy implications. The capital costs are financed by the public sector, but farmers are responsible for the operating costs. Scarce public sector investment resources and a need for forcing farmers to invest increasingly from their own savings would dictate a choice of shorter screen lengths, while a policy of relieving poor farmers from the heavy burden of operating costs would imply a choice of longer screen lengths. As regards the economy as a whole, there is very little difference. For the purposes of the present study, the assumed screen length is 100 feet for wells with turbine pumps and 140 feet for wells with centrifugal pumps. This difference in screen length is required to make them campárable in term of capacity to lift water.

The second factor influencing costs of screening is the type of material used in their manufacturing. There are two types of screening materials, brass and fiberglass, which are being considered in tubewell irrigation programs in Bangladesh. Thomas, however, raises the possibility of polyvinyl chloride (PVC) as a screen material for use in Bangladesh.[6]

The price per foot of fiberglass, brass and PVC screen is Rs. 53.50, Rs. 50.00 and Rs. 34.5 respectively. Brass screen has been extensively used in Bangladesh and it was being locally fabricated from scrap or sheet brass. Fiberglass may long remain as an imported item though its manufacture within the country would not be very difficult. The foreign exchange components of the prices of these three types of screens were estimated to be 80 percent for fiberglass, 70 percent for brass, and only 34 percent for PVC.[7] The lower foreign exchange component in the price of PVC was estimated assuming possible manufacture within the country. Manufacturing PVC within the country would require a petrochemical industry, which was mostly developed in West Pakistan. In the context of changed circumstances, manufacture of PVC in Bangladesh is a remote possibility. Another important consideration is that the PVC screens have neither been used nor tested experimentally within Bangladesh to determine their technical feasibility. For the purpose of the present study, the PVC screen has, therefore, not been included in the analysis.

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[6] John W. Thomas, The Development of Tubewell Irrigation in Bangladesh (Harvard Advisory Service, Harvard University, Cambridge, U.S.A., 1972), p. 36.

[7] *Ibid.*, p. 37.

Drilling Techniques.--Three techniques of well drilling are generally used in the country. Most foreign contractors and the WAPDA use mechanically powered rotary rigs mounted on truck bodies. The capital cost in this method is quite high but it produces more uniform and vertical wells. In Comilla, the Kotwali Thana Cooperative Association (KTCCA) has primarily been using manually operated cable percussion drilling. This technique is relatively simple, but slow, and produces a well of good verticality and uniformity. The KTCCA has also used water jet drilling. This technique involves the least amount of capital cost. Drilling by power rigs produces a well within a week, whereas the water jet drilling technique and the cable percussion method take about three and four weeks, respectively. It has sometimes been questioned whether the water jet drilling produces a well of adequate verticality to mount a turbine pump, but U.S. manufacturers of pumps indicate that verticality is irrelevant to the performance and durability of turbine pumps.[8] It is therefore assumed that the drilling methods do not impose any rigid limits on the type of pump to be utilized.

The technique of well drilling by power rigs was seriously considered by Government when it was considered necessary to install a large number of wells (about 20,000)

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[8] Ibid., p. 25.

within a short period of time (5 years). Moreover, most of these wells were proposed to be financed through various forms of foreign assistance, and the aid donors had a tendency to tie the aid to the installation of wells by contracting firms from their own countries. These foreign firms generally preferred the power drilling method of well installation. In comparing the alternative techniques of well drilling, the time factor must be taken into consideration. If power drilling method saves time, then the contribution of this time is one of the method's positive features. If only one or a few wells are involved, then the differences of two weeks only do not make any meaningful savings of time, for wells installed in one year are not likely to be utilized in the same year. However, if a large number of wells involving a number of irrigation projects are considered, the differences in time taken by different methods of installation may mean meaningful savings of time with a consequent impact on the economy. For example, the program of 20,000 wells may be completed by five years if the power drilling method is used, or it may take seven years if the cable percussion method is used. Use of the first method rather than the second would make a difference of approximately two years' net gain from the use of water in crop production. However, such reasoning would seem invalid in the long run. The power drilling method, involving heavy equipment and highly skilled man power, is rigid and inflexible as far as increasing the short run capacity is concerned. On the other hand, the other two methods are relatively flexible, and rather rapid expansion in capacity is possible. These two methods require light equipment, which is easily and to a large extent, locally available, and four to six months' training can produce the required skilled manpower. Thus, though in the initial period, the power drilling method will enable a larger number of wells to be drilled, in the later years, the total number of wells that can be drilled by the other two methods will very likely exceed that by the power drilling technique. For this reason, for the present study no consideration is taken of the time differences in drilling of wells associated with various techniques.

Type of Pumps.--Two types of pumps are generally considered for use in Bangladesh, the centrifugal pump and the turbine pump. Centrifugal pumps are being extensively used at the present in the country and limited production of the pumps within the country has also been undertaken. The major disadvantage of the centrifugal pump is that if the well draw-down increases with the drop in water level to below about 18 feet, it begins to lose efficiency, and it stops pumping entirely below about 25 to 27 feet. On the other hand, the turbine pump is submerged in the well and the higher draw-downs do not affect its efficiency. However, the declining efficiency of the centrifugal pump with the increasing draw-downs can be offset by providing longer well depth and screen. In making comparisons between the two types of pumps, a well depth of 220 feet with 140 feet of screen has been assumed for the centrifugal pump, and a well depth of 200 feet with 100 feet of screen for turbine pump. Submerging the turbine pump within the well requires an expanded top called a pump housing, which is not necessary with a centrifugal pump.

Engine.--Two sources of energy can generally be used for operating the pumps to lift water. One is the diesel engine which uses diesel oil as the source of energy; the second type is the electric engine ? using electricity as the source of energy. Further, there are two types of diesel engines, high speed diesel engines and low speed diesel engines. So far the high speed diesel engine has been used most extensively in tubewell irrigation projects. Why? Some electric engines were installed in Comilla and Thakurgaon. In Thakurgaon project Rs. 110,000.00 per well was required for providing electricity generation and transmission installations. In Comilla, electric connections were provided to only a few wells from the nearby transmission lines at a relatively lower cost. The main argument in favor of electrically run wells is that the operating costs of such wells are quite low how much? However, such estimates of operating costs are based on subsidized rates for electricity (about Rs.

0.06 per KWH).[9] Most of the tubewell sites in Bangladesh will be in remote rural areas which would require enormous costs for installation of transmission lines if electricity were to be used as a source of energy for tubewells. Only in areas where the tubewells are very near the transmission lines and surplus capacity in power generation is available, would electrically run tubewells be an economic proposition. Locations where the above conditions hold being few and far between, the possible alternative use of electricity as an energy source for operation of tubewells is not considered in the present analysis.

In case of diesel engines, low speed and high speed diesel engines provide a choice between the two alternatives. High speed diesel engines have been in use in Bangladesh quite extensively, as the entire fleet of low-lift pumps in the country is run by high speed diesel engines. The low speed diesel engines have not yet been tried. High speed diesel engines are complicated but relatively reliable. Due to the complex nature of the engines careful maintenance is required to insure reliability. Low speed diesel engines, on the other hand, are relatively simple and have higher degree of tolerance for rough handling. They can be run by kerosene oil, a common energy source widely used in Bangladesh.

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[9] A. Ghafur, "Economics of Irrigation in East Pakistan: A Case Study", Pakistan Institute of Development Economics, Research Report No. 23, Karachi, 1964, p. 12.

The main reason for considering the low speed diesel engine in the present analysis is that they provide a possibility of large scale production, at a relatively cheaper cost, within the country. Experience with this type of engine in Pakistan held out much hope for domestic production. Bangladesh is a land of rivers, and river transport is a major means of communication. For greater speed, the rivercrafts in the country require mechanization. The low speed diesel engines, having simpler mechanism and requiring common kerosine oil as fuel, are considered most suitable for the rivercraft, and are commensurate with the skills of the common people. The combined demand for such engines for river transport and agriculture will provide a solid base for their large scale production in the country. Moreover, the simpler nature of the engines permits their manufacture by small scale rural industries, as has been done in Pakistan.[10]

Discharge Capacity of a Well.--For the present study, wells of two cusec rated capacity are considered for analysis. However, from the equation for optimum screen length presented earlier, it appears that increased capacity means better economy in terms of cost per cusec or acre-foot. But a higher discharge rate does not necessarily mean a larger acreage under irrigation. The organizational constraints

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[10] Edwin H. Smith, Jr., The Diesel Engine Industry of Daska, Sialkot District, Reprint Paper No. 20, Planning and Development Department, Lahore, Pakistan, 1969.

and the deltaic topography of the region generally do not allow proper utilization of water if discharge capacity exceeds two cusec. This has been found true in both the WAPDA's irrigation areas and the low-lift pump project of the ADC. Considering these difficulties all the proposed tubewell irrigation projects in Bangladesh have been formulated on the basis of wells of two cusec rated capacity.[11] For this reason, the analysis in the present study will proceed with the assumption of a two cusec rated capacity of a tubewell.

So far in the foregoing sections of this chapter discussion has centered around finding possible technical alternatives in the installation of tubewells in Bangladesh. In summary, we have:

1. Two types of tubewell screens--brass and fiberglass screens. Let them be represented by S_1 and S_2, respectively.
2. Three techniques of drilling

   T_1 = water jet method

   T_2 = cable percussion method

   T_3 = power drilling
3. Two types of pumps

   P_1 = centrifugal pump

   P_2 = turbine pump

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[11] East Pakistan, Tubewell Irrigation Project, op. cit., p. 27.

4. Two types of engines

D_1 = low speed diesel engines

D_2 = high speed diesel engines

All these alternatives form (2x3x2x2 = 24) twenty-four combinations, each of which is possible and technically feasible. The respective capital cost estimates of these combinations are shown, item by item, in the Appendix XVIII.

In Appendix XIX, the same cost estimates are shown with foreign exchange component being valued at \$1.00 = Rs. 9.5 instead of the previous official rate of \$1.00 = Rs. 4.75. This shadow price of currency is very close to the present exchange rate of Bangladesh currency (which is about \$1.00 = Rs. 8.00).

The estimates of capital costs have been arrived at based on data from three main sources: (1) the fourth plan tubewell irrigation projects, (2) the IBRD report on tubewell irrigation in Bangladesh, and (3) the study by John W. Thomas on alternatives available in tubewell irrigations in Bangladesh. Thomas's estimates of capital costs suffer from underestimation due to the omission of some important cost items. He does not include the overhead and supervision costs and the costs of the main distribution channels. He also does not consider the supporting services in agricultural extension necessary to realize higher levels of crop yields. Costs of agricultural extension services are difficult to divide between crops in irrigated and non-irrigated areas. But the costs of supporting services specifically meant for irrigation areas, such as are proposed in the fourth plan irrigation projects, are included in the present analysis. Without their inclusion, the higher levels of yields could not be properly justified. The cost estimates made by the IBRD and in the project proposals of the ADC are smaller, although the project proposal of ADC includes the taxes on imported goods in its estimates of costs of materials and the IBRD report shows the taxes separately. In the present analysis, the taxes, being in the nature of transfer payment, have been excluded.

Operating and Maintenance Costs.--Operation and maintenance costs for tubewells in the fourth plan projects of ADC have been shown as Rs. 4,350.00 per well. However, this estimate includes only the costs of personnel, overhead, and oil-fuel, and does not include the costs of workshop facilities established through a separate project. Apportioning the total annual depreciation of workshop facilities among the total number of tubewells in the program, the total operation and maintenance costs per well per annum work out to be Rs. 4,940.00. This compares with the IBRD's estimate of operation and maintenance cost at Rs. 5,438.00 per well per year, assuming an irrigated area of 60 acres. Combining the ADC's estimate and that of the IBRD, the estimate of operation and maintenance costs per tubewell used in the present analysis is shown in Table 3.

Table 3. Estimated operation and maintenance costs per well (for 60 acres), study area, Bangladesh, during project life (about 1968-1988).

Items of Cost	Cost	Cost (at Shadow Prices)
	(Rs.)	(Rs.)
1. Personnel (mechanics, etc.)	1,374.	1,374.
2. Transportation	160.	160.
3. Office and Workshop Space	50.	50.
4. Workshop Maintenance, tools, replacements, etc.	33.	48.
5. ADC's Overhead	45.	45.
6. Operator	660.	660.
7. Oil and Fuel	2,625.	1,785.*
8. Spares	340.	510.
	5,287.	4,632.

Note: *Excludes Taxes
Foreign exchange valued at Rs. 9.50 = $1.00

The operation and maintenance cost will vary with the variation of areas irrigated. This variation of operation cost will mainly result from the variation in the cost of oil and fuel, larger areas requiring longer hours of operation of the engine and hence more oil and fuel consumption. This fact has been considered in the annual phasing of costs. The oil and fuel cost to the farmers is about

2.38 rupees per imperial gallon. This can be broken down into: (1) direct foreign exchange, equivalent to Rs. 0.70 (Rs. 4.75 = $1.00), (2) taxes--Rs. 1.38, (3) marketing margin--Rs. 0.05, and (4) freight--Rs. 0.25. Excluding taxes and valuing foreign exchange component at Rs. 9.50 = $1.00, the economic cost works out to be Rs. 1.70 per gallon, which has been used to calculate the oil-fuel cost shown in Table 3.

Project Life and Replacement Cost.--The life of a tubewell is assumed to be 20 years, excluding the engine and the pump, which are assumed to have a life of 5 years and 10 years, respectively. This is the assumption which the IBRD considered realistic in its report on tubewell irrigation in Bangladesh. So the replacement of the engine and the pump is provided at every fifth and tenth year. The life of any engine is dependent on the rate of utilization. If the hours worked per day is increased, the life will be shortened. The assumptions of engine and pump life as mentioned above imply normal usage as required for covering about 60 acres of crops. The assumptions of engine and pump life are considered conservative. The ADC's estimate of life of engine is about 8 years, but this is based on the relatively lower rate of utilization which held true in the past. In the future the rate of utilization of engines and pumps may increase so as to irrigate about 60 acres of cropped area per pump. With this consideration in mind, lower life expectancies of engines and pumps have been assumed in the present analysis. The salvage value of the well at the end of 20 years is assumed zero. In the second phase of the analysis, different life expectancies of engines and pumps, consistent with different rates of utilization, have been assumed.

Cost of Production of Crops.--The concept of cost that is relevant for economic analysis differs from that which is relevant for private profitability analysis. The cost of production of crops, mentioned in Chapter IV, was not netted out of transfer payments, such as subsidies, taxes, etc. For the analysis in the present chapter, however, the elements of transfer payments are excluded from costs.

The present prices of fertilizers paid by the farmers are heavily subsidized. It is estimated that the extent of subsidies in the prices of fertilizers in Bangladesh is 50 percent.[12] As such, the full costs of fertilizers have been estimated by doubling the farm level prices. The foreign exchange component has been valued at $1.00 = Rs. 9.50. Similarly, the cost on plant protection has been revalued at full cost allowing for subsidies and foreign exchange costs.

The opportunity cost of land and management is taken care of automatically in the model. In the model, net benefit attributable to irrigation is defined as the net benefit

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[12]East Pakiston (Bangladesh), Planning Department, Economic Survey, 1968 (Dacca, Planning Department, 1969).

with irrigation minus the net benefit without irrigation. Net benefit without irrigation mostly represents the opportunity cost of land and management. The cost of construction of main distribution channels has been included in the capital cost. However, there are other costs for secondary and tertiary distribution channels which have been included in the cost of production of crops. This cost is assumed to be Rs. 20.00 per acre.

The most important item of cost in the crop production in Bangladesh is labor. Remaining consistent with the concept of opportunity cost in economic analysis, the cost of labor in the production of crops would be grossly overestimated if the market wage rate were to be used in calculating the economic cost of production of crops. It is necessary to derive an appropriate value of the opportunity cost of agricultural labor in Bangladesh. The opportunity cost of the marginal units of labor may be defined as the value of output foregone by using the units of labor in agriculture instead of their use in the next best alternative. In developing economies the alternative productive avenues for labor, particularly agricultural labor, are considered virtually absent, so that the opportunity cost of such labor is considered zero. This argument led to the equivalent hypothesis that marginal product of labor in agriculture in the developing populous countries is zero. Following the logical implication of this hypothesis, some economists came out with theories of initiating and accelerating economic development utilizing rural surplus labor, a costless development process.[13] Too much emphasis on the hypothesis of zero marginal product of labor and its development implications has, perhaps, detracted attention of economists from other important aspects. A zero marginal product of labor is not necessary for economic development. By improving technology of production and production organizations in agriculture, it may be possible not only to release labor from agriculture for development of non-agricultural sectors, but it may also simultaneously increase productivity in agriculture. However, the hypothesis of zero marginal product of labor has been seriously contested and the controversy is considered to be more of a definitional nature rather than of any real content. It is generally agreed that the marginal product of labor in agriculture in such countries is positive but very small.[14] Bangladesh is a country with a very high population density and has primarily an agricultural economy. Robinson in a recent study with the aggregate data of Bangladesh for the period 1951-1961 concluded that the marginal product of labor in agriculture was, in

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[13]Ragner Nurski, Problems of Capital Formation in Underdeveloped Nations (New York, Oxford University Press, 1953).

[14]Charles H. C. Kao, Kurt R. Anschel and Carl K. Eicher, Disguised Unemployment in Agriculture: A Survey in Agriculture in Economic Development by Eicher and Witt (New York, McGraw Hill, 1964).

fact, negative in 1961.[15] Falcon and Gostch with the data of 1960 to 1965 concluded that the contribution of incremental output in agriculture during the period was substantial.[16] This will imply a positive marginal product of labor. The issue, so far as Bangladesh is concerned, appears to be unsettled. But there is little doubt about a very small marginal product of labor in agriculture. Labor with a near zero marginal productivity remains in agriculture only because of an absence of alternative opportunity. This being the case, for the purposes of an economic analysis such as the present one, the labor cost in production of crops should be valued not at the going wage rate, which is institutionally rigid, but at a much lower wage rate reflecting the economic cost. What this lower economic cost of labor should be is still uncertain.

It is difficult to derive an accurate measure for the opportunity cost of labor. Theoretical expositions, however, often help clarify concepts which may be involved in the process of such measurement. A theoretical framework is, therefore, presented here. An elaboration of the framework for general analytical applications will be found

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[15]W. C. Robinson, "Disguised Unemployment Once Again: East Pakistan 1951-1961", American Journal of Agricultural Economics, Vol. 51, No. 3, 1969.

[16]P. Walter Falcon and Carl H. Gostch, An Analysis of East Pakistan Agriculture During the Second and Third Plan Periods (Cambridge, Harvard Advisory Service, 1965).

elsewhere.[17] In the diagram 2, the MVP represents the marginal value product curve for labor. The acquisition price ($P_{acq.}$) of labor service is defined as the cost of attracting a laborer into the business. The salvage price ($P_{sal.}$) is defined as the net earnings that can be received by releasing a unit of labor services from business. We are dealing with the acquisition and disposal of units of labor identical to those at hand at a given point in time. The acquisition price as defined here is equivalent to the market wage rate. The market wage rate is determined by the supply of and the demand for hired labor. It represents the cost at which another unit of labor service can be added to the business. In the context of the less developed countries where a large pool of landless agricultural labor exists, such a wage rate is generally very low. The $P_{acq.}$, however, can not fall below the subsistence level. Because a low wage rate below the subsistence requirement will not cover the maintenance cost of labor. The $P_{sal.}$ is the opportunity cost of labor. It reflects the off-farm employment opportunities. But the $P_{sal.}$ is what a laborer estimates he will earn in net if he leaves farming for an off-farm employment. The estimation of $P_{sal.}$ will proceed by deducting all transport and contracting costs for an off-farm job from the

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[17] Glenn L. Johnson and L. C. Quance, (ed.), Over Production Trap in U.S. Agriculture (East Lansing, Michigan State University, U.S.A., 1968).

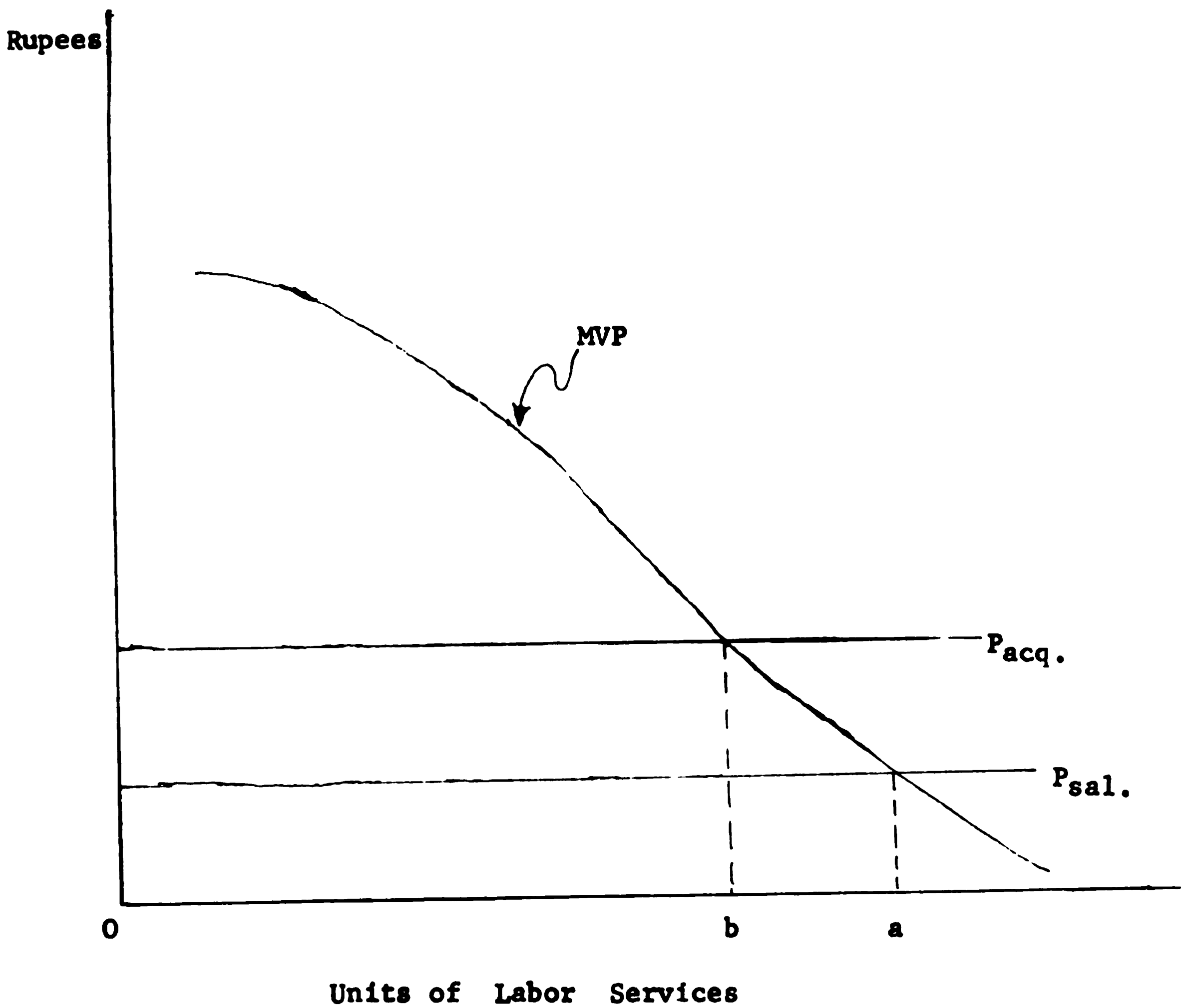

Figure 2. A Conceptual Framework forDetermination of the Opportunity Cost of Labor

estimated off-farm wage rate. In less developed countries the opportunities for off-farm employment are not only scarce but also uncertain. If a laborer considers that the probability of getting a job in the urban areas (with a wage rate say Rs. 4 per manday) is only 50 percent, he will make the estimate of a certain urban wage at Rs. 2. (Rs. 2*0.5). From this he will deduct all transportation and contracting costs (say Rs. 0.5) for comparison with his income on the farm. This potential off-farm net earnings of Rs. 1.5 (Rs. 2.0-0.5) per manday will then be the estimate of $P_{sal.}$. The $P_{sal.}$ of agricultural labor in less developed countries will be very low. The findings of some studies that the MVP of labor in agriculture in these countries is zero or negative imply that the $P_{sal.}$ is also zero or negative in such countries. In diagram 2, the level of farm workers engaged in the farm will be up to 'oa' units where $MVP=P_{sal.}$[1]

The average industrial and agricultural wage rates for unskilled labor in Bangladesh were almost the same during 1965-66 and 1966-67.[18] This wage rate in 1967 was about Rs. 3.0 per manday. The average wage rate for skilled industrial workers was Rs. 4.40 per manday in 1967. If we assume that the difference between the wage rates of skilled and unskilled workers will be equal to the training cost that

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[18]East Pakistan (Bangladesh), Bureau of Statistics, Quarterly Economic Indicators (Dacca, Bureau of Statistics, 1968), p. 15.

has to be incurred by a skilled worker, both these rates can be used for determining the $P_{sal.}$ of farm workers. For calculation of $P_{sal.}$ for farm workers, the wage rate of identical labor in industry will be the starting point. The next step will be determination of the farm workers' expectation, or the probability of getting an industrial job, and an estimate of transport and other migration costs. Given other conditions, the probability of getting an industrial job will mainly be a function of the rate of job expansion in industry and of the rate of increase in the labor force. The transport and migration costs will depend on the general transportation and housing system in the country, and the cost of living in the industrial areas. If socio-economic studies could make estimates of the probability of finding industrial employment and the migration costs, the calculation of $P_{sal.}$ of agricultural workers would be facilitated. Taking an estimate of the probability as 0.4 and an estimate of the migration cost apportioned to a manday as Rs. 0.50, the $P_{sal.}$ is Rs. 0.70 (3.0*0.4-0.5=0.7). This is only 23.3 percent of the wage rate ($P_{acq.}$).

For the purpose of the analysis in the first phase of the present study the opportunity cost of unskilled agricultural labor is assumed to be 25 percent of the market wage rate. In the second phase of the analysis, this assumption is relaxed and the variations of the results obtained in in the first phase are worked out with opportunity costs of labor assuming at the levels of 10 percent, 50 percent, and 100 percent of the market wage rates.

Cost of Agricultural Research.--Calculation of monetary rate of return from investment in irrigation involves identification of not only direct costs of irrigation, but also indirect costs which exert influences on benefits from irrigation. For example, one of the most important contributory factors to returns from irrigation is the new high-yielding varieties of rice. These improved varieties are not costless. But there are complex difficulties in identifying the items and amounts of any research cost to any particular project. The new varieties of rice have been evolved not through efforts of a single country. International efforts and investment have resulted in the evolution of the varieties. It is virtually impossible to establish an objective linkage between the contribution of Bangladesh to these efforts and the benefit it has been getting from the results. However, some research costs are relatively easier to identify and link to the benefits. The costs of adaptive research for introducing these new varieties can, perhaps, be related to the benefits the country has been deriving and will derive in the future from such research. But here again, the question of apportioning these costs to various present and future projects is a complex problem.

The assumed yield rates of crops in the present study are based on the already established findings of research. No new research is considered necessary for realization of these yield rates, although new research may further improve productivity in agriculture.

For these reasons, no costs on agricultural research have been included in the cost estimates in the present study.

Output Analysis

The only output considered in the analysis is the money value of production of crops which would be made possible by the provision of irrigation. Given the cropping pattern, as outlined in Chapter IV, the output will depend on the water utilization in the project area, the yield rates of crops, and the relative prices of the crops grown.

Water Utilization.--Water is an important and costly input. Its proper utilization is, therefore, an important aspect which will influence the benefits and costs of an irrigation project. If the yield response of crops, say rice, to various levels of water application can be obtained from experimental results, the optimum level of water application can be worked out as in the Figure 3. In this figure, the TVP (total value product) curve is obtained by multiplying the yields by constant price of rice at various levels

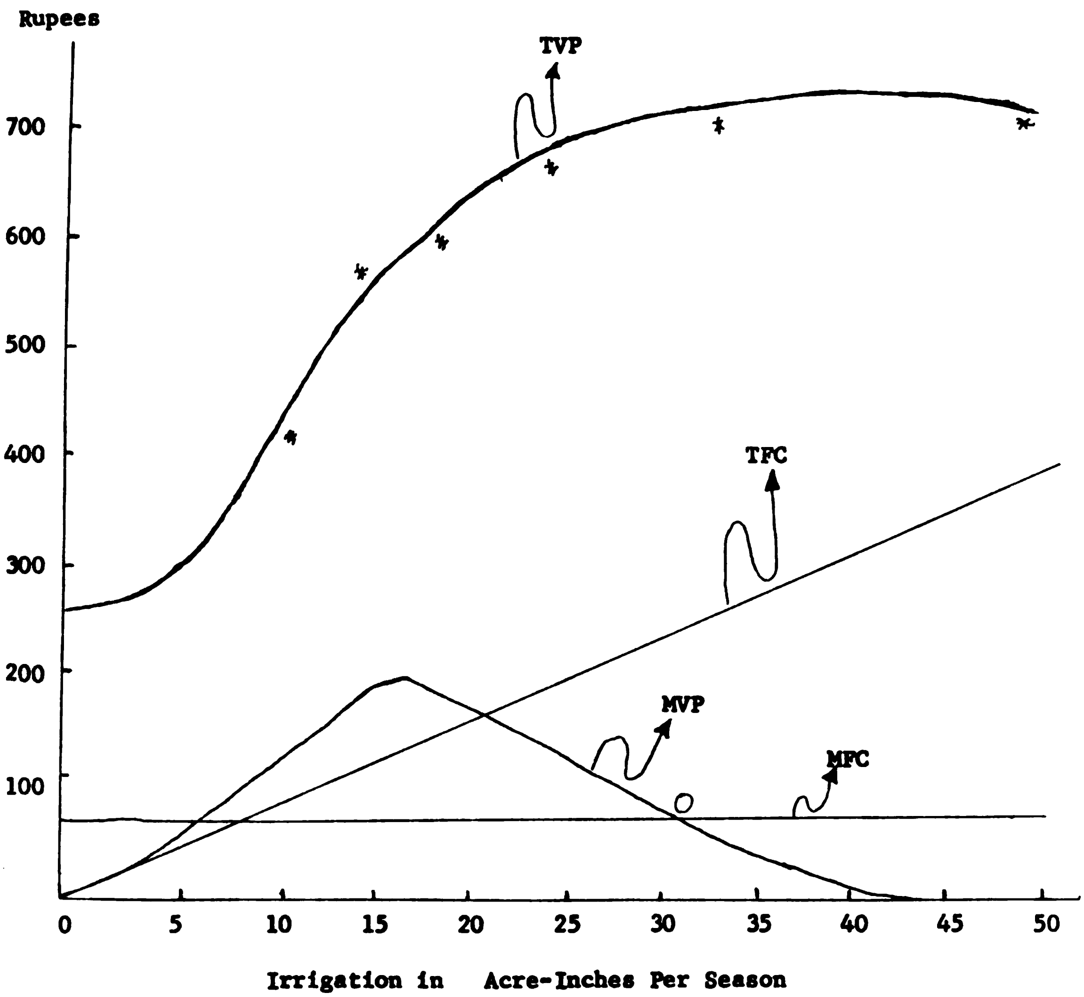


Figure 3. Theoretical Framework for Determination of Optimum Water Use

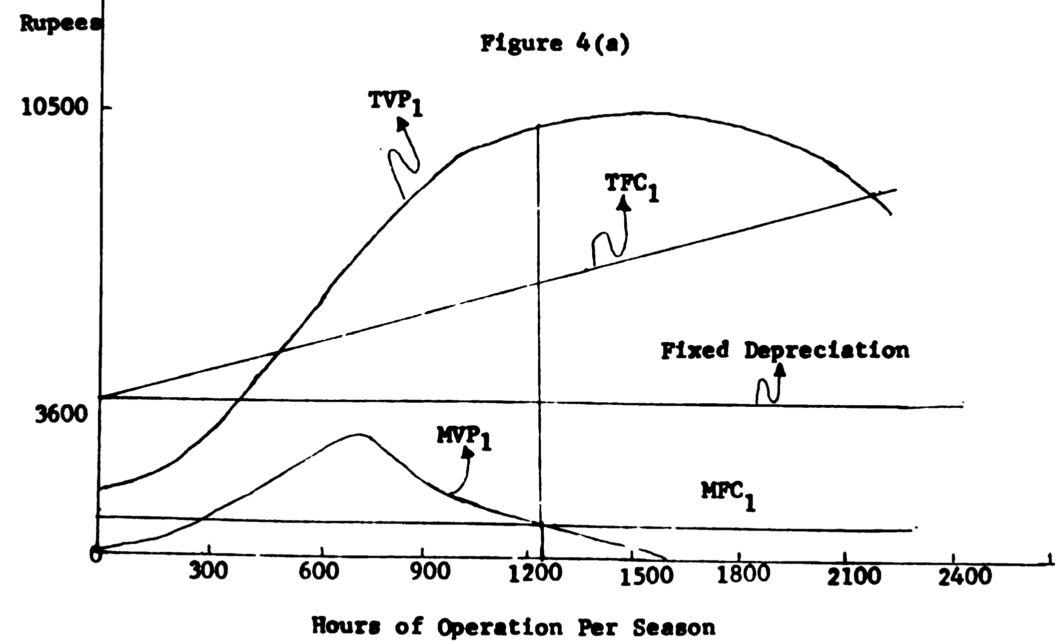
of water application (variable product price may also be assumed). This TVP curve is hypothetical, but a few points around the curve have been plotted. These observations represent the experimental yields of Boro rice in the Hathazari Government farm, Chittagong, at various levels of irrigation application.[19] If a large number of such observations can be obtained, a smooth curve like the TVP curve in the figure can be fitted. The total factor cost (TFC) curve is drawn assuming only the oil and fuel cost of a tube-well varying at a constant rate of Rs. 20.00 per 5 acre-inches of water. The corresponding marginal curves are the MVP and MFC curves and their intersection at 0, i.e., for 30 acre-inches of irrigation would be the optimum level of water application for the illustrated Boro rice crop. Although the example is mostly for illustration of the economic principle relevant to such analysis, it has important implications. At present, rice crop is irrigated at a "flooding" level, i.e., 50 to 60 acre-inches of irrigation water is applied. The marginal product of the incremental application of water beyond 35 to 45 acre inches is very small. The fact that excessive water does not have any negative effect on rice, i.e., the total product curve never starts falling, is one of the reasons why the issue has not previously been given serious attention. Economically this is a waste of

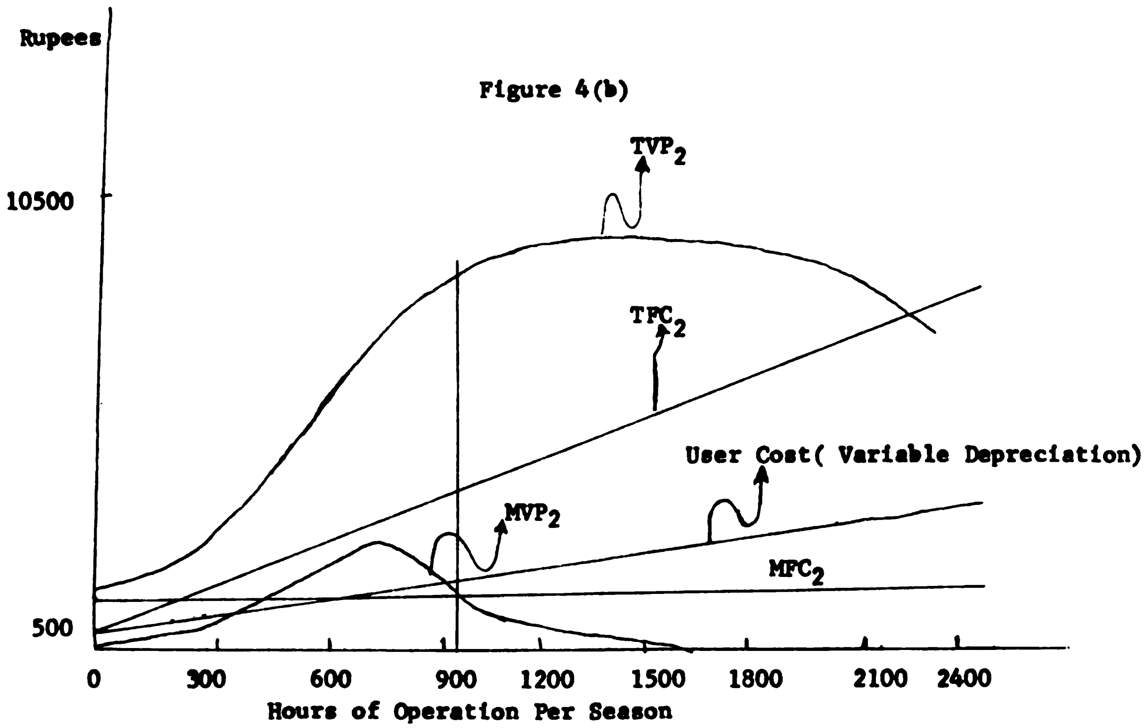
[19]Mohammad Ghulam, Development of Irrigated Agriculture in East Pakistan, op. cit., p. 375.

resources. With the same total hours of operation of the engines, more acreage could be covered if the per acre application of water was reduced to the optimum level. When the optimum level of water application to a crop has been determined, the question becomes one of how much area a well should cover. The area covered will directly vary with the hours of work by a pump; a larger area will imply more hours of daily operation of the engine. More hours of use of the equipment will imply increased wear. In the traditional analysis, the life of a durable asset is usually considered fixed. Technically, this may be so, but from an economic point of view, the life of a durable asset, e.g., the tube-well equipment, is an economic variable determined endogeneously by the rate of utilization and exgeneously by the acquisition price of such assets (not historical price).[20] A simplified illustration of the optimum utilization of an irrigation well (and thereby the optimum area to be irrigated), following each of the two approaches, is shown in the Figure 4. For the sake of simplicity, both input and output prices are assumed constant. Figure 4(a) represents the theoretical framework in traditional analysis, and Figure 4(b) represents the theoretical framework incorporating the user cost concept in the analysis. User cost is

[20] Francis S. Idachaba, "Rate of Use, Investment and Disinvestment", Michigan State University, U.S.A., 1971.

Figure 4. Theoretical Framework for Determination of Optimum Utilization of a Tubewell





defined as the cost due to wear of the durable asset varying with the rate of utilization. It is assumed that a tubewell engine and pump have technical life (in traditional sense) of 18,000 working hours or 10 years. In Figure 4(a), the Total Factor Cost curve is drawn, using a constant depreciation cost of Rs. 3,600.00 per annum, plus the yearly variable costs for operating the engine. In Figure 4(b), the depreciation costs are assumed to vary with the hours of work. Assuming the purchase price of the engine at Rs. 36,000.00, hourly depreciation is Rs. 2.00 per hour. On this basis, the depreciation will be Rs. 600.00 per year if the rate of operation is only 300 hours per year (we ignore interest cost for simplicity, but it will make no difference in the analysis). If the rate of operation is 600 hours per year the depreciation cost will be Rs. 1200.00, and so one. To these variable depreciations, the corresponding variable cost is then added to derive the TFC_2. The total value product curves are the same in both the figures. They are obtained by taking the product of acreage, constant yield rates, and the constant product price. Cost of production of crops other than water costs may be deducted from total value products without changing the relations. The total irrigated acreage for various 'hours of operation' of the engine can be found by dividing the total discharge of water during the total 'hours of operation', by the optimum rate of water application to the crop, as was determined in the Figure 3.

The TVP curve would not be linear. When hours of operation are high, engine breakdowns and other troubles have higher probabilities. In the extreme case, if the engine is worked 24 hours for long, this might cause permanent damage to the engine. All these imply that the user cost function will be a rising curve and TVP curve will start falling after some point. The difference in optimum hours of operation of the well per year or per season following the two theoretical frameworks can be seen in the figure. The optimum point is determined by the maximum difference of the TVP and TFC, or equivalently, at the point of intersection of MFC and MVP. Following the traditional theoretical framework, the optimum rate of operation in Figure 4(a) is about 1200 hours per season/year. When the concept of user cost is incorporated in the traditional theory, the optimum rate of operation is about 900 hours per season/year (Figure 4(b)).

For several reasons in the present study, the theoretical framework presented above is used neither to determine the optimum water application to crops nor the optimum rate of utilization of the tubewells. First, necessary data for such analysis are not available. Second, the problems to date in the tubewell program in Bangladesh have been those of apparent underutilization of capacity, mainly because of institutional constraints. The lack of any comprehensive and effective organization for organizing and training farmers in raising irrigated crops, and the small and fragmented nature of farm holdings, have been obstacles to obtaining sufficient area for irrigation by a single tubewell or low-lift pump to use its full capacity. The impact of such institutional impediments is likely to be removed or reduced in the future. Then the real issue of optimum utilization of water and equipment will emerge, perhaps sooner than expected. In the meantime, it is hoped that the concerned authority in the Government will generate the necessary information to conduct an analysis to determine the optimum levels of water and tubewell utilization.

For the purposes of this study, it is assumed that the maximum area a tubewell will cover is 60 acres. This maximum is assumed to be attained gradually, in the first year, 24 acres, the second year, 40 acres, and in the third year and onwards, 60 acres. This assumption of the maximum irrigated area under a tubewell conforms to the proposal for tubewell programs by the Government.[21] The average area irrigated by a tubewell in Comilla is shown in Table 4. The tubewells in Comilla are of smaller capacity, i.e., of 1.3 to 1.5 cusec capacity. The tubewells in the present study are of 2 cusec capacity, so direct comparison is difficult. Moreover, it is not known how many tubewells are new and how many are relatively older in any year in the Table 4.

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[21]IBRD, Report on Tubewell Irrigation in East Pakistan (Bangladesh), op. cit.

Table 4. Average area irrigated by a tubewell, Comilla Area, 1966-69.

Year	Actual Area: Electric Operated	Actual Area: Diesel Operated
	Acres	Acres
1966	61	40
1967	54	48
1968	49	38
1969	63	50

Source: Compiled from BARD data

Older wells will generally cover larger areas than newer ones. In Comilla there are quite a number of wells covering from 70 to 90 acres, while there are others covering as few as 30 to 40 acres. Considering the impact of past experience on future programs, and in view of the improved organizational pattern under the Integrated Rural Development program, the assumption of 60 acres per well at full development appears reasonable. However, the consequences of any probable lower or higher irrigated areas under a tubewell are also calculated in the analysis.

Yield Rates.--The study is concerned with two sets of crops and their yield rates, one set under irrigation, and the other under non-irrigated conditions. Under each set we have crops in three seasons--Aus season, Aman season and Boro season.

In the Aus season, two main crops, Aus and Jute are grown. Without irrigation Aus is mainly broadcast, rather than transplanted. It has been assumed that without irrigation facilities, broadcast Aus (Deshi) and Jute will continue to be grown, and with irrigation, transplanted Aus (IRRI) and Jute will be the two main crops in this season. The yield of broadcast Aus (deshi) paddy is assumed to rise gradually from the present 15 maunds per acre to 18 maunds per acre in absence of irrigation facilities. The yield rates of Aus (deshi) paddy in the Memensingh district during the decade ending 1965 do not show any stable trend. During the first half of the decade, the yields were almost static at about 9.20 maunds of milled rice (equivalent to about 13.3 maunds of paddy). The highest yield was about 17 maunds of paddy per acre obtained in 1960/61. The lowest yield was 12 maunds in 1964/65 and the average for the decade was about 15 maunds of paddy per acre.[22] Without irrigation facilities, the major risk of drought in the high and medium land will persist, and due to this risk factor other inputs like fertilizers will not be of much demand. Thus a maximum yield rate of 18 maunds of paddy per acre seems reasonable. The increase in yield is assumed to be attained gradually reaching the maximum in seven years in a linear fashion. The cost of production is also phased in consonance with the

[22] Bangladesh, Ministry of Agriculture, Agricultural Production Levels, op. cit.

yield rates. The shift in cropping pattern, from present to future, is also assumed to occur gradually over five years.

Trend analyses for all the crops under consideration indicated wide fluctuations in yields. Moreover, the trend line has the inherent disadvantage of having no upper bound. In the absence of such upper bound, the selection of the most likely yield rate in the future depends heavily on subjective judgement. Considering these factors, the procedure adopted was, in the case of the non-irrigated situation, to analyze the per acre yield rates for the last ten years (ending 1965) and to select that of the best year. This best yield was then adjusted slightly upwards, again subjectively, for any future impact of other inputs, such as fertilizers. It is assumed that this is the most probable average yield that can be obtained in the future without irrigation. It may be argued that the future yield rates of crops can be raised substantially without irrigation. This seems to be based on a weak foundation. First, risk of crop damage in drought conditions is more severe with the application of fertilizer than without. Second, the direct risk of losing the investment on fertilizer during drought conditions is quite high compared to the small additional gain of increased yield under non-irrigated conditions. These factors were reflected in the stagnant position of fertilizer sales in the mid-sixties despite special efforts and higher direct and indirect subsidies on fertilizers during the period.[23] Recently, however, there has been an observable increase in the demand for fertilizers, which was limited to areas where the new varieties of rice and irrigations are available.

The present and future crop yield rates and cropping pattern, both under irrigated and non-irrigated conditions, are assumed as shown in Table 5.

The yield rates of the new high yielding rice varieties, jute and some other crops under irrigated conditions have been discussed in Chapter IV. The mustard crop is not likely to be grown under irrigated conditions. Mustard is generally grown after the Aman harvest or on the partly fallow land after the Aman season. The native varieties of mustard in Bangladesh are not responsive to water and fertilizer application, and as such, this crop is not grown with any application of water and fertilizers. Its yield level is also static. In the present study no consideration is given to any possible new varieties of mustard.

To test the consequences of any divergence from the assumed yield rates, the present study will include results with alternative low and high yield rates.

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[23] R. M. Isler, Demand for Fertilizers in East Pakistan (Dacca, USAID, 1968, occasional paper).

Table 5. Present and future crop yields and cropping pattern, study area Bangladesh. (about 1968-1988).

Crops	Yields Per Acre			Distribution on a 3-Acre Area		
	Present	Without Irrigation	With Irrigation	Present	Without irrigation	With irrigation
		(maunds)			(acres)	
Aus Season:						
a) B. Aus (Deshi)	15	18	--	2.00	2.10	--
b) T. Aus (IRRI)	--	--	40	--	--	1.60
c) Jute	15	19	25	0.50	0.60	0.90
Aman Season:						
a) Aman (Deshi)	16	19	--	2.00	2.00	--
b) Aman (IRRI)	--	--	40	--	--	2.20
Boro Season:						
a) Boro (IRRI)	--	--	45	--	--	1.80
b) Potato	55	65	90	--	--	0.50
c) Mustard	5	5	--	0.30	0.40	--
TOTAL				4.80	5.1	7.00

Relative Prices.--In estimating the monetary benefit from an agricultural project like the one under the present study the question of valuation of outputs and inputs presents a challenging task. The questions generally raised are: Does the product price really reflect the ultimate consumers' preference? Do the economy's resource allocations reflect such preferences? What price should be used, farm gate price, wholesale price or retail price? How shall one predict the future prices which are more relevant for the project analysis? In addition the valuation of any non-market benefits arising out of the project may pose additional problems.

The first question is a knotty one. It originates from the theory that in a market economy and under perfect competition, resources are optimally allocated, i.e., variour resources are allocated to productive activities in accordance with the preferences of the consumers. In real world where we have imperfect competition, the valuation of any project's outputs should be based on, not the market price, but the price that would have prevailed in the absence of such imperfections. The logical consequences of this sort of argument led to the formulation of shadow prices of output which are, in fact, the market prices, adjusted for the influences of imperfections in the market. The problem in using shadow prices of output is more one of practice than of theory. It is hardly possible to work out an accurate and realistic shadow price without some subjective judgment. The problem becomes more acute when, as for the economic analysis of investment, we have to deal with future prices rather than present prices. Gittinger concludes, "Some sort of market price is probably the best approximation of the 'true' value of the goods and services in an agricultural project".[24]

When the project output is a product having a large world market, the international price of the product provides an approximate real value of the output. The rationale for this is that international trade provides for alternatives for satisfying domestic demand, and adjusting domestic supply. In the resource allocation decisions relating to such goods and services, the world price is the relevant price.

Rice and jute are the two main products considered in the present study; both the commodities have large world markets which are relatively free from trade barriers and restriction. The degree of competition in these markets is quite high. The valuations of these products have been based on future projections of world market prices for these two crops.

Since the closing years of the last decade, world rice production has been increasing significantly, mainly due to the new high yielding varieties and associated

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[24]Price J. Gittinger, Economic Analysis of Agricultural Projects (Washington, IBRD, May, 1971), p. 20.

technology. Many countries which were traditionally net importers of rice, have become self-sufficient, or even exporters. For example, a huge surplus stock of rice has been accumulated in Japan, a rice producing developed country which was traditionally a net importer.[25] According to a study by FAO there will be a net surplus of rice supply in the world market of about 2.6 million tons in 1980, at 1970 constant prices.[26] This is about 44 percent of the expected total world consumption. The world rice price has been declining sharply in consonance with the increasing production since 1969. The projected surplus in supply by 1980 implies a further declining trend in the world rice price in the coming decades. The average FOB price for Burmese rice (paddy) during the next decade is projected to decline to about 2.3 U.S. dollars per maund of paddy.[27] Valuing $1.00 equal to Rs. 9.50, the price is Rs. 22.00 per maund.

In personal discussion with the economists at the World Bank, however, it appeared that world prices of rice may even drop further than projected earlier. In the first phase of the present study, rice (paddy) has been valued at Rs. 19.00 per maund; changes in the results using other price

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[25] F.A.O., Agricultural Commodity Projections 1970-1980 (Rome, F.A.O., 1971), p. 107.

[26] *Ibid*., p. 110.

[27] IBRD, World Bank Report on Tubewell Irrigation in East Pakistan, *op. cit*., p. 2, Annex., 13.

assumptions are shown in the second phase. Average retail prices of milled medium quality rice in the country varied from Rs. 28.84 in 1960-61 to about Rs. 43.63 per maund in 1966-67.[28] There is considerable seasonal fluctuation in rice prices, however; prices at harvest season are about 5--7 rupees lower than those in the slack season. Thus, this average price is not really comparable to the one we are using for product valuation of rice in the present study. First, there will be differences between prices of paddy and milled rice in at least the amount of the milling cost. Second, retail prices include the marketing margin as well as storage costs in the marketing channel; these have not been included in the project costs. The relevant price, then, is the farm gate price devoid of marketing margins. The internal procurement price of rice paid by the government may be used as a better approximation of the farm gate paddy price. This is because the procurement prices relate to the harvest season and are in terms of paddy. The procurement price, however, is fixed outside the market mechanism and is considered generally lower than the market price. The compulsory internal procurement price of rice (paddy) was Rs. 19.69 per maund from 1958-59 to 1962-63.[29]

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[28]East Pakistan (Bangladesh), Statistical Digest, op cit., p. 209

[29]Ibid., p. 209.

It was reduced to Rs. 14.00 in 1962-63 when the country had a bumper rice crop. In 1966, the procurement price was again raised to Rs. 22.00 per maund. The average price of paddy in the 1968 harvest season of Boro and Aus crops, as found in the survey by the author, was Rs. 24.52 per maund.

Prices of raw jute vary much with fluctuations of international supply and demand. However, any violent fluctuation is experienced only with serious world crisis. The average grower's prices for raw jute shot up to Rs. 47.25 per maund in 1960-61, from Rs. 19.25 per maund in the previous year. This was due to the very small supply caused by natural calamity, and a stronger demand caused by a prospect of war in Europe. Since 1961-62, the growers' average raw jute prices are steadily increasing; the average was Rs. 23.33 per maund in 1962-63 and went up steadily to Rs. 35.15 per maund in 1966-67.[30] However, these price statistics of raw jute are those reported by the Jute Board, and the prevalent feeling in the past was that the Jute Board was biased (for other than economic reasons) and that their reported prices of raw jute were over reported by about 3 to 5 rupees per maund. The trend of raw jute prices, however, is not concealed by this consistent bias. In 1966 (considered to be a normal year for jute), the FOB Narayanganj average price of raw jute (B-Bottom--the largest grade) was

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[30] *Ibid.*, p. 208.

Rs. 53.50 per maund.[31] In the same year the average price at growers' level was Rs. 30.50 per maund (Jute Board's reported price). The difference of Rs. 23.00 is accounted for by the marketing margin and export duties. The rate of export duty was 10 percent; the share of Government tax was Rs. 4.86 per maund, and that of marketing margin, Rs. 18.14 per maund. For the purpose of project evaluation the relevant price, as in this example, will be the grower's price level of Rs. 30.50 plus Rs. 4.00 for government tax revenue (assuming Rs. 0.86 as cost of tax collection) per maund. As has been discussed in the previous chapter, however, the future world jute prices are expected to fall gradually. Under the pressure of competition, the export duty on raw jute has already been abolished in 1968, without any corresponding effects on farm level prices of raw jute.

For the purpose of the present study, the price of jute is, therefore, assumed to be Rs. 25.00 per maund. However, the sensitivity of the results to changes in jute prices is shown in the second phase of the analysis.

The other two crops, potato and mustard, comprise a small portion of the total crop value. Harvest season prices of these two crops show a static trend (1960-61--1966-67 data).[32] For valuation of these crops, the average prices

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[31] _Ibid._, p. 214.

[32] East Pakistan (Bangladesh), Bureau of Statistics, _Quarterly Economic Indicators_ (Dacca, Eden Buildings, 1967).

existing during 1964-65 to 1966-67 have been used. These prices are Rs. 12.00 per maund for potato and Rs. 40.00 per maund for mustard.

Estimated Relationship of Returns with Design and Installation Alternatives

In the section titled "Cost Analysis', 24 alternatives with various tubewell designs, installation techniques, and quality of materials of tubewell equipment were selected for evaluation. In this section the relative positions of these alternatives in terms of monetary returns are presented and shown in Table 6. The differences in capital costs between the combination numbers 1 and 3, 2 and 4, 7 and 9, 8 and 10, 13 and 15, 14 and 16, 19 and 21, 20 and 22 are less than 0.005 percent in each case. So in the calculation of internal rates of return (IRR), net present value (NPV) and benefit-cost ratio (B-C ratio), the capital costs of the respective pairs were taken as the same, ignoring the very small difference. There being no difference in the assumption of benefits corresponding to each combination, the IRR, NPV and B-C ratio of each of these pairs are the same as will be seen in the table. All the three criteria indicate the same relative positions of the alternatives. With the assumptions outlined earlier, the IRR ranges from the lowest 24.6 percent to the highest 40.1 percent. The highest IRR is obtained with the alternatives $P_1D_1T_1S_1$ and

Table 6. Estimated monetary returns for various design and installation alternatives after irrigation development, study area, Bangladesh.

Alternatives	With No Change in Net Benefits IRR	NPV	B-C	With 6% Reduction in Net Benefits IRR	NPV	B-C	With 12% Reduction in Net Benefits IRR	NPV	B-C
	(Percent)	(Rs.)	(Ratio)	(Percent)	(Rs.)	(Ratio)	(Percent)	(Rs.)	(Ratio)
1. $P_1D_1T_1S_1$	40.1	167275.	2.40	37.6	150087.	2.26	34.9	132898.	2.11
2. $P_1D_1T_1S_2$	38.3	164146.	2.34	35.8	146958.	2.20	33.3	129769.	2.06
3. $P_1D_1T_2S_1$	40.1	167275.	2.40	37.6	150087.	2.26	34.9	132898.	2.11
4. $P_1D_1T_2S_2$	38.3	164146.	2.34	35.8	146958.	2.20	33.3	129769.	2.06
5. $P_1D_1T_3S_1$	30.0	145700.	2.03	28.0	128512.	1.91	25.9	111323.	1.79
6. $P_1D_1T_3S_2$	29.0	142601.	1.99	27.0	125413.	1.87	25.0	108224.	1.75
7. $P_1D_2T_1S_1$	37.0	161875.	2.30	34.6	144687.	2.16	32.1	127498.	2.02
8. $P_1D_2T_1S_2$	35.4	158746.	2.24	33.1	141558.	2.11	30.7	124369.	1.97
9. $P_1D_2T_2S_1$	37.0	161875.	2.30	34.6	144687.	2.16	32.1	127498.	2.02

11.	$P_1D_2T_3S_1$	28.2	140300.	1.96	26.3	123112.	1.84	24.3	105923.	1.72
12.	$P_1D_2T_3S_2$	27.3	137171.	1.92	25.4	119983.	1.80	23.5	102794.	1.69
13.	$P_2D_1T_1S_1$	33.4	154315.	2.17	31.2	137.127.	2.04	28.9	119938.	1.91
14.	$P_2D_1T_1S_2$	32.4	152080.	2.13	30.3	134892.	2.00	28.1	117703.	1.88
15.	$P_2D_1T_2S_1$	33.4	154315.	2.17	31.2	137127.	2.04	28.9	119938.	1.91
16.	$P_2D_1T_2S_2$	32.4	152080.	2.13	30.3	134892.	2.00	28.1	117703.	1.88
17.	$P_2D_1T_3S_1$	26.4	134081.	1.88	24.6	116893.	1.77	22.7	99704.	1.65
18.	$P_2D_1T_3S_2$	25.9	132051.	1.86	24.1	114863.	1.74	22.2	97674.	1.63
19.	$P_2D_2T_1S_1$	31.2	148915.	2.08	29.1	131726.	1.96	27.0	114538.	1.83
20.	$P_2D_2T_1S_2$	30.4	146685.	2.05	28.3	129496.	1.93	26.2	112308.	1.80
21.	$P_2D_2T_2S_1$	31.2	148915.	2.08	29.1	131726.	1.96	27.0	114538.	1.83
22.	$P_2D_2T_2S_2$	30.4	146685.	2.05	28.3	129496.	1.93	26.2	112308.	1.80
23.	$P_2D_2T_3S_1$	25.1	128881.	1.82	23.3	111692.	1.71	21.5	94503.	1.60
24.	$P_2D_2T_3S_2$	24.6	126655.	1.79	22.8	109466.	1.68	21.1	92278.	1.58

Note: NPV based on discount factor = 0.10

$P_1D_1T_2S_1$, i.e., the tubewell with centrifugal pump, low-speed diesel engine, brass screen, and drilled either by the water jet or the cable percussion method. The tubewell with turbine pump, high-speed diesel engine, fiber glass screen, and drilled by power ($P_2D_2T_3S_2$), has the lowest IRR. The reduction in the net benefits[33] does not change the relative positions of the alternatives but it does affect the rate of returns. The IRR of the alternative $P_2D_2T_3S_2$ falls further from 24.6 percent to 22.8 percent and 21.1 percent with the uniform reduction of the net benefits by 6 percent and 12 percent respectively. The fall in IRR is almost, but not quite linear. For the first fall in the net benefit by 6 percent, the IRR is reduced by 1.8; for the second fall in the net benefit by an additional 6 percent the IRR is reduced by 1.7. A fall in the net benefit may be caused either by a rise in the cost of production of crops under irrigated conditions, relative to that under non-irrigated conditions, by a fall in prices of products, or by a fall in the yield rates of crops in irrigated condition, relative to that under non-irrigated condition. A uniform increase in the cost of production of all crops by 10 percent works out to be equivalent to a reduction of the net benefit by about 6 to 7 percent in the first six years and 3 percent in the remaining years.

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[33]Net Benefits = (Gross value of crops with irrigation--Cost of production of crops)-Gross value of crops without irrigation-Cost of production of crops).

The independent effects of each element of the alternatives, i.e., the effects of the mutually exclusive categories of pumps, engines, techniques of drilling and screens are analysed following the procedure outlined below.

To determine the difference in effects of the elements P_1 and P_2 the two types of pumps, centrifugal and turbine--the IRR or NPV of all combinations with P_1 were calculated which may be written as ΣP_1. The average is then calculated as:

$$\bar{P}_1 = \frac{\Sigma P_1}{\eta_{P_1}}$$ where η_{P_1} is the number of combinations with P_1

Similarly, the $\bar{P}_2$ is calculated and the difference between $\bar{P}_1$ and $\bar{P}_2$ indicates the magnitude of economic advantage, in terms of the criteria (IRR or NPV), of P_1 over P_2. All these independent effects of various elements in the combinations are shown in Table 7.

It will appear from Table 7 that the choice among techniques of drilling is the most important element in the alternatives. Where there is no difference between T_1 and T_2 (water jet and cable percussion methods), these two methods have considerable economic superiority over the T_3 (power drilling method). The choice of T_1 or T_2 over T_3 improves the IRR by about 8 percent points and the NPV by about Rs. 21000. The choice of a centrifugal pump (P_1) over a turbine,

Table 7. Estimated independent effects of the elements in the design and installation alternatives in tube-wells, study area, Bangladesh.

Elements	IRR	NPV
	(Percent)	(RS.)
$\bar{P}_1$	34.7	155,821
$\bar{P}_2$	29.7	143,696
$\bar{P}_1-\bar{P}_2$	5.0	12,125
$\bar{T}_1$	34.8	156,755
$\bar{T}_2$	34.8	156,755
$\bar{T}_3$	27.0	135,767
$\bar{T}_1-\bar{T}_2$	0.0	0
$\bar{T}_3-\bar{T}_1$ or $\bar{T}_3-\bar{T}_2$	7.8	20,988
$\bar{D}_1$	33.3	152,505
$\bar{D}_2$	31.1	147,012
$\bar{D}_1-\bar{D}_2$	2.2	5,493
$\bar{S}_1$	32.8	151,144
$\bar{S}_2$	31.6	148,207
$\bar{S}_1-\bar{S}_2$	1.1	2,937

increases the IRR by about 5 percent points and the NPV by about Rs. 12000. The other two choices, i.e., the selection between a low speed diesel engine (D_1) and a high speed diesel (D_2), and that between a brass screen (S_1) and a fiberglass screen (S_2), are relatively less important in terms of the differences they make in the IRR and NPV. The choice of the low speed diesel engine over the high speed diesel engine improves the IRR by only about 2 percent points and the NPV by about Rs. 5500. Similarly the selection of a brass screen instead of a fiberglass screen improves the IRR only by about one percent point and the NPV by about RS. 3000.

Sensitivity of the Returns

In this second phase of the analysis, attempts are directed towards testing the stability of the results obtained in response to any changes in the underlying assumptions. The results presented in the previous section are based on important assumptions about: (1) wage rates of agricultural labor, (2) yield rates of crops, (3) relative prices of outputs, (4) acreage of irrigation from a tubewell (rate of utilization), and (5) the time lag involved in the attainment of the maximum acreage under a tubewell. These are crucial assumptions shrouded with considerable uncertainty. It is therefore essential to test the results to see what happens if the assumed values fluctate either on the high or low sides. Before we proceed with such tests we have to decrease the scope of all possible combinations. We have 24 technical alternatives in the installation of tubewells and five important assumptions listed above. Even if we assume two levels, low and high, of each assumption, we will have a total of 768 combinations. To limit the combinations within manageable numbers without sacrificing important outcomes, the following procedure is adopted.

First, the technical alternatives in tubewell installation and design are classified as low, medium, and high cost wells. The well with a capital cost of about Rs. 50,000. per well is defined as low cost well and those with capital costs of Rs. 70,000 and Rs. 90,000 per well are defined as medium and high cost wells. Second, the sensitivity of the results with respect to the changes in the wage rates and time lags is analysed separately using these three classes of wells. All possible combinations of high and low levels of each of the assumptions on yield rates, relative prices, wage rates, and the maximum rates of utilization of the wells with the three classes of wells, are then undertaken for sensitivity analysis.

Wage Rates and Time Lags

In the first phase of the analysis, the net benefits were calculated assuming the opportunity cost of agricultural labor to be 25 percent of the market wage rate. A realistic estimation of the opportunity cost of agricultural labor is a complex task. A detailed discussion on this problem was made in an earlier section in this chapter. It is, therefore, considered essential to test the sensitivity of the results with respect to different estimates of opportunity cost of agricultural labor.

The time lag in reaching the maximum irrigated area of 60 acres under a well was assumed to be three years--first year 24 acres, second year 40 acres, and 60 acres in the third year and onwards. In the Thakurgaon Tubewell Project in the district of Denajpur, it took about six years to reach the maximum rated area under irrigation. But the Thakurgaon project was in the nature of a pilot project. There was no provision in the project for agricultural extension workers for organizing and training the farmers. With the introduction of the management system evolved by the Comilla Rural Development Academy in the project area in 1967 there has been a sharp rise in the utilization of capacity, almost reaching the rated capacity in three years. In the present study, there is special provision of agricultural services in the tubewell project area, and hence the time lag in reaching the maximum area under a tubewell command is less likely to exceed three years.

The changes in the internal rates of returns, net present value and the benefit-cost ratio with alternate values of wage rates of unskilled agricultural labor and alternate time sequences of lags are shown in Table 8.

Table 8. Estimated effects of different wage rates and time lags on monetary return from irrigation, study area, Bangladesh.

Changes in Assumptions	Low Cost Wells			Medium Cost Wells			High Cost Wells		
	IRR	NPV	B-C	IRR	NPV	B-C	IRR	NPV	B-C
	(Percent)	(Rs.)	(Ratio)	(Percent)	(Rs.)	(Ratio)	(Percent)	(Rs.)	(Ratio)
1. Initial	40.1	167275	2.40	30.4	146685	2.05	24.6	126351	1.79
2. Labor Cost 10% of Market Wage	44.1	191875	2.61	33.4	171285	2.23	27.1	151255	1.95
3. Labor Cost 50% of Market Wage	33.5	121103	2.02	25.0	100513	1.72	19.9	80483	1.50
4. Labor Cost Equal to Market Wage	17.8	32986	1.28	12.2	12396	1.09	8.8	-7634	0.95
5. Five Years' Lag	32.7	142845	2.25	25.3	122255	1.91	20.8	102225	1.66
6. Seven Years' Lag	28.4	122600	2.10	22.2	102010	1.77	18.3	81980	1.54

The initial assumptions included a wage rate of unskilled agricultural labor at 25 percent of the market wage rate and a time lag of three years. The time lags of five and seven years to reach full development, as shown in Table 8, are assumed to have the following order. The five years' lag is sequenced as 21,24,30,42, and 60 acres in the first, second, third, fourth and fifth years, respectively. From the fifth year onwards the acreage is assumed to remain at the same level. The seven years' lag is sequenced as 18, 21,24,30,39,48, and 60 acres in the first, second, third, fourth, fifth, sixth, and the seventh year respectively. From the seventh year onwards, the acreage is assumed to remain at the same level. In keeping with the different lags, adjustments are made proportionately in the operation, maintenance, and replacement costs in calculating the rate of returns.

The IRR falls by 4 percent points in the case of low cost tubewells, and by 3 and 2.5 percent points in the case of medium and high cost wells, respectively, when the unskilled agricultural labor input is priced at 25 percent of the market wage, rather than 10 percent. In terms of NPV the difference, for the same changes in wage costs, is Rs. 24,600 in all the three cases of low, medium and high cost wells.[34] However, when the wage rate is considered

[34]The fact that the IRR criterion gives a large fall in case of low cost wells than that in the case of high cost wells in response to increased rate of wage, whereas the NPV criterion shows no differential impact among the low and

equal to market wage rate and as such used in the calculation of returns, the IRR falls sharply to 17.8 percent in the case of low cost wells, to 12.2 percent in the case of medium cost wells, and to 8.8 percent in the case of high cost wells. In the case of the high cost wells the IRR goes below the discount rate (10%), and the NPV becomes negative.

The length of time in reaching the maximum area under irrigation has important policy implications. This is a factor which can be controlled by appropriate action. Relaxing the initial assumption of three years lag to five or seven years, the IRR, the NPV, and the B-C ratio are simultaneously reduced. For lag of five years instead of three, the IRR is reduced by 7.4 percent points in case of low cost wells, and by 5.1 and 3.8 percent points in the cases of medium and high cost wells, respectively. The reductions in the IRR are by 11.7, 8.2 and 6.3 percent points respectively, in the low, medium, and high cost wells, when the lag extends to seven years. In terms of NPV, the extension of lag to five years reduces the NPV by Rs. 24,430 in both the cases of low and medium cost wells, and by Rs. 24,126 in the case of high cost wells. In the case of the seven years' lag the NPV falls by Rs. 44,763 in the case of low cost wells, by Rs. 44,675 in the case of medium cost wells, and by Rs. 44,371 in the case of high cost wells. This net economic benefit which could be gained if the time

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high cost wells, need not be confusing. This is obvious from the fact that the IRR is a ratio whereas the NPV is an absolute magnitude and the low cost wells have higher labor/capital ratio than the high cost wells.

lag in reaching the rated capacity of a well can be substantially reduced, will be further discussed in the subsequent section.

Yield Rates, Relative Prices and Rates of Utilization

Investigating the sensitivity of the monetary returns due to changes in the yield rates, relative prices of major crops, and the rates of utilization of a tubewell, two levels, designated as low and high, of each of the above three factors are selected. These are combined with two levels of wage rates for unskilled labor, one at 25 percent of the market wage rate and the other at full market wage rate, and the three types of wells--low, medium, and high cost wells as defined earlier. Thus, there are in all, 48 combinations. The internal rates of return, net present values, and benefit-cost ratios of these combinations are shown in Table 10.

The values of the low and high levels of each of the factors are shown in Table 9. The selection of the high and low values is made on the basis of judgment of probable ranges of such factors as discussed in the foregoing section, "output analysis." The changes in yield rates and relative prices are assumed to originate from uncertain factors, and as such no corresponding changes in cost structures associated with these factors are necessary. But in the case of the rate of utilization of a well, measured by the maximum

Table 9. Assumed ranges of prices, yield rates and rates of coverage by a well, study area, Bangladesh, (about 1968-1988 period).

Factors	Low	Original	High
Relative Prices (Rs/maund)			
Rice	16.00	19.00	24.00
Jute	22.00	25.00	30.00
Yield Rates (maunds/acre)			
Without Irrigation			
B. Aus (deshi)	16.00	18.00	20.00
Jute	17.00	19.00	21.00
T. Aman (deshi)	17.00	19.00	21.00
With Irrigation			
T. Aus (IRRI)	35.00	40.00	50.00
Jute	20.00	25.00	30.00
T. Aman (IRRI)	35.00	40.00	50.00
T. Aman (deshi)	20.00	25.00	30.00
T. Aus (deshi)	20.00	25.00	30.00
Boro	35.00	45.00	55.00
Maximum Irrigation Coverage (acres)	39.00	60.00	81.00

Note: Original levels relate to the values of the factors used in the first phase of analysis. A note on the assumptions of low yield level is presented in Appendix XXIII.

Table 10. Estimated effects of changes in the major parameters on the monetary returns from tubewell irrigation, study area, Bangladesh.

Parameter Conditions	Labor Valued at 25% of Market Wage			Labor Valued at 100% of Market Wage		
	IRR	NPV	B-C	IRR	NPV	B-C
	(Percent)	(Rs.)	(Ratio)	(Percent)	(Rs.)	(Ratio)
1. $R_1P_1Y_1C_1$	3.5	-23405	0.78	*	*	*
2. $R_1P_1Y_1C_2$	0.6	-43933	0.65	*	*	*
3. $R_1P_1Y_1C_3$	-1.4	-64023	0.56	*	*	*
4. $R_1P_1Y_2C_1$	32.9	116094	2.09	17.0	28669	1.27
5. $R_1P_1Y_2C_2$	24.5	95504	1.75	11.5	8079	1.06
6. $R_1P_1Y_2C_3$	19.4	75474	1.51	8.1	-11950	0.92
7. $R_1P_2Y_1C_1$	25.1	78218	1.74	7.6	-9197	0.91
8. $R_1P_2Y_1C_2$	18.6	57628	1.45	4.1	-29787	0.77
9. $R_1P_2Y_1C_3$	14.7	37598	1.26	1.9	-49817	0.66
10. $R_1P_2Y_2C_1$	57.0	286779	3.70	45.8	199364	2.88
11. $R_1P_2Y_2C_2$	43.7	266189	3.10	34.7	178774	2.41
12. $R_1P_2Y_2C_3$	35.8	246159	2.68	28.1	158744	2.08
13. $R_2P_1Y_1C_1$	17.5	36922	1.28	*	*	*

Table 10. Contd.

Parameter Conditions	Labor Valued at 25% of Market Wage			Labor Valued at 100% of Market Wage		
	IRR	NPV	B-C	IRR	NPV	B-C
	(Percent)	(Rs.)	(Ratio)	(Percent)	(Rs.)	(Ratio)
14. $R_2P_1Y_1C_2$	12.6	16322	1.11	*	*	*
15. $R_2P_1Y_1C_3$	9.5	-3698	0.98	*	*	*
16. $R_2P_1Y_2C_1$	59.5	321561	3.40	37.1	142047	2.06
17. $R_2P_1Y_2C_2$	46.0	300971	2.95	27.8	121457	1.79
18. $R_2P_1Y_2C_3$	37.9	280941	2.61	22.3	101427	1.58
19. $R_2P_2Y_1C_1$	46.3	245094	2.83	22.2	65600	1.49
20. $R_2P_2Y_1C_2$	36.1	224504	2.45	16.6	45010	1.29
21. $R_2P_2Y_1C_3$	29.9	204474	2.17	13.0	24980	1.14
22. $R_2P_2Y_2C_1$	95.3	67191	6.02	78.8	492323	4.68
23. $R_2P_2Y_2C_2$	74.5	651201	5.22	61.3	471733	4.06
24. $R_2P_2Y_2C_3$	62.2	631171	4.62	51.0	451703	3.59

Note: *Gross value of products minus cost of production in these cases are negative in almost all years. Outcome being so obvious they were not processed through computer.

R_1 = Low rate of utilization of a well; R_2 = high rate of utilization; P_1 = low price; P_2 = high price; Y_1 = low yield; Y_2 = high yield; C_1, C_2, C_3 = low, medium, and high cost wells respectively.

area under it, will definitely influence the associated costs, e.g., operation costs and wear and tear of the well. The question of optimum rate of utilization was discussed, mainly from the theoretical point of view, in a previous section of this chapter. But the theoretical framework could not be used for determining the optimum rate of utilization, for reasons mentioned in that section. There is empirical evidence which indicates that the maximum rate of utilization of a tubewell is necessarily not an optimum. Mellor and Moorti studying on tubewell irrigation in India found that the state tubewells working at the full rated capacity were substantially less efficient than the private tubewells working at around two-thirds of their rated capacities. The higher rate of utilization of the public tubewells resulted in an increased breakdown and an unreliable water supply, which were reflected in the relatively higher costs of maintenance and replacements.[35] Thus it would be unrealistic not to make changes in the related costs along with the changes in the rates of utilization. For the present analysis, the costs associated with the rates of utilizations are those for oil and fuel, spare parts, and replacements. The costs for oil and fuel and spares are changed proportionately to the acreage under different rates

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[35]John W. Mellor and T. V. Moorti, Dilemma of State Tubewells, Cornell University, Ithaca, New York, 1971 (Reprint from the Economic and Political Weekly, Vol. VI, No. 13, 1971).

of utilization. The replacement provisions are phased almost proportionately to the total hours of work involved under different rates of utilization. Thus, the replacement of engines is made at the fifth year in the case of 60 acres of coverage, at the seventh year in the case of 40 acres of coverage, and at the fourth year in the case of 80 acres of coverage. The replacement of pumps is made at the 12th year in the case of 40 acres, 10th year in the case of 60 acres, and the 8th year in the case of 80 acres of maximum irrigation coverage by a tubewell. The salvage value of these, if useful life continues after 20 years of project life, are then added to the benefit in the final year.

In Table 10, R_1, R_2, P_1, P_2, Y_1 and Y_2 are symbols for low and high levels of rate of utilization, prices and yields, respectively. The symbol C_1 stands for low cost, C_2 for medium cost, and C_3 for high cost wells. The results with 25 percent market value of labor are comparable with those obtained in the first phase. The first phase results varied from the lowest IRR of 24.6 percent (NPV Rs. 126351), associated with the high cost well, to the highest IRR of 40.1 percent, associated with the low cost well. With the low and high levels of the factors the range widens from the lowest negative IRR of -1.4 percent (NPV Rs. 64,023) to the highest IRR of 95.3 percent (NPV Rs. 671791). The lowest result is associated with the low levels of the rate of utilization, prices, yield rates and high cost wells. The highest result is associated with high levels of the rate of utilization, prices, yield rates and the low cost well. The probability of having a situation where both high prices and high yield rates or low prices and low yield rates may occur is, perhaps, very low. They may occur if expansion of the overall irrigated area in the country is slow so that yield rates in the project area are high but the rate of increase in overall production in the country falls much below the rate of increase in overall demand, thus creating a high price situation. Such a situation is likely only temporarily in the initial stage of irrigation development. The low prices and low yield rates seem to be even less probable. The more probable outcomes are those with low prices and high yield rates or high prices and low yield rates. The results of such combinations range from the lowest IRR of 14.7 percent (NPV Rs. 37598), associated with the combination $R_1P_2Y_1C_3$, to the highest IRR of 59.5 percent (NPV Rs. 321561), associated with the combination $R_2P_1Y_2C_1$. The average IRR and NPV of these combinations are 32.6 percent and Rs. 169838, respectively.

Following the procedure outlined in the first phase of the analysis, the main effects of the factors, defined as the differences in the average outcomes with the low levels of the factors and those with the high levels of the factors, are calculated and presented in the Table 11. The figures in the table correspond to the results with labor valued at the 25 percent of market wage rate.

Table 11. Estimated individual effects of rates of utilization, crop yields, prices, and tubewell investment costs on monetary returns, study area, Bangladesh.

Factors	IRR	NPV
	(Percent)	(Rs.)
$\bar{R}_1$	22.9	921,024
$\bar{R}_2$	43.9	298,439
$\bar{R}_2-\bar{R}_1$	21.0	204,415
$\bar{P}_1$	21.9	99,717
$\bar{P}_2$	44.9	300,067
$\bar{P}_2-\bar{P}_1$	23.0	200,350
$\bar{Y}_1$	17.8	63,809
$\bar{Y}_2$	49.1	328,653
$\bar{Y}_2-\bar{Y}_1$	31.3	264,844
$\bar{C}_1$	42.1	216,632
$\bar{C}_2$	32.1	196,050
$\bar{C}_3$	26.0	176,012
$\bar{C}_1-\bar{C}_2$	10.0	20,582
$\bar{C}_1-\bar{C}_3$	16.1	40,620
$\bar{C}_2-\bar{C}_3$	6.1	20,038

It will appear from the table that the yield rates, the relative prices, and the utilization of the tubewell capacity are the three main factors to which the results are very sensitive. A change in the yield rates of the crops from the low levels to the high levels (as shown in Table 9.) causes, on the average a change of 31.3 percent points in IRR, and of Rs. 264,844. in the NPV. The changes caused by the price and the rate of utilization are almost the same; the changes in the IRR and the NPV are by 21.0 percent points and by Rs. 204,415, respectively, in the case of utilization factor, and by 23.0 percent points and Rs. 200,350, respectively, in the case of the price factor. The effects of the variation in capital costs, as reflected in the three types of wells, are relatively low in magnitude. The yield rates of crops, the utilization of well capacity, and the reduction of the lag in reaching the full development are important factors amenable to changes by an appropriate agricultural extension service and management organization. In the past, there has been criticism of economic justification for any proposal for expansion of agricultural extension services and rural development organizations. In the absence of any criteria these arguments usually revolved around some vague rhetoric. The project proposal for agricultural extension services, specifically meant for irrigated areas, can now be evaluated in terms of their economic contribution. To make such an appraisal, the first step will be determination of the magnitudes by which an agricultural extension service will be effective in reducing the time lag in reaching full development, in extending the areas under tubewells, and in increasing the yield rates of crops. The second step will be computation of the incremental NPV from these three factors and comparison with the discounted present value of the stream of costs for the agricultural extension proposal, or any other similar organization intended to serve the irrigation project management. The example presented is, no doubt, a simplified one. The underlying purpose is to stress the importance of the three factors in their contribution to economic performance of irrigation projects and the existence of a basis for economic analysis of proposals intended to improve the conditions with the three factors.

The Rate of Discount and Its Effects on Returns

The streams of benefits and costs originating from an investment spread throughout the time horizon of the investment project. A rupee ten years hence is not equal to a rupee at hand. The future costs and benefits have, therefore, to be standardized to a common and uniform value. The discount rate serves this purpose. It reflects the time preference of individual investor in case of private investment and society as a whole in case of public investment. The factors behind such time preferences originate from an intricate set of relationships of factors influencing decisions on investment, savings, and consumption. The consumption and savings decisions are simultaneous. It is a question of whether one would prefer to consume less (save more) at present to insure a higher future consumption. The investment decisions involve the productivity of capital and risk and uncertainty factors. Then there are varieties of interest rates. Even if one can select a single or average risk-free, long-term rate, it is not clear what significance can be attached to it, Straight away, we come up against all the old arguments about whether market rates of interest bear any close relationship to the marginal productivity of investment, or whether the relationship is so blurred as to be imperceptible. These are partly a matter of different interest rate theories, and partly a matter of how a particular economy works--do governments intervene in capital markets, how well organized and unified is the capital market, etc.?

Another issue is whether any market-determined interest rate would suffice for public decision making, even if a perfectly capital market is assumed. Some writers believe that social time preferences attach more weight to the future than private time preferences, and that it is the former which is relevant for determining the allocation of a society's current resources between investment and consumption. Pigou, for instance, suggested that individuals were shortsighted about the future and that government intervention might be needed to give adequate weight to the welfare of unborn generations.[36] Eckstein attempted to establish the views of Pigou on a firmer basis. One of his arguments was that any one individual's preference for current consumption, relative to future consumption by himself or his successors, will be less if there is sort of government organized program for imposing sacrifices on everybody--or at least on a large section of the population--than if the solution is left to the market.[37] Whatever the ultimate pros and cons of these arguments, there are two difficulties, if one tries to give effect to them. The first is actual determination of the social rate of discount. Marglin accepts that this does pose serious difficulties, but goes on to suggest that one can set about it my choosing the growth rate for an economy and thence (on the basis of the marginal capital/output ratio) determine the rate of investment; the social rate of discount must then be equated with the marginal productivity of investment.[38] It is not known whether the practicability of the concept has been tested.

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[36] A. C. Pigou, The Economics of Welfare (4th ed.) (London, McMillan, 1932), pp. 24-30.

[37] Otto Eckstein, Water Resource Development (Cambridge, Mass.: Harvard University Press, 1958).

[38] S. A. Marglin, "The Social Rate of Discount and Optimum Rate of Investment", Quarterly Journal of Economics, Vol. SXXVII, February, 1963.

Prest and Turvey conclude "Discussions about social rates of time preference social opportunity cost, etc., do not cut very much ice in most empirical work, and we have not been able to discover any cases where there was any convincingly complete application of such notions."[39] In practice, empirical studies generally select any interest rate considered appropriate on the basis of subjective judgment.

However, the selection of interest rates has serious implication in ranking projects. When projects differ in length of life, and the sequences in the generation of benefit and cost streams are dissimilar among different projects, different interest rates will produce different rankings in such cases. Projects of longer life and gestation period will generally be ranked lower if interest rate is higher than they would be otherwise.

In the present study, an interest rate of 10 percent has been used for discounting. This rate is generally used by the government in project appraisal analysis. However, a sensitivity of the results under the assumptions of the analysis in the first phase is presented in Table 12. In the table, the changes in the NPV for low, medium, and high cost wells are shown for different rates of discount. These

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[39] A. R. Prest and R. Turvey, Cost Benefit Analysis--A Survey, op. cit., p. 700.

results could be used for extrapolation or intrapolation without major inaccuracy for testing other cases because the project life and sequences in the cost and benefit streams in the present study are more or less constant and uniform.

Table 12. Relationship of discount rates and monetary returns (NPV) from low, medium, and high cost wells, study area, Bangladesh (about 1968-88).

Discount Rates	Low Cost Wells (NPV)	Medium Cost Wells NPV	High Cost Wells NPV
(Factor)	(Rs.)	(Rs.)	(Rs.)
0.02	395795	375205	353871
0.04	314674	294084	272750
0.06	252772	232182	210845
0.08	204863	184273	162939
0.10	167275	146685	125351
0.12	137395	116805	95471*
0.14	113341	92751	71417
0.16	93746	73156*	51821
0.18	77602	57012	35678
0.20	64158	43568	22234
0.22	52853*	32263	10929
0.24	43257	22667	1333
0.26	35041	14451	-6883

Note: * Nearest to the break-even point (the break-even points are at Rs. 49604, Rs. 70194, and Rs. 90224 for the low, medium, and high cost wells, respectively).

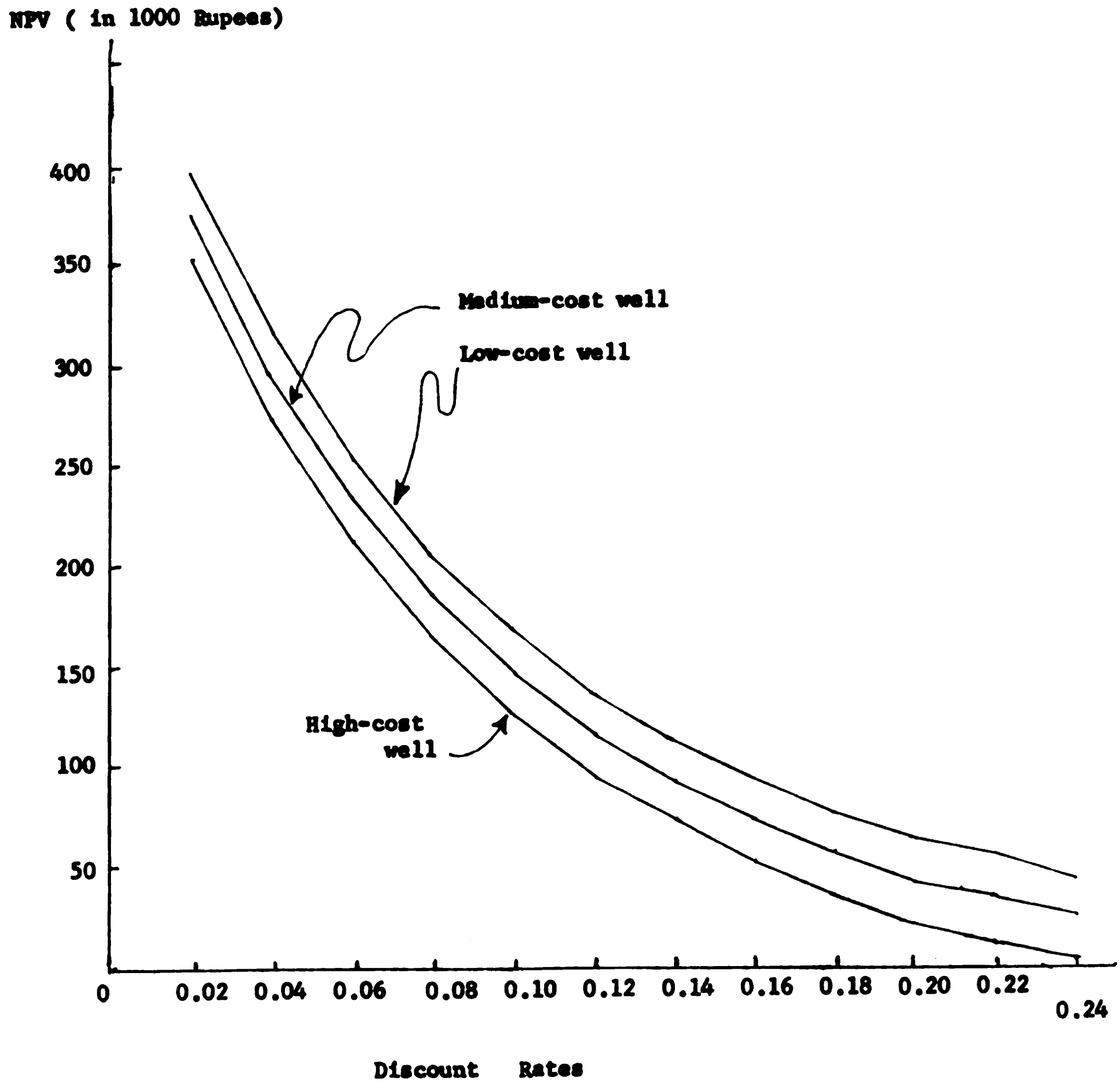

Figure 5. Relationship between Discount Rates and the Net Present Values from Three Types of Wells

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Policy Implications

Implications for Resource Allocation.--The rates of returns from investments in a tubewell irrigation program, with the most likely sets of assumptions, are quite high. The internal rates of returns for various types of wells range from the lowest, 24.6 percent, to the highest, 40.1 percent (Table 6). These estimates of returns from investments in a tubewell irrigation project will facilitate comparison of projects in the water sector in particular and in the agriculture sector in general. Such comparisons based on the rates of returns of projects will aid in selecting a set of projects that will maximize the contribution of a given investment budget to the growth of national income. Within the water resource sector the comparison may involve tubewell irrigation projects in different locations. The comparison between a tubewell irrigation project and a low-lift pump project will be of special interest. The current practice in the public resource allocation for irrigation has remained favorable to the low-lift irrigation program. Economic advantages of a low-lift pump in an area very near to the surface water sources may be obvious. But the extent of such favorable areas is limited. Any expansion in the low-lift irrigation program beyond such a limit will require additional costs. Such additional costs will be necessary for bringing water nearer to the field either by construction of canals, dams, or by provision of double-lifts, or by both.

Calculation of the rates of returns from such low-lift pump programs will provide a basis for comparison with a tubewell project as an alternative for supplying irrigation water to such areas. The present policy of considering any low-lift pump project superior to a tubewell project should be abandoned in favor of a policy which will take the comparative advantages of the alternatives into consideration.

Low-Cost Wells and Technical Training.--In the past, one of the arguments in favor of the power drilling technique was that the drilling was fast. The technique was considered necessary because the government wanted to implement a large tubewell program within a period of five years. This was considered not possible with the other methods of drilling. This argument, however, was based on the implicit assumption that a large number of trained drillers for the cable percussion or water jet methods would not be available within the country. Thomas has shown in his study that such an assumption is based on wrong foundations.

Training in drilling techniques is relatively simple and most of the training can be accomplished by associating the unskilled apprentices with the process of drilling in one season. The Rural Development Academy at Comilla has already trained a large number of drillers in this way. A modest program of training, following the experience at Comilla, will provide a large pool of drillers. Thus, the number of wells within the first two years may be smaller if drilling is done by the cable percussion method. But in the subsequent years the total number of wells that can be drilled by this method will exceed the total number of wells by the power drilling method. The choice of a drilling technique has a substantial influence on the rate of return. Drilling by cable percussion method improves the internal rate of return by about 8 percent points over that by power drilling method. Thus, a training program which will facilitate the simpler method of drilling is considered very desireable. Moreover, such a training program will produce trained manpower which will multiply in time through associations in work and will provide a necessary technical basis for future programs of the same or similar nature.

Low-Cost Wells and Industrial Programs.--In addition to the technique of drilling, types of pumps and engines, and the quality of the well screen material must be considered in selection of a low cost well. Although the choice of a low speed diesel engine over a high speed one makes a small difference in the rates of return (only 2 percent points in IRR), these types of engines will have very large demand in the transport sector. Bangladesh is a riverine country. River transport will continue to be a major means of communication. For enhancing speed of the existing rivercrafts, low-speed diesel engines are considered very suitable. Moreover, these engines are easier to manufacture locally. In Pakistan, such engines are being manufactured by small scale industries. The combined demand for such engines in the agriculture and the transport sector will provide a viable basis for such an industry in Bangladesh. Similarly, manufacture of centrifugal pumps and brass screens is simpler than that of turbine pumps and fiberglass screens. Manufacture of these items within the country is considered important. This would not only save foreign exchange of the country, but would also reduce the uncertainty of supply of these important tubewell components. The manufacture of tubewell components within the country, therefore, deserves special consideration by the country's industrial planners.

Marketing Facilities.--The need for special attention to marketing facilities will arise from two factors. First, provision of irrigation facilities will be limited to certain areas due to limited investible funds and technical considerations. The increased production possibilities in the irrigated areas, compared to those in the non-irrigated areas, will create a substantial difference in the per capita output of agricultural products between such areas. A speedy distribution of the surplus products of the irrigated areas to the deficit non-irrigated areas will be important. This will be important to maintain a product price in the irrigated areas such that farmers have an incentive for production; it will also be important for the consumers in the deficit areas so that they can obtain agricultural products at reasonable prices. Second, irrigation will accelerate the process of commercialization in crop production. With the increased productivity of land under irrigation, a smaller portion of the land will be able to satisfy the present subsistence requirements. Thus, a portion of the land which is currently used for subsistence crop production will be available for producing products for sale.

Considerations of the above two factors will have to be given adequate weight in the formulation of the agricultural marketing policies and programs in the country.

Rates of Utilization of the Wells.--Although the problem of supply of irrigation water has received considerable attention in the past, no attention has so far been given to the questions of water management and the rate of utilization of the established facilities in the country. No study has been conducted (at least not known to the author) to determine the optimum water applications to crops as well as the optimum area that a tubewell should cover. Limited evidence indicates that the present policy of attempts to cover as many acres as possible with a single tubewell is not economically the optimum. Similarly, the supply of water to rice crops at the flooding level (i.e., much in excess of what is optimally required) is sheer waste of costly water input. These two related issues should receive immediate attention as a first step towards formulation of a policy of optimum water utilization for irrigation purposes.

Research and Extension.--Two research topics appear to be of extreme importance in so far as they are relevant to the present study. The first topic is agronomic-economic in nature. The main objective of any research on this topic will be the determination of optimum crop production practices under irrigated farming in general, and introduction of new crops in the irrigated area in particular. The second topic is engineering-economic in nature. The objective of research on this topic will be determination of efficient methods of operation, maintenance, and replacement of tubewells. For example, a well, after discharging regular flows of water for ten years, may start losing efficiency. The discharge of water may decrease to a very low level. In these circumstances an ordinary procedure very likely to be followed in Bangladesh, will be pulling out the pipes and screen for removal of deposits in the screen. In the process of pulling out and then drilling in, the screens and pipes may be damaged. Research objectives in this case will be to determine: 1) the causes of diminishing discharge of water, 2) the most efficient way of correcting the defect (e.g., calcarious deposits on the screen may be removed by some chemicals instead of pulling out the whole outfit, 3) whether any preventive technique could be adopted at the time of initial drilling if it were known from soil and water tests that the possibility of calcarious deposits was very high in that particular region. These and many other operation and maintenance problems will form the subjects of research under the second topic.

The need for a reoriented agricultural extension service for irrigated farming follows from the need for research outlined above. For dissemination of the research findings to the farmers a properly trained extension service is essential. Bangladesh does have a comprehensive agricultural extension service. Moreover, some irrigation projects have exclusive provisions for agricultural extension workers. It will be necessary to hold regular training courses for these workers so that they can effectively advise the farmers in the irrigated areas.

CHAPTER VI

GENERATION OF EMPLOYMENT OF LABOR RESOURCES FROM INVESTMENT IN IRRIGATION

The problem of widespread unemployment and underemployment is acute in Bangladesh. For insuring rapid creation of jobs for the unemployed and underemployed people in the country through planned resource allocations, information on the effects of development projects on employment generation is essential. In Chapter I, we set the determination of the impact of tubewell irrigation on employment generation as one of our major objectives in the study. In this chapter we shall present the results with respect to that objective. The results deal mainly with important aspects of labor demand in agriculture in Bangladesh. The supply side of agricultural labor is not directly relevant to the objective of the study. When it is intended to evaluate the impact of increased demand for labor on the unemployment situation, both the supply and demand sides are necessary for such analysis. However, no discussion on supply of agricultural labor and theoretical concepts of unemployment is included in this study.

Employment Generation from Investment on Irrigation

The impact of investment on one tubewell assumed to cover an irrigated area of 60 acres is shown in Table 13. In the table the 24 technical alternatives available in the installation of tubewells, as elaborated in the previous chapter, are evaluated in terms of their employment generation capacities. It will be seen from the table that the E/K ratio (as defined in Chapter III) is highest for the alternatives with centrifugal pump (P_1), low speed diesel engine (D_1), brass screen (S_1), and either waterjet (T_1) or cable percussion (T_2) methods of drilling. The alternatives with turbine pump (P_2), high speed diesel engine (D_2), fiberglass screen (S_2) and power drilling (T_3) have the lowest E/K ratios. If the results in Table 13 and those in Table 6 in the previous chapter are compared, it will be seen that the ranking of the alternatives by the income objective criteria and the E/K criterion do not conflict; alternatives considered superior in terms of their IRR, NPV or B-C ratio are also superior in terms of E/K ratio. Generally speaking the low cost wells were found to rank higher than the medium cost wells, which in turn were superior to high cost wells, all of which were evaluated as alternatives from the point of view of the income objective. The same pattern of ranking is discerned when the alternatives are evaluated from the point of view of the employment

Table 13. Technical alternatives in tubewell installation and their employment investment ratios, study area Bangladesh.

Alternatives	E/K	Alternatives	E/K
1. $P_1D_1T_1S_1$	3.378	13. $P_2D_1T_1S_1$	2.679
2. $P_1D_1T_1S_2$	3.178	14. $P_2D_1T_1S_2$	2.586
3. $P_1D_1T_2S_1$	3.378	15. $P_2D_1T_2S_1$	2.680
4. $P_1D_1T_2S_2$	3.178	16. $P_2D_1T_2S_2$	2.588
5. $P_1D_1T_3S_1$	2.342	17. $P_2D_1T_3S_1$	2.013
6. $P_1D_1T_3S_2$	2.244	18. $P_2D_1T_3S_2$	1.965
7. $P_1D_2T_1S_1$	3.047	19. $P_2D_2T_1S_1$	1.965
8. $P_1D_2T_1S_2$	2.883	20. $P_2D_2T_1S_2$	2.387
9. $P_1D_2T_2S_1$	3.047	21. $P_2D_2T_2S_1$	2.468
10. $P_1D_2T_2S_2$	2.884	22. $P_2D_2T_2S_2$	2.468
11. $P_1D_2T_3S_1$	2.177	23. $P_2D_2T_3S_1$	1.894
12. $P_1D_2T_3S_2$	2.091	24. $P_2D_2T_3S_2$	1.848

Note: P_1 = centrifugal pump, P_2 = turbine pump

D_1 = low speed diesel engine, D_2 = high speed diesel engine

S_1 = brass screen, S_2 = fiber glass screen

T_1 = waterjet method of drilling, T_2 = cable percussion, T_3 = power drilling objective. This convergence of results from the points of view of both income and employment objectives emphasizes the superiority of low cost and medium cost wells over the high cost wells in Bangladesh.

The creation of employment in terms of man-years or man-days[1] by a tubewell irrigation project will show the magnitude of additional jobs created for the surplus labor force. Such figures are presented in Table 14. The installation and utilization of a tubewell will generate additional 139,765 man-days of work for unskilled agricultural labor over a period of 20 years (project life). This is equivalent to 423.53 man-years assuming 330 man-days are equal to one man-year. It implies the creation of permanent jobs (for a 20 year working life per laborer) for about 21.2 workers per well. The generation of employment for skilled workers amounts to 9,900 man-days (or 30 man-years) for the operation of a well, and agricultural extension works over the 20 year period of project life. It is equivalent to the permanent creation of jobs for 1.5 workers per tubewell. The creation of jobs in the construction process of a well is very small as compared to that in crop production and well operation activities. In the cable percussion drilling method, 15 unskilled workers and 2 skilled workers require only 30 days to install a well. It is equal to only

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[1]A man-day is defined as 8 hours of work by an adult worker.

Table 14. Creation of additional employment by one tubewell for irrigation in the directly related activities, study area, Bangladesh.

Years	Crop Production Activities[1] (unskilled)	Installation Activities* (unskilled)	(skilled)	Operation & Agricultural Service (skilled)
		Man-days		
0	--	450	60	--
1	1,392	--	--	495
2	3,253	--	--	495
3	5,840	--	--	495
4	6,200	--	--	495
5	7,240	--	--	495
6	7,240	--	--	495
7	7,240	--	--	495
8	7,240	--	--	495
9	7,240	--	--	495
10	7,240	--	--	495
11	7,240	--	--	495
12	7,240	--	--	495
13	7,240	--	--	495
14	7,240	--	--	495
15	7,240	--	--	495
16	7,240	--	--	495
17	7,240	--	--	495
18	7,240	--	--	495
19	7,240	--	--	495
20	7,240	--	--	495
Total	139,765	450	60	9,900

[1]The figures indicate the difference in man-days in crop production activities with and without irrigation system in each of the years. Area under a well is assumed to be 60 acres. The cropping pattern and intensity represent the ones in Chapter IV and first phase of Chapter V.

*Represents the cable percussion method of drilling.

450 man-days of unskilled work and 60 man-days of skilled work. In the waterjet method of drilling, 2 skilled workers along with 15 unskilled workers can install a well within 20 days, which is equivalent to 300 man-days of unskilled and 60 man-days of skilled employment. If power drilling is employed in the construction of a well, seven days for each of 4 unskilled workers and 2 skilled workers are required to complete construction of a well; this is equivalent to 28 man-days of skilled work and 14 man-days of unskilled work. Neglecting the small differences in the employment generation caused by different techniques of drilling, we can show how the low, medium, and high cost wells stand in respect to their employment generation per rupee of investment. Assuming the total volume of additional employment to be 140,215 man-days (139,765 + 450) in case of unskilled work, and 9,960 man-days in case of skilled work, the unskilled employment in man-days per rupee of investment cost works out to be 2.83 for low cost wells, 2.00 for medium cost wells, and 1.55 for high cost wells. The similar ratio for skilled labor is very small, 0.20 for low cost, 0.14 for medium and 0.11 for high cost wells.

Thomas, on the basis of a cross-sectional study, estimated the impact of the public works program on employment generation in rural Bangladesh.[2] He estimated that

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[2]John W. Thomas, The Rural Public Works Program and East Pakistan's Development (Cambridge, Harvard University, Ph.D. Thesis, 1968), p. 110.

during the period from 1962-63 to 1966-67, an average of 41.7452 million mandays of employment was created annually by the public works program in Bangladesh. The average annual expenditure on this program for the same period was estimated to be Rs. 142 million. Thus, the employment-investment ratio (mandays per rupee of expenditure) is only 0.294. The similar ratio in the present study is 2.83 for low-cost wells, 2.00 for medium cost wells, and 1.55 for high cost wells. A direct comparison of these ratios will not be strictly correct. One reason why such a comparison is not strictly valid, is the non-comparable denominators in the ratios. The denominator of the ratio in the case of the public works program includes all expenditures on the works program. But the denominator of the ratio in the case of the present study does not include all costs. It represents only capital costs. Even then, the wide differences between them indicate a higher impact of investment in irrigation than that of the public works program on employment creation.

Another favorable aspect of tubewell irrigation in general, and low cost wells in particular, is the backward link of such programs with labor intensive activities. We mentioned in Chapter V that the combined demand for low-speed diesel engines in agriculture and river transport would provide a solid base for domestic manufacture of these engines. We also mentioned that these engines and some other tubewell materials could be produced by small scale rural industries if properly organized. Such industries are generally labor intensive compared to many large scale manufacturing industries. Hence, the low-cost tubewells are preferable not only for their higher effects on income and employment generation in directly related activities but also for a high employment effect of such programs in secondary activities.

The Nature of Labor Demand Under Irrigated Conditions

The problems of unemployment must be approached both from the supply and demand sides. Without denying the importance of the forces behind the supply side, the present study has concentrated on certain aspects of demand for labor, especially those related to an irrigation project. We might ask how the demand function for labor behaves when a major new production input like irrigation water is introduced in the farming system. Availability of controlled water enables growth of the high yielding varieties which have been claimed to have a high demand for labor per acre. Farouk in his study in the Ganges-Kabodak Irrigation Project areas observed that smaller farms were more labor intensive than larger farms.[3] It is also quite plausible that the

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[3]A. Farouk, Irrigation in Monsoon Land: Economics of Farming in the Granges-Kabodak (Dacca University, Bureau of Economic Research, 1968).

variation of wage rates at which farmers can hire labor may have some influence on the quantity of labor employed.

Variation of wage rates in cross-sectional studies are generally limited to a relatively small range. The data available for the present study from cross-sectional sources indicate a wage range from Rs. 2.50 to Rs. 4.50, and as such it was considered desirable to analyze the effects of wage rates on the quantity of labor demanded. Another factor which is considered to have a definite influence on the demand for labor by any farm is the relative acreage under high and low yielding varieties on the farm. To test the hypothesis implicit in these propositions regression analysis with ordinary least square methods (OLS) is employed.

The demand function is defined as:

$$D_L = f\ (V,R,W,S,K) + e$$

where:

D_L = Demand for labor

V = Variety of crops grown

R = Regions

W = Wage rates

S = Farm size

K = Area under high yielding variety relative to low yielding variety

e = Random error term

The relationship of demand with respect to wage rate may be misleading unless some assumptions are made about the labor supply function. The supply of agricultural labor is assumed perfectly elastic within the relevant range. This assumption appears to be very realistic considering the surplus labor situation in agriculture in Bangladesh. The specific forms of the equations used for estimation are presented below. The equations are generally of two types--one is a simple linear function and the other a log linear function commonly known as the Cobb-Douglas function.

(1) $D_{TL} = a + B_1V + B_2R + B_3W + B_4S + B_5K + e$

(2) $D_{TL} = a + B_1V + B_2W + B_3S + B_4K + e$

(3) $\text{Log } D_{TL} = \text{Log } a + B_1V + B_2R + B_3\text{Log } W + B_4\text{Log } S + B_5\text{Log } K + e$

(4) $\text{Log } D_{TL} = \text{Log } a + B_1V + B_2\text{Log } W + B_3\text{Log } S + B_4\text{Log } K + e$

(5) $D_{HL} = a + B_1V + B_2R + B_3W + B_4S + B_5K + e$

(6) $D_{HL} = a + B_1V + B_2W + B_3S + B_4K + e$

(7) $\text{Log } D_{HL} = \text{Log } a + B_1V + B_2R + B_3\text{Log } W + B_4\text{Log } S + B_5\text{Log } K + e$

$$(8) \quad \text{Log } D_{HL} = \text{Log } a + B_1V + B_2\text{Log } W + B_3\text{Log } S + B_4\text{Log } K + e$$

where:

D_{TL} = Demand for total labor per acre of rice crop in man-days

D_{HL} = Demand for hired labor per acre of rice crop in man-days

V = Dummy variable for variety
It is = 1 if higher yielding variety, or
It is = 0 if local low yielding variety
(Each farm represented two observations, one for high-yielding and the other for low-yielding variety.)

R = Dummy variable for region
It is = 1 if Dacca region, or
It is = 0 if Mymensingh region

W = Wage rate of agricultural labor measured in rupees per man-day

S = Farm size measured in acres of cultivated area per holding

K = Is a ratio of the area of a farm under high-yielding variety to the area under low-yielding variety. If the area under high-yielding variety is 2.0 acres and that under low-yielding variety 1.0 acre, then the ratio is 2. K is defined as $O < K < \infty$

a, B_1, B_2, B_4, and B_5 are the respective parameters to be estimated.

e = The random error term

The specific form of the equations have been selected on the basis of previous results of studies made in India using similar equations.[4] The conditions of Indian agriculture and agricultural labor market are not very different structurally from those in Bangladesh. This is particularly true for the West Bengal province of India and Bangladesh. In these studies primarily the Cobb-Douglas type of function has been employed for estimation of the demand function for agricultural labor in India with quite satisfactory results.

Data.--The data used in the regression analysis were collected by the author in the 1968 Boro season. All these farms were within the ADC's low-lift irrigation areas. The farms were selected at random from the list of the ADC's local Land Procurement Assistant. However, at the time of actual interviewing, some selected farmers were not available and their neighbors, who were available, were interviewed. Most of the farmers in the irrigation areas grew both the high-yielding and low-yielding local varieties of rice on their farms. Each farm, therefore, represented two observations, one for high-yielding varieties and the other for low-yielding varieties. In all, 45 farmers were interviewed in the North Dacca and the North Mymensingh areas. In the present regression analysis, 78 observations (39 farms) were selected from the area. The remaining 12

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[4]R. C. Agarwal, et al., "A Study of the Factors Affecting the Demand for Rural Labour in Agriculture," The Indian Journal of Agricultural Economics, Vol. XXV, No. 3, 1970, p. 60. (Also see some other similar studies in the same issue of the Journal).

observations (6 farms) were dropped because of zero values for some real variables in these 6 farms. The data were originally collected for use in the planning department of the then East Pakistan Government. The data used in the regression analysis are presented in Appendix XXIV.

Results.--The equations with the estimated parameters are presented below. The figures in the brackets represent the standard error of the respective regression coefficients.

(1) $\hat{D}_{TL} = 51.6618 + 42.7795V - 2.5414R - 1.8285W - 0.9899s + .5316K$

(21.6184) (4.4277) (7.3326) (6.9808) (0.6060) (1.6163)

$R^2 = 0.5733$

(2) $\hat{D}_{TL} = 56.0602 + 42.7795V - 3.6143W - 0.9387S + 0.7093K$

(17.3957) (4.4009) (4.6816) (0.5842) (1.5237)

$R^2 = 0.5726$

(3) $\text{Log } \hat{D}_{TL} = 1.6859 + 0.3263V - 0.0794R - 0.0501 \text{ Log } W - 0.0839 \text{ Log } S + 0.0006 \text{ Log } K$

(0.1822) (0.0302) (0.0538) (0.3718) (0.0443) (0.0403)

$R^2 = 0.6367$

(4) $\text{Log } \hat{D}_{TL} = 1.8658 + 0.3263V - 0.4637 \text{ Log } W - 0.0700 \text{ Log } S + 0.0309 \text{ Log } K$

(0.1365) (0.0304) (0.2461) (0.0436) (0.0350)

$R^2 = 0.6258$

(5) $\hat{D}_{HL} = 31.6053 + 19.9826V - 13.8664R - 2.2417W + 0.2269S - 0.5147K$

(14.4974) (3.0345) (4.9738) (4.6654) (0.4170) (1.1325)

$R^2 = 0.5089$

(6) $\hat{D}_{HL} = 53.5647 + 19.8652V - 11.4973W + 0.5529S + 0.5974K$

(12.7626) (3.1817) (3.4372) (0.4198) (1.1115)

$R^2 = 0.4520$

(7) $\text{Log } \hat{D}_{HL} = 1.2907 + 0.3967V - 0.3039R - 0.1247 \text{ Log } W + 0.1484 \text{ Log } S + 0.1182 \text{ Log } K$

(0.3685) (0.0628) (0.1159) (0.7528) (0.1087) (0.0895)

$R^2 = 0.5529$

(8) $\text{Log } \hat{D}_{HL} = 1.8779 + 0.3920V - 1.5475 \text{ Log } W + 0.2451 \text{ Log } S + 0.2534 \text{ Log } K$

(0.3050) (0.0654) (0.5438) (0.1066) (0.0762)

$R^2 = 0.5071$

Demand functions for total labor equations (1) through (4).--Equation (1) differs from the equation (2) by omission of R in the latter. The same is true between the equations (3) and (4), (5) and (6), and (7) and (8). The coefficients of the explanatory variable V (variety) were highly significant in all the demand equations, both for the demand for toral labor and hired labor (it was significant in most of the cases at less than a 0.5 percent level of significance). The magnitude and positive sign of the coefficient indicates that the effect of high yielding variety is by far the most important factor in contributing to the higher demand for agricultural labor, both total and hired. The regional effects on demand for labor are not so pronounced and reliable. In the case of total demand for labor, the coefficients of R become significant only at 73 percent level of significance in the simple linear equation (1) and at the 14.5 percent level of significance in the log-linear equation (3). It appears that a change in the specification of the demand function from the simple linear to log-linear form relatively reduces the standard error and also the value of the coefficient of R considerably in equations (1) and (3).[5] The same is true in the case of the coefficients of S. But in the cases of the coefficients of W and K the opposite effects occur; the standard errors of these coefficients get larger as the form of the equation is changed from simple linear (1) to log linear (3). The coefficients of W and K are also highly unreliable, particularly in equations (1) through (3). The coefficient of W becomes significant at the 79.4 percent level in equation (1), at the 44.3 percent level in equation (2), at the 89.3 percent level in equation (3) and at the 6.4 percent level in equation (4). The coefficient of K

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[5] The comparison is not strictly valid. For valid comparison one has to take antilog of the residuals to construct comparable standard errors in case of log-linear function.

becomes significant at the 74.3 percent level in equation (1), at the 64.3 percent level in equation (2), at the 98.7 percent level in equation (3) and at the 38.0 percent level in equation (4). The coefficient of S is relatively more reliable. It becomes significant at the 10.7 percent level in equation (1), at the 11.2 percent level in equation (2), at the 6.2 percent level in equation (3), and at the 11.2 percent level in equation (4). In general, when the variable R is omitted from the equations, the results get better (i.e., they become significant at a lower level of significance), with considerable reduction in the errors and little sacrifice in R^2. We would, in balance, consider equation (4) to be the best for the demand function for total labor. The R^2 of equation (4) is 0.6258 and all the coefficients in this equation are significant at a relatively lower level compared to those in other equations. However, we do not have regional effect in this equation and the results from the equation would have to be interpreted as the average of the two regions. However, it would be observed that when R is omitted, most of its effects are picked up by W, i.e., the coefficient of W gets larger. This becomes plausible from the degree of multicollinearity between R and W (simple correlation between R and W is 0.76). Thus the influences of W on labor demand are mixed with regional effect. Another important aspect of the demand function is the direction of the relationship indicated by the signs of the coefficients.

We expected demand to be inversely related to wage rate which is confirmed by the negative coefficients of W in all the equations. Similarly the negative sign of S conforms to the hypothesis that larger farms use less labor per acre in Bangladesh. The positive sign of K also conforms to the relationship we expected. Perhaps the meaning of K in the demand equations needs further elaboration. It has been argued in the past that the demand for labor is high for high-yielding varieties, not only for direct higher requirements in various operations in raising these varieties, but also due to some indirect labor requiring activities related to the varieties. These indirect activities can only be properly identified through intensive cross-section studies. As a proxy for these indirect factors, the variable K was included in the demand functions. The positive sign of K in the demand equation (4), supports the hypothesis, i.e., the per acre demand for total labor increases with the increase in the area under high-yielding varieties relative to that under low-yielding varieties. However, the magnitude of such effects is small and the estimate is not reliable.

The demand function for hired labor equations (5) through (8).--In general demand equations for hired labor have relatively lower values of R^2 but the coefficients are more reliable compared to the equations for demand functions for total labor. But the magnitudes of such differences are not quite large. Again, equation (8) which is of the same form of equation (4), appears to be best on balance. In equation (8), the constant term and the coefficient of V is highly significant at less than the 0.5 percent level of significance. The coefficient of W is significant at the 0.6 percent level and that of S and K at the 2.5 and 0.1 percent levels of significance respectively. The coefficient of K appears to be more reliable in the case of hired labor (8), than in the case of total labor demand (4). The value of R^2 is 0.5071 in equation (8). Dropping the variable R from equation, the standard error of the coefficient of W decreases and the absolute value of the coefficient increases. It appears, as was observed in the case of the demand functions for total labor, that the regional effect is picked up by the coefficient of W in the equation (8). This will be clear from the extent of multicollinearity between R and Log W (simple correlation is 0.74). The coefficient of V is significant at less than the 0.5 percent level of significance in all the equations. The coefficient of R is significant at the 0.7 percent level in equation (5) and at the 1.1 percent level in equation (7). However, the coefficient of W is significant at the 0.1 percent level in equation (6) and at the 0.6 percent level in equation (8) but highly unreliable (significant only at the 63.2 percent level in equation (5) and the 86.9 percent level in equation (7)) when R is included in the equations. The coefficients of S and K are highly unreliable in equation (5);

they become significant only at the 58.8 and 65.1 percent levels respectively. But they become relatively more reliable in all other equations; they are significant at the 19.2 and 59.3 percent levels respectively in equation (6) and the 17.7 and 19.1 percent levels respectively in equation (7). In respect to the directions of relationships between the dependent and explanatory variables, we get again the results as expected except in the case of K in equation (5). The inverse relationship between hired labor demand and wage rate conforms to our expectations and the magnitude of the coefficient is larger in the case of the demand function for hired labor than that of the total labor. This is what was expected. One interesting point to note is that the coefficients of S in all the demand functions for total labor are negative, while they are positive in all the demand functions for hired labor. It implies that though the per acre employment of total labor decreases with increased farm size, the opposite is true in the case of the per acre employment of hired labor.

What general conclusions can we make from the discussion above? We shall list the general conclusions as an average for the two regions based on equations (4) and (8). The validity of each conclusion is expected to hold within the probability range explicit in the respective levels of significance.

a. The effect of variety is by far the most important factor in generating demand for labor. Taking the average values of W, S, and K and solving the equations (4) and (8), we can estimate the average effects of varieties. The demand for total labor per acre, calculated in this way, is found to go up by 112 percent due to a shift from low-yielding local variety to high-yielding new variety. The demand for hired labor is estimated to go up by 149 percent for a shift from low-yielding to high-yielding varieties.

b. Even if farming in Bangladesh is a predominantly of a subsistence type, there is some inverse relationship between the demand for labor in farming and the wage rate. The wage elasticity of demand for all labor is -0.46, and that of hired labor is -1.55. However, this effect is somewhat mixed up with the regional effects and should be taken with some caution for any policy purpose. The wage elasticity of demand for hired labor in the Nainital district in India was found to be -1.33 by Agarwal.[6]

c. The per acre demand for all labor is negatively related with farm size, and the per acre demand for

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[6] Agarwal, Study of Rural Labor Demand, op. cit., p. 62.

hired labor is positively related with farm size. The size elasticity of demand for all labor is -0.07, and that for hired labor is 0.25.

d. With the increasing ratio of land under high-yielding varieties to that under low-yielding varieties, the demand for both total and hired labor will grow. With an increase in the ratio of the acreage under high-yielding to low-yielding varieties by one percent, the demand will likely increase by only 0.3 percent for total labor demand and by .25 percent for hired labor demand.

Seasonality of Agricultural Employment

It was mentioned in Chapter II that present agricultural production activities in Bangladesh are dependent on rainfall patterns. As a result, the employment of agricultural labor force, following the pattern of crop production activities, is seasonal in nature. Provision of a regular supply of the water will bring about a shift in the pattern of cropping, along with a consequent change in the distribution of demand for labor in various seasons. The nature of this shift is presented in Table 15. The present seasonal distribution of demand for labor reflects non-irrigated conditions. The shift may be attributed to the provision of irrigation. The table has been constructed on the basis of various crop production operations and labor requirements for each operation for various crops. Fortnights, instead of the customary Aus, Aman, and Boro seasons, have been chosen as the units for the time period. However, these can be easily converted to the customary seasons. The reason for selecting fortnights, instead of other time-lengths, as the indicators of seasons is that most of the farm operations extend over a fortnight period and the balance of the fortnightly supply of family labor and demand for total labor in farm operations will give an approximate indication of the demand for hired labor for farm operations.

From Table 15 it will appear that with the irrigated cropping pattern the demand for agricultural labor will not only increase in the present peak periods of labor requirements, but will also create considerable demand for labor in the traditionally slack period. In the period from the last of December to the first week of March, no employment presently exists for the farm labor force. This period falls within the customary Boro season when about two-thirds of the cultivated area in the country remains fallow. Under present farming conditions, the peak period (being defined as the period when family labor on the average, falls short of total labor requirement) labor demands are limited to the fortnights approximately from the 7th of April to the 22nd of April, from the 22nd of July to the 22nd of August, and from the 22nd of November to the 7th of December.

Table 15. Change in the seasonal distribution of the level of demand for labor on a three-acre farm area, study area, Bangladesh.

Fortnights	Present Level (man-days)	Level After Irrigation Development (man-days)
(1) 7th Dec - 22nd Dec	8.1	106.2
(2) 22nd Dec - 7th Jan	--	16.7
(3) 7th Jan - 22nd Jan	--	14.4
(4) 22nd Jan - 7th Feb	--	5.6
(5) 7th Feb - 22nd Feb	--	11.0
(6) 22nd Feb - 7th March	--	6.0
(7) 7th March - 22nd March	6.8	--
(8) 22nd March - 7th April	4.0	58.4
(9) 7th April - 22nd April	52.5	100.3
(10) 22nd April - 7th May	4.0	6.4
(11) 7th May - 22nd May	9.0	14.6
(12) 22nd May - 7th June	7.0	8.6
(13) 7th June - 22nd June	3.0	5.4
(14) 22nd June - 7th July	2.0	3.6
(15) 7th July - 22nd July	--	--
(16) 22nd July - 7th Aug	43.0	60.6
(17) 7th Aug - 22 Aug	52.0	109.0
(18) 22nd Aug - 7th Sept	14.0	26.8
(19) 7th Sept - 22nd Sept	8.0	17.6
(20) 22nd Sept - 7th Oct	4.0	4.4
(21) 7th Oct - 22nd Oct	--	--
(22) 22nd Oct - 7th Nov	--	--
(23) 7th Nov - 22 Nov	--	--
(24) 22nd Nov - 7th Dec	34.4	51.2
Total for Year	251.8	526.8

During the fortnight from the 7th of April to the 22nd of of April, land preparation and sowing of Aus rice and Jute crops create one of the peaks in labor demand. The period from the 22nd of July to the 22nd of August coincides with harvesting activities of Aus and Jute crops, as well as land preparation and planting activities of Aman rice crops. These activities create another peak in the labor demand in this period. The third peak in the labor demand occurs in the fortnight from the 22nd of November to the 7th of December, mainly for harvesting of Aman crop.

Under the irrigated cropping pattern, the peak labor demand extends to the fortnight from the 7th of December to the 22nd of December, mainly for land preparation and planting of Boro rice and other winter crops and also to the fortnight from the 22nd of March to the 7th of April, for land preparation and raising of seedlings for Aus crops and Jute. In addition, the present peaks in the labor demand are further reinforced, the extent of reinforcement being evident from Table 15. However, no change in employment for the fortnight from the 7th of October to the 22nd of November appears possible by providing irrigation in the areas under this study.

Assuming that an average family has two labor units of workers, and that the average number of working days per fortnight is 13.5 days, the fortnightly supply of family labor is 27 man-days. Comparing this with the fortnightly demand for labor for crop production purposes, as presented in Table 15, one may obtain an approximate idea of the seasonal nature of demand for hired labor. Following this approach (under irrigated conditions as discussed in the previous paragraph), the demand for hired labor appears to be quite substantial and limited to the six peak periods of labor demand.

Employment Implication

From Table 15, it will be seen that the present total labor requirement for a 3-acre non-irrigated area is 251.8 man-days. After provision of irrigation and with the irrigated cropping pattern as outlined in Chapter IV and V, the total labor requirement goes up to 526.8 man-days. The increase in the requirement for labor is 109.2 percent. Using the results of the regression analysis and assuming a static wage rate, farm size, and ratio of high-yielding to low-yielding varieties, about 62 percent of the total increase in the demand for labor can be attributed to the new high-yielding varieties and the remaining 38 percent to the increased cropping intensity, made possible by irrigation.

The Bureau of Statistics conducted a study in 1964-65 to determine the amount of surplus labor in paddy cultivation in Bangladesh. The present study area falls within stratum IV of the sample of that study. The surplus labor in stratum IV was determined to be 40.2 percent.[7] Assuming this 40.2 percent surplus labor in agriculture before the provision of irrigation, we can calculate the extent by which this margin of surplus will be reduced by an irrigation program. The fourth plan tubewell irrigation program in the Mymensingh district (including Tangail) provides 2,620 tubewells for the area. Assuming 60 acres per tubewell, the total irrigatable area under these 2,620 wells is only 157,200 acres. According to the 1960 census, the total cultivated area in the district is 2,847,330 acres. Thus the area of 157,200 acres irrigated by tubewells is only 5.5 percent of the total cultivated area. An increase in the labor demand by 109 percent in only 5.5 percent of the total area is approximately equivalent to an increase of only 6.0 percent of the total labor demand in the entire area of the district. Therefore, a program of 2,620 tubewells in the Mymensingh district will reduce the surplus labor of 40.2 percent by only 3.6 percent points. Thus, there will still exist a surplus labor of 36.6 percent. Even if we assume an irrigation program in the district that will cover 20 percent of the cultivated area, this will leave a surplus labor of 27.2 percent. An irrigated area of about 60 percent of the cultivated area, in the district will wipe out the assumed surplus of 40.2 percent.

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[7] Bureau of Statistics, Surplus Labor in Paddy Cultivation, op. cit., p. 24.

So far, we have assumed a fixed level of surplus labor, wage rates, and farm sizes. The initial level of surplus labor at 40.2 percent may gradually rise with the growth rate of labor force. The farm size may not change very much; but the wage rate will most likely go up. As indicated by the wage elasticity of demand for labor, a 20 percent rise in the wage rate during the next five years will reduce the demand for labor by 8.6 percent. A final calculation of the extent of a possible surplus labor with any program of irrigation will have to take into consideration the effects of any likely changes in the wage rates, labor force, relative extent of the high-yielding to low-yielding rice varieties, and farm size. This discussion is based on the assumption that no labor-saving or labor-intensive new equipment are introduced in the cultivation. If such new machines are introduced in the production processes, their impact on employment will be an additional consideration in the estimation of the surplus labor.

Policy Implications

One major implication which becomes evident is the possibility of regional imbalance in labor supply and demand. If irrigation facilities are established in some regions and some other regions go without them, due to either technical or political reasons or to a short run scarcity of investible resources, a wide disparity between such regions will be created in the demand for labor. Given no change in the relative supply situations and assuming no great improvement in the mobility of labor between regions, this imbalance will give rise to higher wages, both real and monetary, and relatively better employment situations in the irrigated region. In the non-irrigated regions unemployment and underemployment situations will worsen relative to the irrigated areas, giving rise to a fall in the real wage rates. This situation might ultimately lead to social and regional unrest.

While considerable scope might exist in maintaining some regional parity in the allocation of public investment funds for irrigation, technical considerations may impose limitations to such a policy. In such situations public policy will have to either find ways and means to increase mobility of agricultural labor among regions, or allocate a relatively larger investment in non-agricultural development projects in the agriculturally depressed regions. The mobility of agricultural labor in Bangladesh is a subject which has not yet been studied (at least not known to us). Before formulating any policy to improve labor mobility among regions, it would be necessary to find out factors related to the mobility and the nature of such relationships.

The second implication of the impact of irrigation on employment generation relates to the peak period supply and demand for labor. Though studies have been conducted in the past to estimate the extent of overall surplus labor in agriculture, no study appears to have been directed to measure the supply and demand situation of labor in the peak periods. There is a general feeling that peak labor demand already has some restraining effect on the increase in cropping intensity in some areas, particularly the "Haor" areas of Bangladesh. With the establishment of an irrigation system, peak labor demand goes up quite substantially. From Table 15, it will appear that the highest peak in labor demand under irrigated conditions occurs in the winter season (7th December to the 22nd of December), which is usually a slack period in the existing system. Moreover, the peak labor demand under irrigated conditions, compared to the corresponding peak demand under the present conditions, is higher in every case, the increase ranging from 41 to 110 percent. This tremendous upsurge in the peak period labor demand may create temporary shortages of labor in the peak periods. This, in fact, may stand as an obstacle in the exploitation of the full potential of irrigation facilities. Specifically, the shortage of labor in the peak periods may restrict the expansion of cropping intensity that would otherwise be possible under irrigated conditions.

One solution to the possible problems of the peak period labor shortage would be partial mechanization. By partial mechanization, we mean introduction of mechanized farm operations in the peak period of labor demand. Such a proposal of partial mechanization will involve many questions to be answered before the mechanization program is formulated. Some of the important questions, for example, will be of the following nature: Which particular farm operation should be mechanized? What type of organizational structure will have to be formulated for mechanization programs? Should it be left to individual farmers or should cooperative societies be organized for this purpose? What facilities exist and what facilities would have to be created for adequate maintenance and operations of the proposed equipment? The answers to these questions are not within the scope of this study. Solutions to these questions will have to be found before formulating any partial mechanization programs. However, we intend to make one conditionary observation in this respect. If mechanization, in the name of partial mechanization, is allowed to go to the extensive length, it might cause severe income distribution and unemployment problems. The landless laborers, who depend for their earnings mainly on selling their labor services, may be rendered unemployed if mechanization goes beyond the limit that would keep such laborers employed.

The third policy implication is related to the non-agricultural development program vis-a-vis the increased agricultural employment opportunities in the winter (Boro) season, arising from irrigated farming. Most of the non-agricultural investment programs e.g., the construction of roads, houses, bridges, and dams are implemented in the winter season, because such activities are restricted in the monsoon rain. An increased demand for labor in the winter season in the agricultural sector may raise the real wage rates quite considerably in such industries. This rise of wage rate will have a choking effect on the expansion of such industries. The magnitude of such effect will depend on the rates at which irrigation facilities, non-agricultural programs and labor supply grow in the country. The rates of investment on irrigation and non-agricultural development programs are likely to grow faster than experienced in the past. The labor force is also likely to grow faster, mainly for two reasons. First, those who will be joining the labor market during the next decade or so are already born. The demographic structure is such that a large percentage of the population are in this lower age group which would tend to inflate the labor force in the coming years. Second, the labor participation rate is not likely to change very much; on the one hand, expected higher rates of school attendance will tend to lower the labor participation rate, and on the other hand, a higher participation of the women in the labor force may tend to raise the labor participation rate. On the balance one can surmise that the increased rate of investment in the agricultural and non-agricultural development programs will be accompanied by an increased rate of growth of the labor force. Because of this, the likely impact of any increased investment on irrigation programs on the wage rates in the non-agricultural sector may not be too substantial. However, such conclusions are only superficial. The purpose of this discussion in this section is only to indicate that such a situation may arise and the issue deserves special study.

CHAPTER VII

SUMMARY AND CONCLUSION

This chapter is organized in five sections. In section 1, a summary of the background of the study and the methodology employed is presented. In section 2, a brief indication of the expected cropping pattern under irrigated conditions is provided. Returns from investments in tubewell irrigation are summarized in section 3. Section 4 is devoted to a summary of the likely impact of irrigation on employment generation. Some important policy implications are listed in the final section.

Background and Methodology

The economy of Bangladesh is predominantly an agricultural one. Agriculture is the largest source of income and employment for the people. Growth of this important sector has been slow during the past. Lack of a controlled water supply for irrigation is one of the main causes of slow progress in agriculture. Crop production is heavily dependent on rainfall, which is often untimely and not in the required quantity. Because of an absence of rainfall in the winter season, cultivation is concentrated in the rainy season. Provision of a controlled water supply will increase production of agricultural products and greatly reduce the prevailing fluctuations in production. Before undertaking any large investment program in irrigation, however, it is necessary that adequate analytical studies are made to determine the rates of return from various methods of supplying irrigation water. It is also essential to know beforehand the likely policy implications that may arise from an irrigation program in agriculture. This information is important not only for a successful program, but also to ensure efficient resource allocation in the economy. The specific objectives of the study, therefore, were set as follows:

1. Determination of the monetary profitability of investment in tubewell irrigation in one area of Bangladesh.
2. Investigation of the relative merit, measured in monetary terms, of various technical alternatives available in the installation and operation of tubewells for irrigation.
3. Investigation of the impact of tubewell irrigation on employment generation.

Attempts were made to indicate the policy implications arising from the process of adjustment from non-irrigated to irrigated farming.

The study area falls in the district of Mymensingh. The tubewell areas selected are located in the flat, medium, and high lands around the west, south, and northern edges of the Madhuper Jungle tract, and also on the northern side of the old Brahmaputra River. The modal farm size in the area is about 3.00 acres, and most of the farms are owner operated. Soil characteristics vary from loamy to clay-loamy. Limited explorations of underground water strata indicate the presence of sufficient underground water in the area. The present cropping pattern in the area is one of Aus rice and jute in the Aus season, Aman rice in the Aman season, and various rabi crops in the winter season.

The main feature of the model used was to trace and measure the direct cost and benefit streams through time of two farming systems--one with irrigation and the other without irrigation. The difference in effects of these two systems was attributed to irrigation. The effects of an irrigation project on income generation were measured by the criteria of: 1) the internal rates of return (IRR), 2) the net present values (NPV), and 3) the benefit-cost ratio (B-C ratio). For measuring the impact of irrigation on employment generation, the ratio of marginal employment to investment was constructed. These criteria were used to evaluate the relative positions of the various alternatives available in the installation and operation of a tubewell in Bangladesh. A large number of sensitivity runs were conducted to evaluate the extent of variations in the results due to changes in the important parameters. The analysis of the returns from investment on tubewell was carried out in two phases. The results of the analysis in the first phase represented the outcome with a set of values of parameters considered most likely. In the second phase, the probable lowest and highest values of these parameters were selected to evaluate the variations of results in the directions of pessimism and optimism. Individual effects of important variables were determined through appropriate technique.

The sources of data were diverse. Farm management studies and other published and unpublished reports were consulted. The author collected data from 60 farmers in the 1968 Boro season. These data formed an important source. The regression analysis to determine the nature of the demand function for labor under irrigated conditions was mainly based on these data. The sources of data being so diverse it was necessary to combine all these sources to generate necessary information for the study.

Irrigated Cropping Pattern

A linear programming model was employed for determining the expected cropping pattern under irrigated conditions. A model farm with three acres of irrigated area was taken for the programming. The farmer was assumed to maximize monetary profit from the allocation of lands to various crops subject to a set of constraints. The constraints were as follows:

1. The maximum cropping intensity cannot exceed 234 percent.
2. The farmer ensures a minimum of 30 maunds of rice production for consumption.
3. The family labor available in one fortnight is 27 mandays.
4. The maximum working capital available is Rs 400 per season. (This is relaxed to Rs. 600 to see the variation).

The crop production activities included in the model were the low and high-yielding rice varieties, jute, wheat, and potato. The cropping pattern, with the most probable assumptions of prices and yield rates, was as follows:

Aus Season--Aus (IRRI) rice on 1.59 acres and jute on 0.91 acres;

Aman Season--Aman (IRRI) rice on 2.20 acres;

Boro Season--Boro (IRRI) rice on 1.79 acres and potato on 0.51 acres.

The net income (return to family labor, fixed capital, and land) with the cropping pattern was calculated to be Rs. 2910. The net income to individual farmers with irrigated crops was estimated to be more than double the present income.

Some interesting results were obtained from the model. First, an indication of the extent of a fall in the profitability of jute relative to that of rice was obtained. With the existing relative prices of jute and rice, jute production may not be undertaken by the farmers in the irrigated areas. The possibility of a higher price of jute is remote. Competition of synthetic fibers with jute in the international market suggests a declining future world price of jute. These considerations point out the importance of an effort to bring about a cost-minimizing technological breakthrough in jute, like the one in rice. Second, it was found from the results that the working capital restriction imposed a limit on the expansion of the cropping intensity. A working capital below Rs 400 per season may not lead to a cropping intensity of 234 percent. This points out the need of a judicious credit program. With farm practices under non-irrigated conditions most of the productive credit needs are limited in the Aus season. Under an irrigated farming system the demand for working capital will be highest in the Boro season.

As in the case of rice and jute in the Aus season, the relative profitability of winter vegetables (potato) will fall compared to the Boro (IRRI) rice. Thus, the farmers will tend not to grow such vegetables if the prices are not higher and no new technology is introducted to increase productivity. Some rise of these prices is expected from an expected higher demand. But this may not be sufficient. Thus, an introduction of new high yielding vegetables may be an important necessary program.

The process of adjustment from a non-irrigated to an irrigated farming system will require a trained agricultural extension service. The farmers will have to be taught cropping practices appropriate for growing a crop, sometimes a new one, under irrigated conditions. An adjustment in the desired direction will not be an automatic process. It will require guidance, particularly in the first few years of the supply of water.

Returns from Investment in Tubewell Irrigation

Rates of returns from investment in tubewell irrigations were calculated for 24 technical alternatives in the installation and operation of wells. All these alternatives were considered technically feasible in Bangladesh. The alternatives were composed of the following elements:

1. Three techniques of drilling--waterjet method, cable percussion method, and power drilling method.
2. Two types of pumps--centrifugal and turbine pumps.
3. Two types of screens--fiberglass and brass screens.
4. Two types of engines--low speed and high speed diesel engines.

In the first phase of the analysis the major assumptions were as follows:

1. The maximum coverage by a well was 60 acres and this was gradually reached in 3 years.
2. A project life of 20 years--replacement of the engine and pump was provided at the fifth and tenth year respectively.
3. The opportunity cost of unskilled labor was assumed at 25 percent of the market wage rate.
4. The assumed yield rates of crops without irrigation were--Broadcast Aus 18 maunds per acre, jute 15 maunds per acre, Aman (deshi) 19 maunds per acre, potato 65 maunds per acre, and mustard 5 maunds per acre. Rice yields are in terms of paddy.
5. The assumed yield rates of crops with irrigation were--Aus (IRRI) 40 maunds per acre, jute 25 maunds per acre, Aman (IRR) 40 maunds per acre, Boro (IRRI) 45 maunds per acre, and potato 90 maunds per acre.
6. The assumed relative prices of products were--rice Rs. 19 per maund, Jute Rs. 25 per maund, potato Rs. 12 per maund, and mustard Rs. 40 per maund.

With these assumptions the internal rates of returns (IRR) of the 24 alternatives ranged from the lowest of 24.6 percent to the highest of 40.1 percent. The highest IRR was obtained with the alternative having centrifugal pump, low-speed diesel engine, brass screen, and the well drilled either by waterjet method or cable percussion method. The lowest IRR was associated with the alternatives having turbine pump, high-speed diesel engine, fiberglass screens, and the wells drilled by power drilling method. A uniform percent reduction in the net benefit streams did not change the rankings of the alternatives, but it affected the rates of return. The IRR of the alternative having turbine pump, low-speed diesel engine, brass screen, and drilled by power drilling technique fell from 24.6 percent to 22.8 percent for a reduction in the net benefits by 6 percent. When the net benefits were further reduced by another 6 percent, the IRR of the same alternative shrank further to 21.1 percent. The fall in IRRs due to uniform percent reductions in the benefit streams appeared to be almost linear.

The independent effects of each of the mutually exclusive categories of pumps, engines, techniques of drilling, and services were analyzed. The choice of the power drilling method over the other two methods of drilling reduced the IRR by about 8 points. The choice of a turbine pump over centrifugal reduced the IRR by about 5 points. The other two choices were relatively less important. The choice of a low-speed diesel engine over a high-speed diesel engine improved the IRR by only 2.2 percent points.

Similarly, the selection of a brass screen instead of a fiberglass screen improved the IRR by 1.1 percent points.

In the second phase of the analysis tests were conducted to determine the stability of the results obtained in the first phase, in response to changes in their underlying assumptions. For keeping the scope of analysis within a manageable limit, the technical alternatives were classified as low, medium, and high cost wells. The well with a capital cost of about Rs. 50,000 was defined as low cost. Similarly the wells with capital costs of about Rs. 70,000 and Rs. 90,000 were defined as medium and high cost respectively. The sensitivity of the results with these three categories of wells to changes in the wage rates and time lags, were separately analyzed. Then all the possible combinations of high and low levels of each of the assumptions on yield rates, relative prices, wage rates, and the maximum rate of utilization of the wells with the three classes of wells were undertaken for sensitivity analysis.

When the cost of unskilled labor was valued at 10 percent of the market wage rate (initially valued at 25 percent), the IRR of the low cost well increased from 40.1 percent to 44.1 percent. For the same treatment of labor cost, the IRR of the medium cost well increased from 30.4 percent to 33.4 percent and that of high cost wells from 24.6 percent to 27.1 percent. When the cost of unskilled labor was assumed at 50 percent of the market wage instead of 25 percent, the IRR of the low cost well fell from 40.1 to 33.5 percent. The IRR of the medium cost well fell from 30.4 percent to 25.0 percent and that of high cost wells from 24.6 percent to 19.9 percent for the same assumption of labor cost. With the assumption of the cost of labor equal to the market wage rate, the IRRs were greatly reduced. It was 17.8 percent in the case of low cost wells, 12.2 percent in the case of medium cost wells, and 8.8 percent in the case of high cost wells. In the case of high cost wells the net present value was negative (the IRR was less than the discount rate which was assumed to be 10 percent).

In the analysis of the first phase the assumed time lag to reach the full utilization of a well was three years. In the second phase of the analysis, two time lags, one of five years and the other of seven years were assumed. For a lag of five years instead of three, the IRR reduced by 7.4 percent points in the case of the low cost well, by 5.1 percent points in the case of the medium cost well, and by 3.8 percent points in the case of the high cost well. The reductions in the IRRs were by 11.7, 8.2 and 6.3 percent points in the cases of the low, medium and high cost wells respectively when the lag was extended from three to seven years.

The results obtainted in the first phase varied from the lowest IRR of 24.6 percent, associated with the high cost well, to the highest IRR of 40.1 percent, associated with the low cost wells. With the low and high levels of each of the factors of yield rates of crops, prices of output, and rate of utilization of the wells (Table 9, Chapter V) the range of the results widened. The results varied from the lowest IRR of -1.4 percent to the highest IRR of 95.3 percent. The lowest IRR was associated with the combination of all low levels of each of the factors and the high cost well. The highest IRR was associated with the combination of high levels of each of the factors and the low cost wells. The probability of having a situation when both high prices and high yield rates or low prices and low yield rates may occur is, perhaps, very low. The more probable outcomes are those with low price and high yield rates or high price and low yield rates. The results of such combinations ranged from the lowest IRR of 14.7 percent to the highest IRR of 59.5 percent. The average IRR of these combinations was 32.6 percent.

The results were very sensitive to any changes in the yield rate, the extent of lag, the relative prices, and the rate of utilization of the tubewell capacity. A change in the yield rates of crops from the low to the high levels caused, on the average, a change of 31.3 percent points in the IRR. The changes in the IRR caused by changes in the price and the rate of utilization factors were almost the same. The IRR increased by 21.0 percent points, on average, for the change in the rate of utilization from the low to the high level. For a similar change in the relative prices of output, the IRR changed by 23.0 percent points. The effects of probable variations in capital costs, as represented by the three types of wells, were relatively low in magnitude.

Impact on Employment

For evaluation of the 24 technical alternatives available in designing and installation of tubewells, in terms of their contribution to employment generation, E/K ratios for all these alternatives were constructed. The E/K ratio was defined as the present discounted value of the unskilled labor used per unit of project investment cost. The creation of employment in terms of man days or man years by a tubewell project was also calculated. This magnitude of job creation indicates the extent by which the existing surplus labor in agriculture could be reduced. In addition, the nature of demand functions for labor under a system of irrigated rice farming was analyzed.

The ranking of the 24 technical alternatives in terms of their E/K ratios displayed the same pattern as the ranking in terms of the IRR, NPV or B-C ratio. The low cost wells were superior to medium and high cost wells from the points ov view of both income and employment generation. The E/K ratio ranged from 1.848 for a high cost well to 3.378 for a low cost well. The medium cost well had a E/K ratio of 2.387.

It was estimated that the installation and operation of a tubewell would generate an additional 139,765 man days of work for unskilled agricultural labor over a period of 20 years (project life). It implies the creation of permanent jobs for about 21.2 workers per well. The generation of employment for skilled workers was estimated to be 9,900 man days over the period of 20 years. This is equivalent to the creation of permanent jobs for 1.5 workers per tubewell. Most of the jobs that would be created by an irrigation well were found to be limited to the crop production activities. Of the total additional employment, only 7 percent was estimated to originate from the tubewell installation and operation activities.

The nature of the demand function for agricultural labor in irrigated rice production was determined using cross-section data from the North Mymensingh and the North Dacca areas. Regression analysis using the technique of ordinary least squares was employed to estimate the demand functions. The results of this analysis may be listed as follows:

a. The effect of variety is by far the most important factor in generating demand for labor. On the average, the demand for total labor per acre was found to go up by 112 percent due to a shift from a low-yielding local variety to a high-yielding new variety. The demand for hired labor was estimated to go up by 149 percent for a similar shift.

b. Even if farming in Bangladesh is of a subsistence type, there appears to be some inverse relationship between the demand for labor in farming and the money wage rate. The wage elasticity of demand for all labor is -0.46, and that of hired labor is -1.55. However, this effect is somewhat mixed up with the regional effects and should be taken with caution for regional purposes.

c. The per acre demand for all labor is negatively related with farm size, and the per acre demand for hired labor is positively related with farm size. The size elasticity of demand for all labor is -0.07, and that for hired labor is 0.25.

d. With the relatively increasing allocation of land under the high-yielding variety, compared to that under low-yielding variety, the demand for both total and hired labor will grow. With an increase of the ratio of the acreage under high-yielding to low yielding varieties by one percent, the demand will likely increase by only 0.03 percent for total labor demand, and by 0.25 percent for hired labor demand.

The seasonal nature of the demand for agricultural labor is expected to undergo a substantial change due to the controlled supply of irrigation water. It was found that with the irrigated cropping pattern the demand for agricultural labor would not only increase in the present peak periods of labor requirement, but would also create considerable demand for labor in the traditionally slack periods.

The incremental labor requirement for an irrigated cropping pattern was estimated to be 109 percent over that for a non-irrigated cropping pattern. Using the results of the regression analysis, and assuming a static level of wage rate and farm size, about 62 percent of the increased demand for labor could be attributed to the new high-yielding varieties. The remaining 38 percent was attributable to the increased cropping intensity made possible by irrigation.

The Bureau of Statistics estimated the surplus labor to be 40.2 percent in the areas similar to the one under present study. It was estimated that if about 60 percent of the total cultivated land in these areas could be brought under irrigation the surplus labor of 40.2 percent would be fully wiped out. However, this estimate was based on the assumptions of static wage rate, farm sizes, labor-neutral technology, and a static labor force. Any changes in these parameters would accordingly require an adjustment in the estimate.

Important Policy Implications

a. A research program for delivering a technological breakthrough in jute production, like the one in rice, is important if jute has to maintain its competitive position vis-a-vis rice. Similar programs for winter crops are also necessary for preventing a large scale allocation of land to Boro (IRRI) and thereby reducing production of winter vegetables and other winter crops.

b. Lack of working capital may work as a constraint to expansion in cropping intensity under irrigated conditions. For a farmer with a three acre irrigated area, the minimum working capital was estimated to be about Rs. 1,000 per year with more than Rs. 400.0 being required in the Boro season. How much of this working capital will be necessary to be financed externally, depends on the incremental savings rate of the farmers.

c. The ratio of return from investments in tubewells in general, and low-cost tubewells in particular, were found to be quite high. For an efficient resource allocation, it is therefore, necessary to compare these returns with alternative investment proposals within the water subsector as well as within the agricultural sector.

d. The techniques of well drilling, types of pumps used, time lags in reaching a full utilization of irrigated area, rate of utilization of wells, price of products, and the yield rates of crops are the important elements which were found to have considerable influence on the rate of return. Policies related to these factors are, therefore, important in a successful tubewell irrigation program.

e. A comprehensive training program in drilling and other skilled works is an important prerequisite for a large low cost tubewell irrigation program in the country.

f. The industrial program of the country should include the requirement of a tubewell program in agriculture. The combined demand for low-speed diesel engines and pumps in agriculture and transportation sectors will provide a substantial base for production of such machinaries within the country.

g. For a successful irrigation program, the marketing facilities within the country will also have to be developed. The development of the marketing facilities will have to be tuned to the irrigation programs.

h. Adjustment from a non-irrigated to an irrigated farming system will not be automatic. As such research and extension activities will be necessary in aiding such adjustments.

i. A distribution of investments in irrigation which is not uniform in all regions will create a wide disparity in the demand for labor between such regions. Given no change in the relative supply situations and assuming no great improvement in the mobility of labor between regions, this imbalance will give rise to higher wage rates and a relatively better employment situation in the irrigated regions. The impact of this imbalance will be felt not only in potential total production but it may lead to social unrests also. One solution to this problem would be to allocate more resources in nonagricultural sector in the agriculturally depressed regions or to encourage mobility of labor among regions or to formulate a policy encompassing both.

j. The peak period supply and demand for labor deserve special attention. Provision of irrigation will increase both the number of peaks in a year and the total demand for labor in the peak periods. The traditionally slack period of labor demand in the winter season will turn out to be the one with the highest demand for labor. In the existing peaks, demand for labor was estimated to go up by 41 to 110 percent. A peak-period shortage of labor may restrict the expansion of cropping intensity. One solution to this problem would be to introduce a selective mechanization program.

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APPENDIX I

Normal monthly rainfall and low-high ranges for selected recording stations, Bangladesh, 1953-1963 (in inches).

Months	Chittagong			Comilla			Narayanganj			Mymensingh			Sreemangal		
	low	high	nor.	low	high	nor.	low	high	nor.	low	high	nor.	low	high	nor.
January	0.0	2.6	0.3	0.0	2.0	0.3	0.0	3.7	0.3	0.0	4.5	0.2	0.1	1.3	0.4
February	0.0	1.0	1.1	0.0	2.0	1.2	0.0	1.9	1.2	0.0	2.1	0.9	0.0	3.2	1.5
March	0.0	10.0	2.5	0.3	4.0	3.0	0.3	5.9	2.4	0.2	4.2	1.1	0.1	7.6	1.9
April	0.0	2.3	5.9	1.2	4.5	5.9	1.3	11.6	5.4	1.2	9.4	5.5	7.9	11.0	3.3
May	1.3	25.0	10.4	3.2	10.7	12.4	2.8	14.1	9.6	1.8	18.5	11.4	8.3	22.7	8.1
June	14.1	37.4	21.0	10.6	38.5	18.3	9.2	34.1	31.4	18.1	22.9	17.6	22.1	30.0	12.3
July	8.3	51.3	23.5	15.1	26.0	16.4	11.2	22.0	13.0	10.3	16.3	16.0	4.7	18.8	13.9
August	12.4	33.8	20.4	5.3	14.6	17.2	3.5	16.4	13.3	4.5	30.6	15.5	9.8	18.8	14.3
September	7.5	16.6	12.6	8.5	20.0	11.3	3.6	12.7	9.8	9.6	24.6	14.1	10.4	16.2	11.8
October	6.3	22.8	7.1	1.7	9.3	6.7	1.4	8.7	5.3	5.1	8.9	6.3	1.8	7.7	7.1
November	0.0	10.5	2.2	0.0	5.8	1.3	0.0	3.4	1.0	0.0	0.8	0.9	0.0	8.1	1.4
December	0.0	0.2	0.6	0.0	0.0	0.3	0.0	0.1	0.2	0.0	0.4	0.1	0.0	0.2	0.3
Total	49.9	213.5	107.3	73.2	233.3	140.2	45.9	136.6	94.3	41.2	133.0	79.0	33.3	134.6	92.9

APPENDIX I (continued)

Months	Barisal			Khulna			Jessore			Faridpur			Bogra		
	low	high	nor.	low	high	nor.	low	high	nor.	low	high	nor.	low	high	nor.
January	0.0	4.2	0.4	0.0	3.5	0.4	0.0	1.0	0.4	0.1	2.3	0.4	0.3	4.5	0.4
February	0.0	0.4	0.9	0.0	1.0	0.9	0.2	1.5	1.3	0.0	1.4	1.2	0.2	0.3	0.8
March	0.0	2.2	2.1	0.0	0.7	1.6	0.2	4.5	1.9	0.0	5.1	2.1	0.0	3.8	1.1
April	0.1	3.6	4.2	0.3	3.8	2.9	0.4	2.4	3.5	0.6	6.5	4.7	0.0	1.9	2.2
May	1.1	13.4	8.3	1.5	10.5	7.6	0.6	2.4	8.1	6.5	9.6	9.6	0.1	6.3	8.4
June	9.5	30.8	16.1	9.5	21.7	12.5	7.2	26.6	12.2	6.4	31.4	12.8	5.7	22.4	12.0
July	9.9	21.6	16.3	9.4	20.6	14.4	7.6	13.6	12.2	12.8	26.0	15.0	7.5	21.8	12.8
August	12.7	17.1	14.9	5.6	11.0	13.8	8.2	18.7	11.0	8.3	17.4	12.1	7.2	21.5	13.0
September	5.6	28.3	10.1	5.5	13.5	7.9	3.2	14.8	8.5	3.7	12.4	9.3	7.3	13.6	11.3
October	4.3	14.7	6.1	2.0	6.5	4.3	1.2	4.3	4.6	1.5	9.7	4.9	2.9	10.6	5.1
November	0.0	7.1	1.5	0.0	4.5	1.1	0.0	2.5	1.0	0.0	2.9	1.1	0.0	1.5	0.8
December	0.0	0.7	0.3	0.0	0.2	0.2	0.0	0.3	0.2	0.0	0.9	1.2	0.0	0.4	0.1
Total	50.8	143.2	89.6	65.2	145.6	76.3	28.6	92.7	64.9	39.9	125.6	74.4	31.2	109.6	68.0

Appendix I (Continued)

Months	Stations											
	Denajpur			Pabna			Rajshahe			Rangpur		
	low	high	nor.	low	high	nor.	low	high	nor.	low	high	nor.
January	0.0	3.7	0.4	0.0	3.4	0.3	0.0	5.1	0.5	0.3	3.9	0.3
February	0.0	0.3	0.6	0.0	1.9	1.1	0.0	1.9	0.7	0.0	1.0	0.7
March	0.0	0.2	0.7	0.0	5.1	1.4	0.0	1.6	1.2	0.0	3.3	1.0
April	0.0	2.7	2.1	0.0	2.0	2.9	0.0	1.3	1.7	0.0	5.8	3.1
May	0.2	6.4	7.3	0.0	7.3	7.1	0.0	6.9	5.5	3.4	15.2	10.8
June	10.6	18.0	13.6	11.5	18.3	11.8	9.1	11.5	11.2	17.2	38.9	17.8
July	14.8	19.9	15.5	8.9	14.0	11.8	7.7	15.9	11.1	13.8	34.0	16.0
August	11.1	24.7	13.7	5.9	12.4	10.3	4.3	16.7	10.3	7.8	22.7	13.8
September	5.0	15.1	13.1	10.4	18.8	8.3	2.9	13.1	9.8	1.4	23.7	14.1
October	1.3	8.7	4.8	1.0	6.1	5.4	0.0	8.2	3.8	0.8	16.7	5.8
November	0.0	1.0	0.4	0.0	2.2	1.0	0.0	2.6	0.5	0.0	0.7	0.4
December	0.0	0.0	0.1	0.0	0.9	0.2	0.0	0.4	0.1	0.0	0.0	0.1
Total	43.0	100.7	72.3	37.7	92.4	61.5	24.0	85.2	56.4	44.7	165.9	83.9

Source: East Pakistan (Bangladesh), Economic and Engineering Study: Foodgrain Storage and Handling, (Kansas City, U.S.A., Weitz-Hettelsater Engineers, 1966), p. 10.

APPENDIX II

Percentages of number of farms, farm area and cultivated areas under various size-group--Bangladesh, 1960.

Size of Farm (Acres)	Percent of Total Number	Percent of Total Area	Percent of Cultivated Area
Under 0.5	13	1	1
0.5 to under 1.0	11	2	2
1.0 to under 2.5	27	13	13
2.5 to under 5.0	26	26	27
5.0 to under 7.5	12	19	19
7.5 to under 12.5	7	19	19
12.5 to under 25.0	3	14	14
25.0 to under 40.0	*	3	3
40.0 and over	*	2	1
Bangladesh	100	100	100

*Means percentage less than 0.5.

Source: Pakistan, Ministry of Food & Agriculture, Agricultural Census, 1960, Vol. I. (Karachi, Census Organization, 1962), p. 29.

APPENDIX III

Cropping pattern, Bangladesh.

Crops	Average 1955/56 to 1959/60 (1,000 acres)	Average 1960/61 to 1964-65 (1,000 acres)	Percent Change
Aus Rice	5837.8	6319.2	8.2
Aman Rice	13484.5	14518.5	7.7
Boro Rice	791.7	1041.5	31.6
Other Cereals	372.2	373.1	small
Pulses	1154.4	934.0	-19.1
Oilseeds	790.2	805.0	1.9
Spices	302.8	300.9	small
Sugars			
Sugarcane	258.5	317.9	23.0
Others	30.8	19.4	-37.0
Fibers			
Jute	1466.1	1732.3	18.2
Others	69.1	58.6	-15.2
Drugs and Narcotics	519.4	371.5	-28.5
Fruits (annual)	225.8	257.1	1.3
Fruits (seasonal)	284.1	99.7	-64.9
Fodder	77.0	62.3	19.1
Mulberry	1.8	2.5	38.9
Other food crops			
Potato	83.4	138.7	6.7
Sweet potato	94.9	101.3	66.3
Others	310.6	223.7	-28.0
Other non-foods	58.9	21.9	-62.8
Tea	76.5	81.5	6.9
Vegetables	456.0	281.5	-38.3
Total	26746.0	28098.8	5.1

APPENDIX III (con't.)

Crops	Average 1955/56 to 1959/60	Average 1960/61 to 1964/65	Percent Change
Cropping Intensity A	121.6	127.7	5.0
Cropping Intensity B	139.7	146.8	5.1
Cropping Intensity C	124.4	130.7	5.1

Note: Assumed cultivated area for A, 22.1 million acres; for B, 19.4 million acres; for C, 21.5 million acres.

Source: Compiled from: Department of Agriculture, Agricultural Production Levels (Dacca, Agriculture Department, 1968).

APPENDIX IV

Status of underground water utilization in Bangladesh, 1969.

Operational Agencies	Number of Wells	Total Capacity in Cusec	Remarks
1. Agriculture Ministry	25	50	(including 10 wells in Savar Dairy Farm)
2. Sugar Mills			
a) Thakurgaon	7	14	
b) Mahimganj	3	6	
c) Other Mills	5	10	
3. WAPDA			
a) Thakurgaon	380	1140	
b) Test Wells	18	54	
4. Comilla	160	272	
5. A.D.C.			
a) Seed Farms	19	38	
b) For Farmers	421	842	
6. Tea Gardens	15	30	
7. Public Health*	170	351	
Total	1223	2807	

*Excludes hand operated small tubewells.

Source: Compiled from: Harold Rinnan, Review of Irrigation Wells Development in East Pakistan (Dacca, USAID, 1969), and Govt. of Pakistan, Ministry of Agriculture Farm Mechanization in Pakistan, (Rawalpindi, 1968).

APPENDIX V

Farm sizes and tenure in Mymensingh District,[1] Bangladesh, 1960.

Items	Under 0.5	0.5 to under 1.0	1.0 to under 2.5	2.5 to under 5.0
No. of farms	107,690	89,940	266,350	271,580
Total farm area (acres)	26,164	64,986	456,305	958,631
Total cultivated area (acres)	16,804	52,160	401,500	863,994
Average cultivated area (acres)	0.16	0.58	1.51	3.18
% of total No.	11	10	29	29
% of total cultivated area	1	2	14	30
% of owner farms	90	71	50	42
% of owner-cum-tenant farms	8	27	49	57
% of tenant farms	2	2	1	1
% of owner area	91	84	77	78
% of tenant area	9	16	23	22

*means less than 0.5 percent; all figures rounded.

[1]Includes Tangail

Source: Compiled from: Pakistan, Ministry of Agriculture, Agricultural Census, 1960, Vol. 1, (Karachi, Census Organization, 1962).

5.0 to under 7.5	7.5 to under 12.5	12.5 to under 25.0	25.0 to under 40.0	40.0 and over	Total Mymensingh	Total Bangladesh
105,620	63,800	24,250	2,180	490	931,900	6,138,480
632,971	596,104	392,415	63,835	27,680	3,219,091	21,725,827
570,570	528,685	341,610	52,976	19,030	2,847,329	19,138,109
5.40	8.29	14.09	24.30	56.49	3.06	3.12
11	7	3	*	*	100	-
20	18	12	2	1	100	-
48	57	67	79	76	55	61
51	43	33	21	24	44	37
*	*	*	*	0	1	2
83	89	93	96	91	83	82
17	11	7	4	9	17	18

APPENDIX VI

Distribution of crop acreage by size-groups of farms, Mymensingh, Bangladesh, 1960.

Size of Farm (Acres)	Total Cropped (Percent)	Crop Area as Percent of Total Cropped					
		Rice	Jute	Wheat	Fodder	Fruit	Others
Under 0.5	100	58	15	1	*	2	24
0.5 to under 1.0	100	73	12	1	*	1	13
1.0 to under 2.5	100	76	10	5	*	*	9
2.5 to under 5.0	100	76	9	1	1	*	13
5.0 to under 7.5	100	76	9	1	1	*	13
7.5 to under 12.5	100	75	9	1	1	*	14
12.5 to under 25.0	100	75	9	1	1	*	14
25.0 to under 40.0	100	74	8	1	2	*	15
40.0 and over	100	76	7	*	1	*	15
All	100	76	9	1	1	*	14

*Means percentage less than 0.5.

Source: Pakistan, Ministry of Agriculture, <u>Agricultural Census, 1960</u>, Vol. I. (Karachi, Census Organization, 1962), p. 176.

APPENDIX VII

Theoretical Basis for Benefit-Cost Analysis

1. We shall state briefly the derivation of benefit-cost analysis from the classical theory of welfare economics.

Assume that there are n individuals composing our economy. An individual i has preferences which can be described by a utility surface

$$U_i = U_i(X_{i1}, \ldots. X_{im}) \tag{1}$$

where X_{ij} is a quantity of the economic good j enjoyed by i, of a product if it has a positive sign, of a factor if it is negative. If i has an income Y_i he will maximize his economic welfare by maximizing

$$\Phi = U_i(X_{i1}, \ldots. X_{im}) - \lambda_i(P_1X_{i1} + \ldots. + P_mX_{im}-Y_i) \tag{2}$$

where p_j is the price of jth good (j = 1, ... m).

If the utility surface is convex, the maximum conditions are

$$\lambda_i = \frac{\partial U_i}{dX_{i1}} \cdot \frac{1}{P_1} = \ldots. = \frac{\partial U_i}{\partial X_{im}} \cdot \frac{1}{P_m}\ ; \tag{3}$$

λ is the marginal utility of income and assumed to be constant in the relevant range.

Suppose i receives an increment of income ΔY_i which he uses to pruchase--or to cease to supply--ΔX_{i1}, ..., ΔX_{im}. His change in welfare will be[1]

$$\Delta U_i = \frac{\partial U_i}{\partial X_{i1}} \Delta X_{i1} + \dots + \frac{\partial U_i}{\partial X_{im}} \Delta X_{im} \tag{4}$$

But since $\lambda_i = \frac{\partial U_i}{\partial X_{ij}} \cdot \frac{1}{P_j}$

We can write

$$\Delta U_i = \lambda_i P_1 \Delta X_{i1} + \ . \ . \ . + \lambda_i P_m X_{im}$$

$$\text{or} \quad \Delta U_i = \lambda_i \sum_{j=1}^{m} P_j \Delta X_{ij} \tag{5}$$

which only says that the change in the welfare of i is equal to his marginal utility of income times the change in his income. We define a social welfare to be

$$\Delta W = \sum_{i=1}^{n} \Delta U_i$$

$$\text{so} \quad \Delta W = \sum_{i=1}^{n} \sum_{j=1}^{m} \lambda_i P_j \Delta X_{ij} \tag{6}$$

To abstract from welfare effects of changes in the income distribution, we assume that the marginal utility of income is the same for all individuals, or

---

[1]The higher order terms of the Taylor expression are zero because $\partial U_i / \partial X_{ij}$ are constant.

$$\lambda_i = \ldots = \ldots = \lambda_n = \lambda \tag{7}$$

Also let $\sum_{i=1}^{n} \Delta X_{ij} = \Delta X_j$ (8)

Then $\Delta W = \lambda \sum_{j=1}^{m} P_j \Delta X_j$ (9)

Since the utility function is uniquely determined only up to a monotonic transformation, and since our social welfare function is of the same degree of arbitrariness, we can write

$$\Delta W = \sum_{j=1}^{m} P_j \ \Delta X_j \tag{10}$$

If a change in economic welfare involves no change in the amount of factors supplied by individuals, or if national income is defined to include the negative values of factor services, ΔW is equal to the change in national income.

2. A public project transforms economic goods converting inputs into output. Let $X_1, \ldots, X_k$ be quantities of outputs and $X_L, \ldots X_m$ be the quantities of inputs. Let the production function of the project be represented by

$$K(X_1, \ldots X_K, X_L, \ldots X_m) = 0 \tag{11}$$

The increase in social welfare is maximized by maximizing

$$\Psi = \sum_{j=1}^{m} P_j \Delta X_j - \mu K(X_1, \ldots X_K, X_L, \ldots X_m) \tag{12}$$

If the second-order conditions are met, the maximum conditions are

$$P_j - \mu\frac{\partial K}{\partial X_j} = 0 \ (j = 1, \ldots K, L, \ldots m) \tag{13}$$

This implies the usual profit maximizing conditions of firms in the perfect competition:

$$\frac{P_j}{P_r} = \frac{\partial X_r}{\partial X_j} \tag{14}$$

3. Introducing the concepts of benefits and costs, let us define the total benefit of a project to be

$$B = P_1 \Delta X_1 + \ldots + P_K \Delta X_K \tag{15}$$

and total cost to be

$$C = P_L \ \Delta X_L + \ldots P_m X_m \tag{16}$$

Then (10) can be rewritten

$$\Delta W = B-C \tag{10a}$$

and (12) can be rewritten

$$\Psi = B-C - \mu K(X_1, \ldots X_K, X_L, \ldots X_m) \tag{12a}$$

The maximum condition (13) becomes

$$\frac{\partial B}{\partial X_j} - \mu\frac{\partial K}{\partial X_j} = 0 \ (j = 1, \ldots k) \tag{13a}$$

and $\frac{\partial C}{\partial X_r} - \mu\frac{\partial K}{\partial X_r} = 0 \ (r, = 1, \ldots m)$

which imply

$$\frac{\partial B}{\partial X_j} \frac{\partial X_j}{\partial K} = \frac{\partial C}{\partial X_r} \cdot \frac{\partial X_r}{\partial K}$$

or $\frac{\partial B}{\partial C} = 1$ (14a)

In words, this condition means that the marginal benefits should equal marginal cost, or that the benefit-cost ratio for marginal projects and for marginal project segments should be equal to one.

4. So far we have assumed that the outputs $X_1, \ldots X_K$ are marketable, that their prices have been established in perfect markets, and that individuals have been able to adjust to the prices. But, some of the outputs are not marketable; they are collective goods. Formally, this means that if the good G is a collective good, it will appear in the utility function (1), but the individual not be free to allocate his expenditure in accordance with the maximum condition (3). We have no assurance, therefore, that the subsequent analysis holds.

Samuelson has shown that there is no general solution to this problem, and that no voting or interviewing scheme can be devised which will elicit truthful responses about the marginal utility of a collective good.[2]

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[2]Samuelson, P. A., "The Pure Theory of Public expenditures," Review of Economics and Statistics (November, 1954), pp. 387-389.

But for collective goods like flood control and navigation, the value to individuals can be discovered from actual expenditures on alternative methods of achieving the same objective, such as alternative transportation charges that are actually paid, and post flood repair costs.[3] If the price paid for an amount ΔX_{ia} of the alternative by individual i is P_a then

$$\Delta Y_i = P_a \; \Delta X_{ia} \tag{17}$$

that is the collective good releases income equal Y_i, which can be spent by i on other goods. The change in welfare of i is $\Delta Y_i \lambda_i$ or $\lambda_i P_a \Delta X_{ia}$

The change in the social welfare due to G is

$$\Delta W^a = \sum_{i=1}^{n} \lambda_i P_a \; \Delta X_{ia} = \lambda \sum_{i=1}^{n} P_a \; \Delta X_{ia} \tag{18}$$

If a project has some marketable and some non-marketable outputs, the change in social welfare can be written

$$\Delta W = \sum_{j=1}^{m} P_j \; \Delta X_j + \sum_{i=1}^{n} P_a \; \Delta X_{ia} \tag{10a}$$

and its benefit can be written

$$B = \sum_{j=1}^{K} P_j \; \Delta X_j + \sum_{i=1}^{n} P_a \; \Delta X_{ia} \tag{15a}$$

---

[3] Eckstein, Otto, Water Resource Development, p. 74.

The rest of the analysis remains unchanged.

5. We now introduce a budgetary constraint into the analysis. Let us suppose that we seek to maximize the increase in economic welfare attributable to a water resource program, the limits of which are imposed by a constraint on the total amount of government expenditure for this field.

We express the production relations of each project through a benefit function

$$B_L = B_L(C_{Lg}, C_{Lr}), \quad (L = 1, \ldots n) \tag{19}$$

Where B_L is the total benefit of project L, C_{Lg} is the government cost of the project and C_{Lr} is its other associated costs. The budgetary constraint is expressed by

$$\sum_{L=1}^{n} C_{Lg} \leqslant D \tag{20}$$

where D is the total amount of government money available. To maximize the increase in welfare, we maximize the lagrangean expression

$$\Omega = \sum_{L=1}^{n} B_L(C_{Lg}, C_{Lh}) - \sum_{L=1}^{n} C_{Lg} - \sum_{L=1}^{n} C_{Lh} - \nu\left(\sum_{L=1}^{n} C_{Lg} - D\right) \tag{21}$$

The first order maximum condition

$$\frac{\partial B_L}{\partial C_{Lg}} = 1 + \nu$$

and $$\frac{\partial B_L}{\partial C_{Lh}} = 1 \tag{22}$$

Thus, the benefit of the marginal expenditure of government funds must exceed 1 by a factor which depends on the tightness of the budgetary constraint while the benefit of the marginal expenditure of the other associated cost should be equal to 1. This assumes that the constraint is effective; if not, ν must be set equal to zero.

6. The preceding sections have not treated the timing of the benefits and costs explicitly. All values must be discounted at the interest rate of the analysis, and then all the above reasoning applies without change. To illustrate this aspect, we define for each project K, a benefit function

$$B_{Kt} = B_{Kt}(X_k)$$

where X_k is a measure of the scale of the project, either physical or perhaps total expenditure, and the four cost functions

$$O_{Kgt} = O_{Kgt}(X_K); \qquad O_{Kht} = O_{Kht}(X_K);$$

$$K_{Kg} = K_{Kg}(X_K); \qquad K_{Kh} = K_{Kh}(X_K)$$

where O_{Kgt} is the government operation and maintenance cost for project K in period t, O_{Kht} is the other associated operating and maintenance cost, K_{Kg} is the government capital cost and K_{Kh} the associated capital cost. For simplicity, we assume that all capital cost is incurred in the first period or, alternatively, that K includes interest during construction. We seek to maximize the increase in economic welfare

$$\Delta W = \sum_{K=1}^{r} \sum_{t=1}^{T_K} \frac{B_{Kt}(X_K)}{(1+i)^t} - \sum_{K=1}^{r} \sum_{t=1}^{T_K} \frac{O_{Kgt}(X_K)}{(1+i)^t}$$

$$- \sum_{K=1}^{r} \sum_{t=1}^{T_K} \frac{O_{Kht}(X_K)}{(1+i)^t} - \sum_{K=1}^{r} K_{Kg}(X_K) - \sum_{K=1}^{r} K_{Kh}(X_K)$$

subject to the budget constraint

$$\sum_{K=1}^{r} \sum_{t=1}^{T_R} \frac{O_{Kgt}(X_K)}{(1+i)^t} + \sum_{K=1}^{r} K_{Kg}(X_K) \leq D$$

where i is the interest rate and T_K is the economic life of the project. Thus, we maximize the lagrangean expression

$$\Phi = \Delta W - \nu\left[\sum_{K=1}^{r} \sum_{t=1}^{T_K} \frac{O_{Kgt}(X_K)}{(1+i)^t} + \sum_{K=1}^{r} K_{Kg}(X_K) - D\right]$$

which has the first order conditions

$$\sum_{t=1}^{T_K} \frac{dB_{Kt}}{dX_K} \cdot \frac{1}{(1+i)^t} - \sum_{t=1}^{T_K} \frac{dO_{Kgt}}{dX_K} \cdot \frac{1}{(1+i)^t}$$

$$- \sum_{t=1}^{T_K} \frac{dO_{Kht}}{dX_K} \cdot \frac{1}{(1+i)^t} - \frac{dK_{Kg}}{dX_K} - \frac{dK_{Kht}}{dX_K}$$

$$- \nu \sum_{t=1}^{T_K} \frac{dO_{Kgt}}{dX_K} \cdot \frac{1}{(1+i)^t} - \nu\frac{dK_{Kg}}{dX_K} = 0$$

$$(K = 1, \ldots r)$$

This can be written

$$\sum_{t=1}^{T_K} \frac{dB_{Kt}}{dX_K} \cdot \frac{1}{(1+i)^t} - (1+\nu) \left[\sum_{t=1}^{T_K} \frac{dO_{Kgt}}{dX_K} \cdot \frac{1}{(1+i)^t} + \frac{dK_{Kg}}{dX_K} \right]$$

$$- \sum_{t=1}^{T_K} \frac{dO_{Kht}}{dX_K} \cdot \frac{1}{(1+i)^t} - \frac{dK_{Kh}}{d_{XK}} = 0$$

and therefore, the condition can be expressed as

$$1+\nu = \frac{\sum_{t=1}^{T_K} [dB_{KA}/dX_K)(1+i)^{-t}] - \sum_{t=1}^{T_K} [(dO_{Kht}/dX_K)(1+i)^{-t}] - dK_{Kh}/dX_K}{\sum_{t=1}^{T_K} [(dO_{Kgt}/dX_K)(1+i)^{-t}] + dK_{Kg}/dX_K}$$

This is the benefit-cost criterion advanced in section 5 above. It will be noticed that it does not assume equal economic lives for projects or constant annual benefits or costs, the resulting criterion being a ratio of values of present worth. If O_{Kgt} and O_{Kht} remain constant over time, we can factor these terms outside the summation signs. Dividing the numerator and denominatory by [$\sum_{t=1}^{T_K} (1+i)^{-t}$ and calling this term $a_i T_K$, we can write

$$\frac{(dB_{Kt}/dX_K) - (dO_{Kht}/dX_K) - a_i T_K (dK_{Kht}/dX_K)}{(dO_{Kgt}/dX_K) + a_i T_K (dK_{Kg}/dX_K)} = 1 + \nu$$

which is the benefit cost criterion expressed in terms of annual values and using the interest and amortization factor as annual capital charges.

It may be noted that if the constraint had been placed on all capital, that is, if we had assumed that for a suitable constant $\overline{K}$,

$$\sum_{K=1}^{r} (K_{Kg} + K_{Kh}) \leq \overline{K}$$

the resultant criterion would have been

$$\left(\frac{dB_{Kt}}{dX_K} - \frac{dO_{Kgt}}{dX_K} - \frac{dO_{Kht}}{dX_K}\right) \left(\frac{dK_{Kht}}{dX_K} + \frac{dK_{Kgt}}{dX_K}\right)^{-1} = (1+\nu)a_i T_K$$

which is the criterion of the marginal productivity of capital. This criterion is closely related to, but is not identical with, the internal rate of return criterion.

APPENDIX VIII

COLUMNS AND ROWS IN THE PROGRAMMING MATRIX

Key to the Variable Name

Column Name

ASRC = T. Aus paddy (IRRI) for subsistence production

ASDC = T. Aus paddy (Deshi) for subsistence production

AMRC = T. Aman paddy (IRRI) for subsistence production

AMDC = T. Aman paddy (Deshi) for subsistence production

BOROC = Boro (IRRI) paddy for subsistence production

ASR = Aus paddy (IRRI) production not influenced by subsistence consideration (Aus Season)

ASD = T. Aus paddy (Deshi) production not influenced by subsistence consideration (Aus Season)

AMR = T. Aman paddy (IRRI) production not influenced by subsistence consideration (Aman Season)

AMD = T. Aman paddy (Deshi) production not influenced by subsistence consideration (Aman Season)

BORO = Boro (IRRI) paddy production not influenced by subsistence consideration (Boro Season)

JUTE = Jute crop (Aus Season)

POTATO = Potato crop (Boro Season)

WHEAT = Wheat crop (Boro Season)

HL_j = Hired labor in jth fortnight, j = 1, 2, . . . 24.

<u>Row Name</u>

LDASN = Land available in Aus Season = 2.50 acres

LDAMSN = Land available in Aman Season = 2.20 acres

LDBSN = Land available in Boro Season = 2.30 acres

$FLFN_i$ = Family labor supply in the ith fortnight
$i = 1, 2, \ldots 24$

CPMSR = Subsistence requirement of rice ensured from farm production

WCASS = Working capital available in Aus Season

WCAMS = Working capital available in Aman Season

WCBSN = Working capital available in Boro Season

APPENDIX IX

Estimated cost of production of T. Aman (IRRI), T. Aus (IRRI), and Boro (IRRI) per acre, study area, Bangladesh (About 1968-1988).

Cost Items	Labor		Bullock Teams		Material		Total (Rs.)
	Mandays	Costs (Rs.)	Days	Costs (Rs.)	Kinds & Quantity	Costs (Rs.)	
Variable Costs:							
a) Raising Seedlings	14	49.00	2	5.00	Seeds 13 seers*	13.00	67.00
b) Preparation of land	18	52.50	18	45.00	Cowdung	7.60	97.50
					Chemical Fertilizer	47.47	
c) Fertilizing	3	9.00					64.07
d) Transplanting	12	36.00					36.00
e) Interculture Operations	14	42.00			Plant Protection	27.00	69.00
f) Harvesting	13	45.50	Transport	5.00			50.50
g) Threshing & Winnowing	14	42.00					42.00
h) Drying & Storing	2	6.00					6.00
i) Interest on Production Loan							6.00
j) Miscellaneous							25.00
Fixed Costs:**							
a) Depreciation							15.00
b) Interests							5.00
c) Land taxes							8.00
Total	90	282.00	20	55.00		95.07	491.07

Note: *One seer = 2.057 lbs.

**In almost all studies the allocation of joint fixed costs to various crops were arbitrary.

APPENDIX X

Estimated cost of production of T. Aman (Deshi) and T. Aus (Deshi) per acre, study area, Bangladesh (About 1968-1988).

Cost Items	Labor		Bullock Teams		Material		Total
	Mandays	Costs (Rs.)	Days	Costs (Rs.)	Kinds & Quantity	Costs (Rs.)	(Rs.)
Variable Costs:							
a) Raising seedlings	2	7.00	1	2.50	20 seers	21.00	30.50
b) Preparation of land	10	35.00	10	25.00			60.00
c) Fertilizing	2	6.00			Cowdung	7.20	
					Chemical Fertilizer	15.00	28.20
d) Transplanting	10	30.00					30.00
e) Interculture operations	8	24.00			Misc.	12.00	36.00
f) Harvesting	12	42.00	Transport	5.00			42.00
g) Threshing & Winnowing	5	15.00					20.00
h) Drying & Storing	1	3.00					3.00
i) Interest on Production loan							11.00
j) Miscellaneous							10.00
Fixed Costs:							
a) Depreciation							15.00
b) Interest							5.00
c) Land taxes							8.00
Total	50	162.00	11	32.50		55.20	298.70

APPENDIX XI

Estimated cost of production of jute (per acre), study area, Bangladesh (About 1968-1988).

Cost Items	Labor Mandays	Labor Costs (Rs.)	Bullock Teams Days	Bullock Teams Costs (Rs.)	Materials Kinds & Quantity	Materials Costs (Rs.)	Total (Rs.)
Variable Costs:							
a) Land preparation	14	49.00	14	35.00			84.00
b) Fertilizing	2	6.00			Cowdung	16.00	
					Fertilizer	6.20	28.20
c) Sowing seeds	1	3.50	1	2.50	5 seers seeds	6.00	12.00
d) Interculture operations	14	42.00	1	2.50	Pesticides & rentals	12.00	56.50
e) Thinning	4	12.00					12.00
f) Harvesting	14	49.00					49.00
g) Retting	8	22.00	Transport	10.00			32.00
h) Stripping fibre	12	42.00					42.00
i) Drying & storing	8	22.00					22.00
j) Interest on production loan							9.00
k) Miscellaneous							37.00
Fixed Costs:							
a) Depreciation							15.00
b) Interest							5.00
c) Land taxes							8.00
Total	77	247.50	16	50.00		40.20	411.70

APPENDIX XII

Estimated cost of production of wheat (per acre), study area, Bangladesh, (About 1968-1988)

Cost Items	Labor		Bullock Teams		Materials		Total
	Mandays	Costs (Rs.)	Days	Costs (Rs.)	Kinds & Quantity	Costs (Rs.)	(Rs.)
Variable Costs:							
a) Land preparation	8	28.00	8	20.00			48.00
b) Fertilizing	1	3.00			Fertilizer	30.00	33.00
c) Sowing	1	3.00			25 seers seeds	20.00	23.00
d) Interculture operations	6	18.00			Misc.	10.00	28.00
e) Harvesting	8	24.00	Transport	5.00			29.00
f) Threshing	4	12.00					12.00
g) Cleaning & storing	1	3.00					3.00
h) Interest on production loan							5.00
i) Miscellaneous							25.00
Fixed Costs:							
a) Depreciation							15.00
b) Interest							5.00
c) Land taxes							8.00
Total	29	91.00	8	25.00		60.00	234.00

APPENDIX XIII

Estimated cost of production of potato (per acre), study area, Bangladesh (About 1968-1988).

Cost Items	Labor		Bullock Teams		Materials		Total
	Mandays	Costs (Rs.)	Days	Costs (Rs.)	Kinds & Quantity	Costs (Rs.)	Total (Rs.)
Variable Costs:							
a) Land preparation	16	56.00	16	40.00			96.00
b) Fertilizing	5	15.00			Fertilizer & manure	81.49	96.49
c) Sowing	16	48.00			Seeds	289.90	337.90
d) Interculture operations	38	114.00			Misc.	18.00	132.00
e) Harvesting	30	90.00	6	15.00			105.00
f) Storing	2	6.00	Transport	42.38			48.38
g) Interest on production loan							27.00
h) Miscellaneous							60.00
Fixed Costs:							
a) Depreciation							15.00
b) Interest on capital							5.00
c) Land taxes							8.00
Total	107	329.00	22	97.38		389.39	930.77

APPENDIX XIV

Demand for total labor and supply of family labor by crops and fortnights (Mandays per acre) study area, Bangladesh, (about 1970-1972).

Fort-nights	T.Aman (IRRI)	T. Aman (Deshi)	Wheat	Boro	T. Aus (Deshi)	T. Aus (IRRI)	Potato	Jute	Total Demand	Supply of Family Labor[1]
1	9	4	10	43			18		84	27
2				4			19		23	27
3			2	8					10	27
4			3	2			4		9	27
5							22		23	27
6							12		12	27
7										27
8			10	20	2	4	32		68	27
9			3	9	22	43		17	94	27
10					2	4			6	27
11					4	8		2	14	27
12					2	2		6	10	27
13								6	6	27
14								4	4	27
15										27
16	4	2			14	20		22	62	27
17	43	22			4	9			78	27
18	4	2						20	26	27
19	8	4							12	27
20	2	2							4	27
21										27
22										27
23										27
24	20	14		4					38	27
Total	90	50	29	90	50	90	107	77	583	648

Note: Fortnight no. 1 starts from 7th December and ends on 22nd December.

[1] Labor supply is based on 2 family labor of 8 hours each for 13.5 days in a fortnight.

APPENDIX XV

Results of the programing model: allocations of land and net income with various yield and price assumption, study area, Bangladesh.

Run Number	Allocations of Land to Crops (in acres): T. Aus (IRRI)	T. Aus (Deshi)	Jute	T. Aman (IRRI)	T. Aman (Deshi)	Boro	Potato	Wheat	Net Income* (Rs.)	Remarks
1	1.23	1.27	0.0	1.62	0.58	2.07	0.0	0.0	3825.62	Run numbers 1, 2, 4, 6 are with working capital constraint--Rs. 400 per season.
2	0.0	0.0	2.50	1.20	1.00	2.28	0.02	0.0	2918.91	
4	0.0	0.0	2.50	2.08	0.12	0.0	0.51	1.79	2362.50	
6	0.39	1.20	0.91	2.20	0.0	0.0	0.45	1.85	2114.26	
3	0.0	0.0	2.50	2.20	0.0	1.63	0.67	0.0	3207.37	Run numbers 3, 5, 7, 8, 9, 10, 11 are with working capital--Rs. 600 per season.
5	0.0	0.0	2.50	2.20	0.0	0.0	1.03	1.27	2523.68	
7	0.39	1.20	0.91	2.20	0.0	0.0	0.98	1.32	2257.98	
8	1.59	0.0	0.91	2.20	0.0	2.30	0.0	0.0	2561.97	*Net Income = (Gross Revenue) -(variable input costs + interests on working capital + hired labor costs).
9	2.50	0.0	0.0	2.20	0.0	2.30	0.0	0.0	2502.36	
10	2.50	0.0	0.0	2.20	0.0	1.79	0.51	0.0	2687.13	
11	1.59	0.0	0.91	2.20	0.0	1.79	0.51	0.0	2707.53	

APPENDIX XV (a)

Yield and price assumptions of various runs in the model. (Yields are in maunds per acre and prices are in Rs./maund).

Crops	Run Numbers 1	2	3	4	5	6	7	8	9	10	11
T. Aus (IRRI)											
Yields	40	40	40	40	40	40	40	40	40	40	40
Price	26	20	16	16	20	16	16	18	18	18	18
T. Aus (deshi)											
Yields	25	25	25	25	25	25	25	25	25	25	25
Price	26	20	16	16	20	16	16	18	18	18	18
Jute											
Yield	15	25	25	25	25	25	25	25	20	25	25
Price	30	30	25	20	30	25	20	25	25	20	25
T. Aman (IRRI)											
Yield	45	45	45	45	45	45	45	45	45	45	45
Price	27	21	17	17	21	17	17	19	19	19	19
T. Aman (deshi)											
Yield	25	25	25	25	25	25	25	25	25	25	25
Price	27	21	17	17	21	17	17	19	19	19	19
Boro											
Yield	45	45	45	45	45	45	45	45	45	45	45
Price	27	21	17	17	21	17	17	19	19	19	19
Potato											
Yield	90	90	90	90	90	90	90	90	90	90	90
Price	14	14	14	14	14	14	14	11	12	14	14
Wheat											
Yield	30	30	30	30	30	30	30	30	30	30	30
Price	18	18	18	18	18	18	18	11	11	12	12

APPENDIX XVI

Net income to a farmer from a 3-acre area under present conditions (1968), study area, Bangladesh.

Items	Crops				Total
	B. Aus (deshi)	Jute	T. Aman (deshi)	Mustard	
Area (acres)	2.0	0.50	2.0	0.15	4.80
Yield (mds./acre)	15	15	16	5	-
Total production (mds.)	30.0	7.5	32.0	0.75	-
Prices (Rs./md.)	18	25	19	40	-
Total value (Rs.)	540.00	187.50	608.00	30.00	1365.50
Minus variable costs[1] (Rs.)					339.50
Net Income (5-6) (Rs.)					1026.00
Return to family labor; fixed capital and land					1026.00

[1]Variable costs include material input cost of Rs. 103.00 and hired labor cost of Rs. 236.50 (hired labor 30% of total labor). With prices of Aus rice at Rs. 24.00 per maund and that of Aman rice at Rs. 25 per maund, the net income works out to be 1398.00.

APPENDIX XVII

Estimated net income to a farmer from a 3-acre area under irrigated conditions, study area, Bangladesh (about 1975-1988).

Items	Crops					Total
	T. Aus (IRRI)	Jute	T. Aman (IRRI)	Boro	Potato	
Area (acres)	1.59	0.91	2.20	1.79	0.51	7.0
Yield (mds/ac)	40	25	40	45	90	-
Total Production[1] (mds)	63.6	20.25	88.00	80.40	45.90	-
Price (Rs/md)	18	25	19	19	14	-
Total value (Rs)	1144.80	506.25	1672.00	1527.60	642.60	5493.25
Minus variable costs[2] (Rs)						2300.72
Net Income (5-6) (Rs)						3192.53
Minus water input costs @ Rs. 94.0 per acre for 3 acres						282.00
Return to family labor, fixed capital and land (Rs)						2910.53

[1]Includes 30 mds of Boro rice produced for family consumption.

[2]Variable costs include material costs (Rs. 1173.27) and hired labor costs (Rs. 1127.45).

APPENDIX XVIII

Capital costs of 24 alternatives in Tubewell Installation, study area, Bangladesh, 1968-72 (in rupees).

Cost Items	$P_1D_1T_1S_1$	$P_1D_1T_1S_2$	$P_1D_1T_2S_1$	$P_1D_1T_2S_2$	$P_1D_1T_3S_1$	$P_1D_1T_3S_2$	$P_1D_2T_1S_1$	$P_1D_2T_1S_2$
Move in and out	300	300	300	300	4500	4500	300	300
Drilling								
200 feet	--	--	--	--	--	--	--	--
220 feet	1760	1760	2200	2200	10450	10450	1760	1760
Pump housing 10" diameter and 60 feet	--	--	--	--	--	--	--	--
Blind Pipe 8" diameter								
40 feet	--	--	--	--	--	--	--	--
80 feet	3200	3200	3200	3200	3200	3200	3200	3200
Screen								
100 feet	--	--	--	--	--	--	--	--
140 feet	7000	7490	7000	7490	7000	7490	7000	7490
Bail plug reducer	500	500	500	500	500	500	500	500
Gravel pack								
100 feet	--	--	--	--	--	--	--	--
140 feet	2100	2100	2100	2100	2100	2100	2100	2100
Install well hardwares								
200 feet	--	--	--	--	--	--	--	--
220 feet	2650	2640	2640	2640	2640	2640	2640	2640
Testing wells	1500	1500	1500	1500	1500	1500	1500	1500
Pump	750	750	750	750	750	750	750	750
Engine 20 h.p.	4500	4500	4500	4500	4500	4500	6000	6000

Right angle grear drive	--	--	--	--	--	--	--	--
Install pump and engine	750	750	750	750	750	750	750	750
Well hours	3500	3500	3500	3500	3500	3500	3500	3500
Sub-total:	28500	28990	28940	29430	41390	41580	30000	30490
Transport vehicles	430	430	430	430	430	430	430	430
Equipment for office and miscellaneous	110	110	110	110	110	110	110	110
Supervision and overhead	3300	3300	3300	3300	3300	3300	3300	3300
Main distribution channel	1700	1700	1700	1700	1700	1700	1700	1700
Sub-total:	5540	5540	5540	5540	5540	5540	5540	5540
Total without contingency	34040	34530	34480	34970	46930	47120	35540	36030
Contingency (10%)	3404	3453	3448	3497	4693	4712	3554	3603
Grand Total	37444	37983	37928	38467	51623	51832	39094	39094

Note: P_1 = Centrifugal pump, P_2 = Turbine pump.

D_1 = Low speed diesel engine, D_2 = high speed diesel engine.

T_1 = Water jet drilling, T_2 = Cable percussion drilling, T_3 = Power drilling.

S_1 = Brass screen, S_2 = Fiberglass screen.

APPENDIX XVIII (continued)

Cost Items	$P_1D_2T_2S_1$	$P_1D_2T_2S_2$	$P_1D_2T_3S_1$	$P_1D_2T_3S_2$	$P_2D_1T_1S_1$	$P_2D_1T_1S_2$	$P_2D_1T_2S_1$	$P_2D_1T_2S_2$
Move in and out	300	300	4500	4500	300	300	300	300
Drilling cost								
200 feet	--	--	--	--	1600	1600	2000	2000
220 feet	2200	2200	10450	10450	--	--	--	--
Pump housing 10" diameter and 60 feet	--	--	--	--	3600	3600	3600	3600
Blind pipe 8" diam.								
40 feet	--	--	--	--	1600	1600	1600	1600
80 feet	3200	3200	3200	3200	--	--	--	--
Screen								
100 feet	--	--	--	--	5000	5350	5000	5350
140 feet	7000	7490	7000	7490	--	--	--	--
Bail plug reducer	500	500	500	500	500	500	500	500
Gravel pack 100 feet	--	--	--	--	1500	1500	1500	1500
Install well hardware								
200 feet	--	--	--	--	2400	2400	2400	2400
220 feet	2640	2640	2640	2640	--	--	--	--
Testing wells	1500	1500	1500	1500	1500	1500	1500	1500
Pump	750	750	750	750	5500	5500	5500	5000
Engine 20 h.p.	6000	6000	6000	6000	4500	4500	4500	4500
Right angle gear drive	--	--	--	--	1500	1500	1500	1500

Install pump and engine	750	750	750	750	750	750	750	750
Well House	3500	3500	3500	3500	3500	3500	3500	3500
Sub-total:	30440	30930	42890	43380	33750	34100	34150	34500
Transport vehicles	430	430	430	430	430	430	430	430
Equipment for office and miscellaneous	110	110	110	110	110	110	110	110
Supervision and overhead	3300	3300	3300	3300	3300	3300	3300	3300
Main distribution channel	1700	1700	1700	1700	1700	1700	1700	1700
Sub-total:	5540	5540	5540	5540	5540	5540	5540	5540
Total without contingency	35980	36470	48430	48920	39290	39640	39690	40040
Contingency (10%)	3598	3647	4843	4892	3929	3964	3969	4004
Grand total	39578	40117	53273	53812	43219	43604	43659	44044

APPENDIX XVIII (continued)

Cost Items	$P_2D_1T_3S_1$	$P_2D_1T_3S_2$	$P_2D_2T_1S_1$	$P_2D_2T_1S_2$	$P_2D_2T_2S_1$	$P_2D_2T_2S_2$	$P_2D_2T_3S_1$	$P_2D_2T_3S_2$
Move in and out	4500	4500	300	300	300	300	4500	4500
Drilling cost								
200 feet	9500	9500	1600	1600	2000	2000	9500	9500
220 feet	--	--	--	--	--	--	--	--
Pump housing 10" diameter and 60 feet	3600	3600	3600	3600	3600	3600	3600	3600
Blind pipe 8" diam.								
40 feet	1600	1600	1600	1600	1600	1600	1600	1600
80 feet	--	--	--	--	--	--	--	--
Screen								
100 feet	5000	5300	5000	5300	5000	5300	5000	5300
140 feet	--	--	--	--	--	--	--	--
Bail plug reducer	500	500	500	500	500	500	500	500
Gravel pack								
100 feet	1500	1500	1500	1500	1500	1500	1500	1500
140 feet	--	--	--	--	--	--	--	--
Install well hardware								
200 feet	2400	2400	2400	2400	2400	2400	2400	2400
220 feet	--	--	--	--	--	--	--	--
Testing wells	1500	1500	1500	1500	1500	1500	1500	1500
Pumps	5500	5500	5500	5500	5500	5500	5500	5500
Engine 20 h.p.	4500	4500	6000	6000	6000	6000	5000	6000
Right angle gear drive	1500	1500	1500	1500	1500	1500	1500	1500

Install pumps and engines	750	750	750	750	750	750	750	750
Well house	3500	3500	3500	3500	3500	3500	3500	3500
Sub-total:	45850	46150	35250	35550	35650	35950	47350	47650
Transport vehicles	430	430	430	430	430	430	430	430
Equipment for office and miscellaneous	110	110	110	110	110	110	110	110
Supervision and overhead	3300	3300	3300	3300	3300	3300	3300	3300
Main distribution channel	1700	1700	1700	1700	1700	1700	1700	1700
Sub-total	5540	5540	5540	5540	5540	5540	5540	5540
Total without contingency	51390	51690	40790	41090	41190	41490	52890	53190
Contingency (10%)	5139	5169	4079	4109	4119	4149	5289	5319
Grand total	56529	56859	44869	45199	45309	45639	58179	58509

Note: Cost estimates exclude taxes.

APPENDIX XIX

Capital costs of 24 alternatives in Tubewell Installation with shadow price of foreign exchange, Bangladesh, about 1968-72, (in rupees).

Cost Items	$P_1D_1T_1S_1$	$P_1D_1T_1S_2$	$P_1D_1T_2S_1$	$P_1D_1T_2S_2$	$P_1D_1T_3S_1$	$P_1D_1T_3S_2$	$P_1D_2T_1S_1$	$P_1D_2T_1S_2$
Move in and out	300	300	300	300	300	300	300	300
Drilling cost								
200 feet	--	--	--	--	--	--	--	--
220 feet	2200	2200	2310	2310	18286	18286	2200	2200
Pump Housing 10" diameter and 60 feet	--	--	--	--	--	--	--	--
Blind pipe 8" diam.								
40 feet	--	--	--	--	--	--	--	--
80 feet	6400	6400	6400	6400	6400	6400	6400	6400
Screen								
100 feet	--	--	--	--	--	--	--	--
140 feet	11900	14980	11900	14980	11900	14980	11900	14980
Bail plug reducer	1000	1000	1000	1000	1000	1000	1000	1000
Gravel pack								
100 feet	--	--	--	--	--	--	--	--
140 feet	2100	2100	2100	2100	2100	2100	2100	2100
Install well hardware								
200 feet	--	--	--	--	--	--	--	--
220 feet	2640	2640	2640	2640	2640	2640	2640	2640
Testing wells	1500	1500	1500	1500	1500	1500	1500	1500

Pump	1125	1125	1125	1125	1125	1125	1125	1125
Engine 20 h.p.	6750	6750	6750	6750	6750	6750	12000	12000
Right angle gear drive	--	--	--	--	--	--	--	--
Install pump and engine	750	750	750	750	750	750	750	7500
Well house	3500	3500	3500	3500	3500	3500	3500	3500
Sub-total:	40165	43245	40275	43355	60451	63531	45415	48495
Transport vehicles	860	860	860	860	860	860	860	860
Equipment for office and miscellaneous	175	175	175	175	175	175	175	175
Supervision and overhead	3300	3300	3300	3300	3300	3300	3300	3300
Main distribution channel	1700	1700	1700	1700	1700	1700	1700	1700
Sub-total:	6035	6035	6035	6035	6035	6035	6035	6035
Total without contingency	46200	49280	46310	49390	66486	69566	51450	54530
Contingency	3404	3453	3448	3497	4693	4712	3554	3603
Grand total	49604	52733	49758	52887	71179	74278	55004	58133

APPENDIX XIX (continued)

Cost Items	$P_1D_2T_2S_1$	$P_1D_2T_2S_2$	$P_1D_2T_3S_1$	$P_1D_2T_3S_2$	$P_2D_1T_1S_1$	$P_2D_1T_1S_2$	$P_2D_1T_2S_1$	$P_2D_1T_2S_2$
Move in and out	300	300	4500	4500	300	300	300	300
Drilling cost								
200 feet	--	--	--	--	2000	2000	2100	2100
220 feet	2310	2310	18286	18286	--	--	--	--
Pump housing 10" diam. and 60 feet	--	--	--	--	7200	7200	7200	7200
Blind pipe 8" diam.								
40 feet	--	--	--	--	3200	3200	3200	3200
80 feet	6400	6400	6400	6400	--	--	--	--
Screen								
100 feet	--	--	--	--	8500	10700	8500	10700
140 feet	11900	14980	11900	14980	--	--	--	--
Bail plug reducer	1000	1000	1000	1000	1000	1000	1000	1000
Gravel pack								
100 feet	--	--	--	--	1500	1500	1500	1500
140 feet	2100	2100	2100	2100	--	--	--	--
Install well hardware								
200 feet	--	--	--	--	2400	2400	2400	2400
220 feet	2650	2640	2640	2640	--	--	--	--
Testing wells	1500	1500	1500	1500	1500	1500	1500	1500
Pump	1125	1125	1125	1125	11000	11000	11000	11000
Engine 20 h.p.	12000	12000	12000	12000	6750	6750	6750	6750

Right angle gear drive	--	--	--	--	3000	3000	3000	3000
Install pump and engine	750	750	750	750	750	750	750	750
Well house	3500	3500	3500	3500	3500	3500	3500	3500
Sub-total:	45525	48605	65701	68781	52600	54800	52700	54900
Transport vehicles	806	860	860	860	860	860	860	860
Equipment for office and miscellaneous	175	175	175	175	175	175	175	175
Supervision and overhead	3300	3300	3300	3300	3300	3300	3300	3300
Main distribution channels	1700	1700	1700	1700	1700	1700	1700	1700
Sub-total:	6035	6035	6035	6035	6035	6035	6035	6035
Total without contingency	51560	54640	71736	74816	58635	60835	58735	60935
Contingency	3598	3647	4843	4892	3929	3964	3969	4004
Grand total	55158	58287	76579	79708	62564	64799	62704	64939

APPENDIX XIX (continued)

Cost Items	$P_2D_1T_3S_1$	$P_2D_1T_3S_2$	$P_2D_2T_1S_1$	$P_2D_2T_1S_2$	$P_2D_2T_2S_1$	$P_2D_2T_2S_2$	$P_2D_2T_3S_1$	$P_2D_2T_3S_2$
Move in and out	4500	4500	300	300	300	300	4500	4500
Drilling								
200 feet	16624	16624	2000	2000	2100	2100	16624	16624
220 feet	--	--	--	--	--	--	--	--
Pump housing 10" diameter and 60 feet	7200	7200	7200	7200	7200	7200	7200	7200
Blind pipe 8" diameter								
40 feet	3200	3200	3200	3200	3200	3200	3200	3200
80 feet	--	--	--	--	--	--	--	--
Screen								
100 feet	8500	10700	8500	10700	8500	10700	8500	10700
140 feet	--	--	--	--	--	--	--	--
Bail plug reducer	1000	1000	1000	1000	1000	1000	1000	1000
Gravel pack								
100 feet	1500	1500	1500	1500	1500	1500	1500	1500
140 feet	--	--	--	--	--	--	--	--
Install well hardward								
200 feet	2400	2400	2400	2400	2400	2400	2400	2400
220 feet	--	--	--	--	--	--	--	--
Testing wells	1500	1500	1500	1500	1500	1500	1500	1500
Pump	11000	11000	11000	11000	11000	11000	11000	11000
Engine 20 h.p.	6750	6750	12000	12000	12000	12000	12000	12000

Right angle gear drive	3000	3000	3000	3000	3000	3000	3000	3000
Install pump and engine	750	750	750	750	750	750	750	750
Well house	3500	3500	3500	3500	3500	3500	3500	3500
Sub-total:	71424	73624	57850	60050	57950	60150	76674	78874
Transport vehicles	860	860	860	860	860	860	860	860
Equipment for office and miscellaneous	175	175	175	175	175	175	175	175
Supervision and overhead	3300	3300	3300	3300	3300	3300	3300	3300
Main distribution channel	1700	1700	1700	1700	1700	1700	1700	1700
Sub total	6035	6035	6035	6035	6035	6035	6035	6035
Total without contingency	77459	79659	63885	66085	63985	66185	82709	84909
Contingency	5139	5169	4079	4109	4119	4149	5289	5319
Grand total	82798	84828	67964	70194	68104	70334	87998	90228

APPENDIX XX

Adjustments in cropping pattern from non-irrigated to irrigated system on a 3-acre area, study area, Bangladesh.

	Years				
	1	2	3	4	5
Without Irrigation (area in acres)					
B. Aus (deshi)	2.00	2.00	2.00	2.05	2.10
Jute	0.50	0.50	0.50	0.55	0.60
T. Aman (deshi)	2.0	2.0	2.0	2.0	2.0
Mustard	0.30	0.30	0.30	0.35	0.40
With Irrigation (area in acres)					
T. Aus (deshi)	1.60	1.40	0.90	0.50	0.0
T. Aus (IRRI)	0.30	0.50	0.80	1.10	1.60
Jute	0.60	0.60	0.80	0.90	0.90
T. Aman (deshi)	1.80	1.60	1.30	1.00	0.0
T. Aman (IRRI)	0.40	0.60	0.90	1.20	2.20
Boro	1.00	1.60	1.80	1.80	1.80
Potato	0.50	0.50	0.50	0.50	0.50

Note: From the fifth year onwards the same crops and acreage will continue.

APPENDIX XXI

Streams of benefits attributed to irrigation with the assumptions of first phase analysis, study area, Bangladesh (1968-1988).

	Without Irrigation (Rs./3-Acre)			With Irrigation (Rs./3-Acre)			Benefit to Irrigation (Rs.)	
Years	Value of crops	Costs of production	Net value	Value of crops	Costs of production	Net value	For 3-acre	For project*
1	1425.5	623.0	802.5	3917.0	1760.1	2156.9	1354.4	10,835.0
2	1469.8	645.5	824.3	4544.0	2072.5	2471.5	1647.3	21,963.0
3	1514.0	668.0	846.0	4916.0	2258.9	2657.1	1811.1	36,222.0
4	1604.2	714.0	890.2	5101.5	2365.9	2735.6	1845.4	36,908.0
5	1704.8	761.0	943.8	5529.5	2580.4	2949.1	2005.3	40,106.0
6	1751.3	767.5	983.8	5529.5	2580.4	2949.10	1965.4	39,307.0
7	1805.2	767.5	1037.7	5529.5	2580.4	2949.10	1911.4	38,228.0
8	1805.2	767.5	1037.7	5529.5	2580.4	2949.10	1911.4	38,228.0
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

*Project area--first year 24 acres, second year 40 acres, and third year 60 acres. Figures rounded.

APPENDIX XXII

Streams of irrigation costs for first phase analysis (in rupees), study area, Bangladesh, (about 1968-1988).

	Capital Costs	Operation and Maintenance Cost	Replacement Cost	Agri Extension Cost	Total Cost
0	49,758.0*	0		1300.0	
1		3561.0		1300.0	4861.0
2		4037.0		1300.0	5337.0
3		462.0		1300.0	5932.0
4		4632.0		1300.0	5932.0
5		4632.0	13,100.0	1300.0	19032.0
6		4632.0		1300.0	5932.0
7		4632.0		1300.0	5932.0
8		4632.0		1300.0	5932.0
9		4632.0		1300.0	5932.0
10		4632.0	24,100.0	1300.0	30032.0
11		4632.0		1300.0	5932.0
12		4632.0		1300.0	5932.0
13		4632.0		1300.0	5932.0
14		4632.0		1300.0	5932.0
15		4632.0	13,100.0	1300.0	19032.0
16		4632.0		1300.0	5932.0
17		4632.0		1300.0	5932.0
18		4632.0		1300.0	5932.0
19		4632.0		1300.0	5932.0
20		4632.0		1300.0	5932.0

*Capital cost of well with low speed diesel engine centrigugal pump, brass screen and drilled by cable percussion method.

APPENDIX XXIII

A Note on Justification for Selection of High and Low Levels of Yield Rates

Three levels of yields of improved rice varieties have been assumed in the study, the most probable yield rate, an optimistic yield rate and a pessimistic yield rate. The most probable yield is 45 maund per acre in the case of Boro (IRRI), 40 maunds per acre in the cases of both Aus (IRRI) and Aman (IRRI). The optimistic level is assumed at 55 maunds per acre in case of Boro (IRRI), and 50 maunds in the cases of both Aus (IRRI) and Aman (IRRI). The pessimistic level of yield is assumed at 35 maunds per acre in all the three crops. A brief discussion on the basis of selection of these yield levels was provided in Chapter V and IV.

The 40 observations of yield rates collected by the author through a survey in the 1968 Boro season show an average yield of 54 maunds of paddy per acre. However, the most probable yield rate is lower than this average. The average yields obtained in other studies are also higher than the most probable yield assumed in the present study. The reason is that the future average yield rates of high yielding varieties of rice are expected to fall with the expansion of these varieties in progressively inferior soils and gradual varietal deterioration.

From the analysis of the 40 observations of yield rates mentioned above we can establish some justification for the assumed ranges of yield rates. Calculating the standard error of the distribution of these 40 observations we may set a 95 percent confidence interval as follows:

$$\overline{X} - t_{\frac{\alpha}{2}} S_{\overline{x}} \leqslant \mu \leqslant \overline{X} + t_{\frac{\alpha}{2}} S_{\overline{x}}$$

$$54.04 - (2.021 * 2.074) \leqslant \mu \leqslant 54.04 - (2.021 * 2.074)$$

$$54.04 - 4.19 \leqslant \mu \leqslant 54.04 - 4.19$$

$$49.85 \leqslant \mu \leqslant 58.23$$

This indicates a lower limit of 4.19 units below and an upper limit of 4.19 units above the mean. In the present analysis the most probable yield rate is not the mean value; it is lower than the mean value. Selection of the lower limit in the present analysis almost coincides with this statistical estimates, i.e., it is below 5 units, instead of 4.19, from the most probable yield rate in the cases of Aus (IRRI) and Aman (IRRI). However, the upper limits are higher in all the cases (10 units up instead of 4.19). Examining the distribution of 40 observations we find that the variation in the lower range is less than that in the upper range. Only one observation is below 35 maunds. In the upper range, 12 observations are above

60 maunds, varying from 62 maunds to 83 maunds. For this reason a higher value for the optimistic yield rate in the analysis is considered desireable. The observations relate to only one year, considered normal. For a more reliable and smoother distribution, observations for a number of years would have been preferable.

However, the selection of the yield rates were mostly based on the judgment of the author. In the main text we have provided the rates of returns with the three levels of yield rates. If we want to estimate the rates of returns with some other yield rates, a linear intrapolation or extrapolation will provide such rates from the results presented in the text.

APPENDIX XXIV

Data used for determination of labor demand function. (Local variety, Kadda Area, Dacca.)

No.	Farm Size (acres)	Wage Rate (Rs/ Manday)	Area Under Local Variety (acres)	Total Labor Per Acre (mandays)	Hired Labor Per Acre (mandays)
1	2.97	3.50	0.88	55.1	31.8
2	0.35	3.00	0.26	55.8	10.0
3	1.14	3.00	0.62	48.4	19.4
4	2.80	3.50	0.52	44.2	36.5
5	2.28	3.50	0.87	42.5	20.7
6	2.80	3.00	0.88	55.3	31.5
7	8.40	2.50	2.98	44.3	22.5
8	17.50	3.00	11.20	41.8	35.3
9	14.70	3.00	5.25	45.3	27.6
10	2.80	2.50	0.44	36.4	22.7
11	13.00	3.50	4.20	45.6	23.6
12	7.50	3.00	4.02	38.2	14.7
13	4.20	3.50	1.58	67.1	31.0
14	2.45	3.00	1.05	49.5	23.8
15	6.13	2.50	2.10	47.1	29.5
16	1.50	3.00	0.21	78.6	38.1
17	5.60	2.50	1.43	45.8	37.8
18	5.90	3.00	0.70	55.5	28.8
19	1.40	3.00	0.18	97.2	19.4

Note: Farm size represents the total cultivated area under a holding.

APPENDIX XXIV (con't.)

(Local variety, North Mymensingh Area.)

No.	Farm Size (acres)	Wage Rate (Rs/ Manday)	Area Under Local Variety (acres)	Total Labor Per Acre (mandays)	Hired Labor Per Acre (mandays)
20	2.00	3.50	0.80	25.0	3.8
21	2.00	3.50	1.60	27.2	19.4
22	7.60	3.50	3.60	24.0	6.9
23	6.20	4.00	1.30	20.4	9.2
24	3.20	4.50	2.20	25.2	8.2
25	1.60	4.00	0.42	33.8	5.0
26	1.20	4.00	0.10	32.5	1.5
27	1.60	4.00	1.00	31.5	6.0
28	11.00	4.00	3.40	26.2	15.6
29	3.20	3.50	0.80	29.4	12.5
30	3.20	3.50	1.40	40.7	1.4
31	1.60	3.50	0.90	34.4	5.6
32	1.20	3.50	0.90	36.1	5.6
33	2.60	3.50	0.67	23.1	1.5
34	3.20	4.00	1.34	21.6	1.0
35	3.50	3.50	0.80	29.4	12.5
36	2.40	4.00	0.60	32.9	8.3
37	2.40	4.00	0.60	32.5	8.3
38	0.60	4.00	0.56	29.9	3.6
39	2.00	3.50	1.70	27.4	5.9

APPENDIX XXIV (con't.)

(High-Yielding Variety, Kadda Area, Dacca.)

No.	Farm Size (acres)	Wage Rate (Rs/ Manday)	Area Under Local Variety (acres)	Total Labor Per Acre (mandays)	Hired Labor Per Acre (mandays)
40	2.97	3.50	1.57	86.6	54.1
41	0.35	3.00	0.09	77.8	20.0
42	1.14	3.00	0.52	45.2	26.9
43	2.80	3.50	1.05	61.0	55.2
44	2.28	3.50	0.44	75.0	45.5
45	2.80	3.00	1.57	86.6	53.5
46	8.40	2.50	0.52	108.7	63.5
47	17.50	3.00	6.30	62.5	54.6
48	14.70	3.00	2.45	56.3	38.4
49	2.80	2.50	0.35	46.4	34.3
50	13.00	3.50	2.80	68.0	27.5
51	7.50	3.00	0.53	82.1	26.4
52	4.20	3.50	1.22	48.8	17.2
53	2.45	3.00	0.79	62.0	29.1
54	6.13	2.50	2.45	67.8	45.7
55	1.50	3.00	0.21	119.0	61.9
56	5.60	2.50	0.27	98.1	85.2
57	5.90	3.00	5.25	57.1	30.3
58	1.40	3.00	1.05	87.1	27.6

APPENDIX XXIV (con't.)

(High-Yielding Variety, North Mymensingh Area.)

No.	Farm Size (acres)	Wage Rate (Rs/ Manday)	Area Under Local Variety (acres)	Total Labor Per Acre (mandays)	Hired Labor Per Acre (mandays)
59	2.00	3.50	0.20	85.0	40.0
60	2.00	3.50	0.40	76.3	50.0
61	7.60	3.50	0.40	71.3	15.0
62	6.20	4.00	0.70	91.4	31.4
63	3.20	4.50	0.34	86.8	23.5
64	1.60	4.00	0.32	87.5	96.9
65	1.20	4.00	0.40	73.8	40.0
66	1.60	4.00	0.44	84.1	22.7
67	11.00	4.00	0.60	83.3	57.5
68	3.20	3.50	0.70	92.9	29.3
69	3.20	3.50	0.20	142.5	20.0
70	1.60	3.50	0.20	105.0	25.0
71	1.20	3.50	0.10	100.0	15.0
72	2.60	3.50	0.20	72.5	5.0
73	3.20	4.00	0.40	75.0	5.0
74	3.50	3.50	0.40	64.4	30.0
75	2.40	4.00	0.25	122.0	48.0
76	2.40	4.00	0.26	113.5	46.2
77	0.60	4.00	0.04	125.0	8.0
78	2.00	3.50	0.30	96.7	53.3