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THE QUANTITATIVE IMPACT OF THE SEED-FERTILIZER REVOLUTION IN WEST PAKISTAN: AN EXPLORATORY STUDY

INTRODUCTION: THE SEED-FERTILIZER REVOLUTION IN WEST PAKISTAN

Recent events in a number of developing countries have underscored the importance of pursuing strategies for agricultural development that give major attention to the "production" and implementation of new production techniques. Japan and Taiwan furnish conspicuous examples. It has been widely recognized that technical change leading to production-function shifts has enabled their agricultural sectors to increase output at rates greatly exceeding the associated increases in conventional inputs.

Development strategies which look to the "seed-fertilizer revolution" as the primary source of technical change in agriculture include three key elements: (1) agricultural research leading to the development of high-yielding varieties which have the capacity to respond to high levels of soil fertility; (2) greatly increased application of chemical fertilizers; and (3) activities which promote both the widespread use of the new varieties and the associated changes in farm practices which are needed if these varieties are to realize their high yield potential.

Recent breakthroughs in agricultural research, and the continuing technical advance leading to reductions in the real cost of chemical fertilizer greatly increase the potential importance of this type of strategy for agricultural development. The unprecedentedly rapid spread of the new high-yielding, fertilizer-responsive varieties and the expanded use of fertilizers in West Pakistan, the Indian Punjab, and certain other areas already constitute a "seed-fertilizer revolution." Moreover, three characteristics of these "revolutionary" developments suggest that the impact of these striking changes in production possibilities will

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be widespread and will substantially raise the rate of increase of agricultural output for an extended period of time.

(1) New "dwarf" varieties of rice and wheat developed for tropical and subtropical regions have higher grain/nutrient response ratios than traditional varieties, and, even more important, they maintain these ratios up to levels of fertilizer application much higher than those which would be profitable for the traditional varieties. Potential increases in yields per acre with these short-strawed varieties are of the order of 50 to 200 per cent when the introduction of improved varieties is accompanied by high levels of fertilizer application and certain other changes in farm practices. Possibilities exist for similar yield increases from hybrid and synthetic maize.

(2) Geneticists and plant breeders have been able to develop varieties of wheat and rice that are not sensitive to differences in day length. This has enlarged the possibilities for the international transfer of high-yielding varieties, but local research programs continue to be of great importance in safeguarding and extending the gains that have been won.

(3) Cost reductions and declining real prices have been important factors in the tremendous increases in world fertilizer consumption since the end of World War II. Heretofore these increases have largely been concentrated in the richer nations. Fertilizer consumption in the less developed countries is now increasing rapidly, however, and it is in these countries that the further cost reductions and large increases in production now in prospect will have their major impact. With rapid shifts in both the supply and demand functions for fertilizer, there may be short-run periods of shortage or excess capacity which will cause prices to fluctuate considerably. But the underlying conditions of raw material availability and production costs guarantee at least a medium-run trend to lower real prices for chemical fertilizers. Unless fertilizer prices are maintained at unnecessarily high levels to protect high-cost domestic plants, increasing supplies will be available at prices that will ensure favorable returns as long as grain prices remain close to their present levels.

Because of the radical and recent nature of these developments, uncertainty about their likely quantitative impact is inevitable. Quentin West, Director of the United States Department of Agriculture's Foreign Regional Analysis Division, has stated that "it seems unlikely that the new rice varieties will quickly spread beyond about 10 per cent of the rice area . . . in south and southeast Asia . . . and food-deficit countries will become even more dependent on outside food sources" (*49*, pp. 4–5). A subsequent statement by West at the 1969 National Agricultural Outlook Conference, however, makes no reference to increasing dependence on outside sources. A recent statement by Lester Brown, a former colleague of West's, is more optimistic. Brown suggests that enlarged production for export in countries such as Pakistan that are in a particularly favorable position to exploit the new production possibilities will create pressure on European countries and Japan to open up their protected markets (*10*).

The rate of adoption of the new varieties and the resulting increases in per acre yield and total output will obviously depend on a great many factors specific to a particular country or agricultural region. For the high-yielding varieties of rice in particular, the availability of controlled water supplies will be a decisive factor in determining the pace and magnitude of the increases in output that are to be expected (*23*). Economists must try to cope with such uncertainties if they are to formulate agricultural policies and economic strategies suitable to the new circumstances defined by the seed-fertilizer revolution. This paper attempts to quantify, admittedly very roughly, the potential impact of the seed-fertilizer revolution on West Pakistan, and to relate this revolution to the broader questions of Pakistan's development. The physical projection model explained in Section II is used to assess the possible effects of technological change and of changes in the conventional inputs (land, labor, and capital) on the expansion of agricultural output during Pakistan's Perspective Plan period ending in 1985. Alternative expansion paths implied by various assumptions about the changes in production functions and in conventional inputs are explored. Sections III and IV discuss the feasibility and the implications of the alternative projections.

West Pakistan was selected for this exploratory study because the seed-fertilizer revolution there is already beginning to have a dramatic impact on production of wheat and rice, the two major foodgrains of the Province of some 55 million persons. In the 1965/66 crop year some 12 thousand acres were planted to the Mexican dwarf varieties of wheat. In the following season approximately one-quarter of a million acres were planted to the new varieties, and in 1967/68, the first year in which the availability of seed was not a binding constraint, between 2.5 and 3 million acres were planted to dwarf varieties (*12*; *40*). Expansion of the area planted to IR-8, the first of the high-yielding dwarf varieties of rice to be released by the International Rice Research Institute, has been even more explosive, partly because of the rapid seed multiplication permitted by the unusually low seed requirements for rice. In the summer of 1967 Pakistani farmers planted some nine thousand acres to IR-8; in 1968 the acreage planted to this dwarf rice reached approximately 900 thousand acres, more than a quarter of the total rice acreage in West Pakistan (*1*; *13*).

The predominantly irrigated agriculture of West Pakistan constitutes a relatively homogeneous and unusually favorable environment for the spread of the new varieties and the associated changes in fertilizer use and other farm practices. In particular, the programs underway or in prospect for increasing the availability of irrigation water mean that the spread of the new varieties and the heavier application of fertilizers during the Perspective Plan period are not likely to be constrained significantly by the absence of controlled water supplies. Uncertainties relating to future demand prospects, as well as uncertainties on the supply side, make it impossible to predict future changes in production over a 20-year period with any confidence. Nevertheless, enough is known about the yield potential of the new varieties, the ability of these varieties to respond to fertilizer, and the receptiveness of Pakistani farmers to these technical innovations to provide a basis for alternative sets of assumptions that represent the range of production possibilities. In addition to pointing up the contrast between the situation as conditioned by the availability of the new varieties and the situation without the possibilities for shifting production functions, comparison of the expansion paths gives some indication of the returns to be expected from various combinations of investments in fertilizers and other current inputs as compared to investments in tractors and tractor-drawn equipment. Even though the figures that emerge from this exploratory exercise are very rough, they shed light on some important questions of economic policy that would be difficult to evaluate without an assessment of the potential impact of the seed-fertilizer revolution.

We believe that the simple physical projection model outlined in Section II constitutes a valid and useful approach to such an assessment—and one that can easily be revised as accumulating evidence provides a basis for more accurate estimates of the technical coefficients and the rates of change of key inputs. If the approach has merit, it would naturally be desirable for persons with much more intimate knowledge of the Pakistan situation and fuller access to the relevant data to make periodic assessments of the changes in output that are likely to result from the spread of the new varieties and increasingly heavy application of fertilizers. The present dynamic situation makes clear the need to maintain flexibility in agricultural policies and programs so that they can be modified in the light of experience as it unfolds. Comparison of the present potential for increased wheat and rice production with projections made only a few years ago furnishes a useful reminder of the uncertainty that characterizes agricultural change, and of the need for a flexible approach to agricultural development.

PROJECTIONS FOR WEST PAKISTAN

The present study of West Pakistan is based upon alternative expansion paths the economy might conceivably follow in expanding its foodgrain production. Although all of the paths are believed to be feasible in relation to production possibilities, the projected increases in output when allowance is made for the impact of the seed-fertilizer revolution are probably greater than are likely to be realized because of factors on the demand side of the market. The actual increases in the output of wheat, rice, and other farm products will depend upon a complex of factors (including government pricing policies) affecting the relative profitability of alternative economic activities.[1]

The basic cases cover the possibilities for expansion of grain output, with or without the introduction of dwarf varieties, and with or without all-out tractor mechanization.

The low A projections are considered to be a moderately optimistic prognosis

[1] Recent experience with the introduction of the high-yielding varieties of rice emphasizes the difficulty of making reasonably accurate forecasts that take account of factors affecting relative profitability and not merely the physical potentialities for increased output. Farmers in the rice-growing areas of the Central (Punjab) Zone of West Pakistan are reported to have planted only about 200,000 acres to IR-8 in the summer of 1969 compared to something over 350,000 acres in 1968. This was mainly a result of a sharp fall in the price of IR-8 following the 1968 harvest. Millers could not handle the greatly increased volume of commercial sales, and breakage problems were severe because of the antiquated milling equipment and the fact that IR-8 is vulnerable to breakage unless suitable equipment is used. Consequently, the premium quality *basmati* rice enjoyed a threefold price advantage compared to IR-8 which more than offset the higher yield potential of the dwarf variety. In the Sind, however, rice growers do not have this alternative. Climatic conditions are not suitable to growing *basmati*, and because of drainage problems there are almost no other crops that can compete with rice as a summer crop. Moreover, the milling problems for IR-8 were less severe because in that area paddy is parboiled prior to milling, and the price decline was not as extreme. Acreage planted to IR-8 in the Sind in 1969 may have reached 1.8 million acres compared to about half a million acres in 1968. The Rice Adviser to the Government of West Pakistan reports that a new dwarf variety, Mahran 69 (a selection from IR-6), may be planted on close to a million acres in 1970, and as a result the quality and milling problem should be eased somewhat. The competitive position of *basmati* will soon be improved, however, with the release of a dwarf variety that has the *basmati*-type grain and which outyields the local *basmati* by approximately 50 per cent (*37a*).

for Pakistan—including the benefits to be derived from the improved varieties, but without heavy spending for tractors. The use of improved varieties is assumed to spread to all irrigated lands by 1978/79. Cropped acreage (irrigated) is assumed to increase by 20 per cent for wheat and by 30 per cent for rice between 1967/68 and 1984/85. (This and other increases in cropped acreage are assumed to result from a combination of expansion in cultivated area and increases in multiple cropping.) These acreage increases will be facilitated by a projected 42 per cent increase in the farm labor force; the change in size of the farm labor force is calculated as a residual on the basis of the projected increase in the total labor force and the assumed expansion of nonfarm employment. Fertilizer application on irrigated land is assumed to increase steadily, reaching 110 pounds/acre (wheat) and 130 pounds/acre (rice) by 1984/85. The crucial claim which is made for the low A projections, however, is that they can be accomplished with the widespread introduction of improved implements within an agricultural sector which continues to rely primarily on bullock power.

Assumptions for the high A projections differ in three respects. Improved varieties spread to all irrigated lands by 1973/74. Improved bullock implements are introduced more rapidly, and are accompanied by a gradual spread of tractor mechanization. And the latter facilitates a somewhat greater increase in cropped acreage.

Case B calls for rapid tractor mechanization to accompany the introduction of improved varieties. Cropped acreage on irrigated land increases by about 52 per cent (wheat) and 65 per cent (rice) by 1984/85. Other assumptions remain the same as for the high A case.

Cases C and D attempt to represent the choices West Pakistan would have faced were it not for the availability of improved varieties. They make assumptions about mechanization similiar to those for A and B, respectively. Cases C and D are not now realistic possibilities for West Pakistan because improved varieties are being and will continue to be introduced. But they are important in establishing the significance of the improved varieties.

Table 1 summarizes the most important of the assumptions which underlie the projections. The details of the projections are presented in Appendix A.

Physical output in each year of the planning period is calculated for each crop as the sum of the output of local varieties and the output of improved varieties. All rice is grown on irrigated land; for rice, total output is therefore simply the sum of "irrigated improved" and "irrigated local."[2] For wheat, four terms must be summed, because wheat is grown on both irrigated and rainfed land.

Each term is calculated as the product of two factors: (a) the yield per acre (for the particular crop, variety, and land type) and (b) the acreage assumed (for the crop, variety, and land type) for the particular year. Yield per acre is calculated as the sum of: (a) a "base" yield and (b) an increment which is proportional to the amount of fertilizer per acre (above that assumed in the "base" yield) which is applied to the land. The grain-fertilizer response coefficient that

[2] The present analysis does not distinguish between coarse rice and the higher grade *basmati* rice, which is grown largely for export. It did not seem necessary to make such a distinction in this preliminary study; if a more detailed analysis seems justified, coarse rice and *basmati* rice might well be considered as two separate crops.

Table 1.—Input Assumptions for Alternative Expansion Paths*

Alternative	Improved varieties	Fertilizer[a]	Machinery[b]	Cropped land area, irrigated[c]	Labor
Low A	Grown almost exclusively for seed multiplication until 1967/68, when seed became available for widespread use; fairly rapid spread to all irrigated land by 1978/79.	Increases steadily to 110 pounds/acre (wheat) and 130 pounds/acre (rice) of nutrients by 1984/85—for all irrigated land.	Widespread introduction of improved implements to complement a primarily "bullock-powered" agriculture.	Increases of about 20 per cent (wheat) and 30 per cent (rice) between 1967/68 and 1984/85 (for irrigated land).	A 42 per cent increase in the farm labor force from 1968/69 to 1984/85.
High A	More rapid spread completed in 1973/74.	Same as low A.	More rapid introduction of improved implements and gradual spread of tractor mechanization.	Increases of about 40 per cent (wheat) and 50 per cent (rice).	Same as low A.
B	Same as high A.	Same as A.	Rapid introduction of tractors and less sizable introduction of improved implements.	Increases of about 52 per cent (wheat) and 65 per cent (rice).	Same as A.
High C	No improved varieties.	Moderate increases in application to local varieties.	Same as high A.	Same as low A.	Same as A.
Low C	No improved varieties.	Moderate increases in application to local varieties.	Same as low A.	Increases of about 10 per cent (wheat) and 17 per cent (rice).	Same increase in labor force but a slower increase in labor inputs in a flow sense.
D	Same as C.	Same as C.	Same as B.	Same as B.	Same as low C.

* See Appendix A for related figures.

[a] The grain-nutrient fertilizer response ratio for wheat is assumed to rise from 12:1 to 16:1 (on a weight basis). The response coefficient for rice (milled basis) is assumed to rise from 8:1 to 13:1. See Table A-5.

[b] See Table 3 for more detailed description.

[c] All rice is grown on irrigated land. Approximately 4.5 million acres of rainfed land is planted to wheat. Partial introduction of improved varieties on this land is assumed in A and B.

TABLE 2.—ALTERNATIVE PROJECTIONS OF GROSS OUTPUT OF FOODGRAINS IN WEST PAKISTAN*
(Million long tons; rice figures are for clean rice)

	A				B		C				D	
	Low		High				High		Low			
Year	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice
1964/65	4.2	1.3	4.2	1.3	4.2	1.3	4.2	1.3	4.2	1.3	4.2	1.3
1969/70	6.1	2.0	7.1	2.3	7.1	2.3	4.4	1.4	4.4	1.4	4.5	1.4
1974/75	9.3	3.2	11.2	4.2	11.6	4.3	4.7	1.6	4.6	1.5	5.1	1.7
1979/80	13.0	4.9	14.3	5.5	15.1	5.8	5.1	1.8	4.9	1.7	5.9	2.1
1984/85	15.9	6.2	18.2	7.3	19.7	8.0	5.5	2.0	5.1	1.8	6.7	2.6

* See text and Table 1 for description of assumptions.

determines the incremental expansion of output associated with increased application of fertilizer is assumed to rise gradually.[3] Provided the increased fertilizer consumption applies to a rapidly expanding acreage planted to the improved varieties of wheat and rice, as assumed in the projections, it is likely that any tendency toward diminishing returns with heavier rates of fertilizer application will be more than offset by other factors. In particular it seems reasonable to assume that as knowledge concerning efficient fertilizer use spreads, and a growing percentage of Pakistani farmers employ the associated practices required to realize the genetic potential of the new varieties, the average fertilizer response coefficients will rise gradually during the next 15 years.[4]

The procedure employed here makes fertilizer and improved varieties the key inputs in the production process. It is simply assumed that other inputs, notably labor and irrigation water, will be able to "keep up" so that they do not act as limiting factors. These assumptions are defended in greater detail in Section III below.

The projected increases in output under the alternative expansion paths are summarized in Table 2. Clearly, the varietal breakthroughs constitute a revolution in the prospects for agriculture in West Pakistan. Major increases in inputs would, of course, be required to achieve the kind of output increases indicated by the A and B expansion paths. Most important will be very large increases in the application of chemical fertilizers (see Table A-7). There can be no doubt, however, about the profitability of employing greatly increased quantities of this input. Within the ranges of application relevant here, the grain/nutrient response ratios for chemical fertilizers (on a weight basis) are of the order of 10 to 1, while the nutrient/grain price ratios are in the range of 2 to 1 or 3 to 1.

[3] See Appendix A for a fuller explanation of how the yield figures underlying the various projections were calculated. Although many of the assumptions relating to the various technical coefficients used in this exploratory study are fairly arbitrary, we have attempted to make them as realistic as possible. In addition to the annual technical reports relating to the Wheat and Rice Improvement Programs in West Pakistan, we have been guided by the judgment estimates of Narvaez and Aresvik, and by discussions with Kenneth Mueller, Rice Research Adviser assigned by IRRI to the Government of West Pakistan, and Ch. Mohammad Shafi, Officer-in-Charge of the Kala Shah Kaku Rice Research Station (*3*; *4*; *11*; *40*; *41*; *42*). A primary purpose of this exercise, however, is to emphasize the importance of obtaining better estimates of these and other technical coefficients as further research and field experience provide additional evidence.

[4] R. J. Laird, for example, has stressed the great importance of more intensive studies of soil and water management in West Pakistan as a basis for further increases in crop yields (*33*).

Much more controversial is the question of how the power requirements for West Pakistan agriculture are to be supplied. Certainly at the very least many improved implements will be required to augment the available bullock draft power. The key policy issue is whether the government should encourage farmers to replace traditional bullock power with modern tractors; this question is examined in Section IV and in Appendix B.

THE FEASIBILITY OF THE PROJECTIONS

It is obviously a gross simplification to project the increase in production of wheat and rice on the basis of assumed rates of diffusion of improved varieties, increased use of fertilizers, and an increase over time in the grain/fertilizer response coefficients. It has been noted that the projections are *not* intended to be realistic forecasts of probable changes in output of these crops because no attempt has been made to assess the influence of projected supplies on the prices of wheat, rice, and competing crops, or to consider other factors influencing relative profitability. But the projections are intended to be realistic, or at least plausible, as an indication of the capability of West Pakistan to expand output of these crops—given the production functions that are now available.

The decision to concentrate on the spread of the improved varieties and increases in fertilizer use was based on a judgment that for the period under consideration they will be the most important dynamic factors determining the speed at which production of wheat and rice expands. In their analysis of the sources of increased production in the First and Second Plan periods, Falcon and Gotsch very logically singled out the increased availability of irrigation water as the most dynamic influence, although the importance of increased fertilizer supplies was also emphasized (*18*; *19*). It would have been impossible at that time to anticipate the impact, or, in the case of rice, even the availability of the improved varieties that are now of such tremendous importance.

The level of crop production depends, of course, on the interacting influence of a great many factors. At a minimum it is necessary to recognize seven categories of inputs:

(1) labor inputs, determined by the size of the farm labor force and the average amount of work per farm worker;[5]

(2) land inputs, determined by the total cultivated area and the cropping intensity, with the latter a function of incentives, the availability of water, and other factors that determine the prevalence of multiple cropping;

(3) water availability, with attention to timing as well as quantity;

[5] Previous historical experience and recent developments in West Pakistan suggest that an increase in multiple cropping may lead to an increase in farm labor inputs that is considerably greater than the increase in the farm labor force. In Taiwan, for example, an increase in cropping intensity, made possible by increased availabilty of controlled water supplies, led to a sizable increase in farm labor inputs because of an increase in the average number of working days per member of the farm labor force. Although the total cultivated area in Taiwan increased by only about 25 per cent between 1910–15 and 1956–60, the cropped area approximately doubled. Labor inputs per cropped acre remained constant so that total labor inputs measured in working days also doubled even though the increase in the farm labor force was only about 50 per cent (*35*, pp. 93, 99). As noted later, Ghulam Mohammad's survey of tubewell and non-tubewell farmers in West Pakistan indicated that the increase in cropping intensity among tubewell farmers (because supplementary irrigation was available) was associated with a substantial increase in the rate of utilization of the existing farm labor force (*21*).

(4) varieties planted and their yield potential;

(5) soil fertility levels, with major attention to the quantities of nutrients supplied as chemical fertilizers;

(6) farm practices, which are a function of the technical knowledge available and the incentive and ability of farmers to apply recommended practices; and

(7) nonhuman power inputs—animal draft power, tractors and self-propelled machinery such as combines, and electric motors or diesel engines for pumping, threshing, and other auxiliary operations.

Certain farm practices—notably proper seedbed preparation, planting techniques, plant population, weed control, and pest control—take on increased importance with the shift to high-yielding varieties that are more sensitive to such factors as depth of planting and weed competition (and high levels of fertilizer application stimulate growth of weeds). Moreover, a yield increase of, say, 15 per cent is obviously more rewarding when it applies to a per acre yield of 4,000 pounds rather than 1,000 pounds.

Plant protection measures are critically important for the dwarf varieties of rice, and necessary outlays for insecticides will be substantial, perhaps on the order of one-third the cost of the recommended dosage of fertilizer under West Pakistan conditions. (Pest problems are not considered to be as difficult in West Pakistan as in Southeast Asia where humidity is generally higher.) The Mexican dwarf varieties of wheat are rust resistant, and the main requirement is for a continuing plant breeding program to permit varietal changes as some varieties become vulnerable to the present or new races of rust. Experience in Mexico indicates that grain aphids may reach epidemic proportions perhaps once in five years, and at such times dusting becomes important.

Effective performance of the farming operations mentioned above will, of course, be strongly influenced by the types of equipment used and the availability of power—human, bullock, or tractor. It is obvious that the spread of the new varieties and the large increases in production indicated in the A and B expansion paths will require substantial changes in the types of equipment used by farmers, and considerably greater inputs of labor and power. Rapid increase in the use of tractors and tractor-drawn equipment would facilitate expansion of area and would make it easier for farmers to carry out properly such practices as seedbed preparation; furthermore, combine-harvesters would be a technically attractive means of overcoming harvesting bottlenecks. The crucial questions concern the profitability of investment in mechanization to augment the rate of growth of output obtainable by exploiting the possibilities opened up by the seed-fertilizer revolution. In the following section alternative approaches to mechanization are examined, and an attempt is made to assess the cost of three alternatives ranging from almost exclusive reliance on improvements in bullock-drawn equipment to major reliance on rapid expansion of tractor numbers. It is suggested there that the profitability of investments in tractor mechanization, at least from society's point of view, will depend critically on whether the potential demand for foodgrain exports justifies an even more rapid increase in output than that obtainable with rapid spread of the new varieties and increased fertilizer use associated with modest investments in improved farm equipment to overcome labor bottlenecks.

In view of the enormous importance of irrigation water to agriculture in West Pakistan, it is necessary to explain why explicit attention is not paid to this critical factor in the present projections. The importance of irrigation water is appreciated in West Pakistan, and it appears reasonable to assume that supplies of irrigation water during the Perspective Plan period ending in 1984/85 will increase rapidly enough to ensure water availability adequate to the increases in yields and in cropped area assumed in the projections.[6]

Prior to the 1960's irrigation water was supplied primarily through an extensive system of river barrages and canals commanding a gross area of about 38 million acres (although no more than 25 million acres actually received surface water supplies). Following the introduction of a relatively simple and inexpensive tubewell technology in the early 1960's, there has been a rapid increase in irrigation water from this source; the effect on production has been particularly favorable because tubewell water supplements canal supplies at times of greatest need (*19*; *21*; *24*). Expansion of both private and public tubewells is continuing at a rapid pace, and the timely supplementation of canal supplies is making possible a substantial expansion of double cropping.[7] Furthermore, the completion of the Indus Basin Project with its system of link canals and dams (including the huge Tarbela Dam for which foreign economic assistance has already been committed) will allow more upstream storage and a net addition to canal supplies. The addition of Tarbela water in 1974/75 will relieve the general water shortage in the *rabi* (winter) season and will also enable perennial supplies to be delivered to areas which are suited to perennial cropping but are without adequate groundwater resources of suitable quality (*24*, p. 90).

Projections of irrigation water supplies from surface and groundwater sources for consumptive use by crops, after deductions for losses from seepage, conveyance, and evaporation, indicate that 43 million acre feet are currently available, 60 million acre feet will be available by 1975, and 74 million acre feet by 1985 (*24*, p. 90).[8] The total acreage that can be irrigated by this quantity of water depends on the pattern of crops grown and their consumptive use requirements. Assuming the average irrigation requirement to be two acre feet per year, the total potential irrigated acreage by 1975 may be put at around 30 million. On the basis of a cropping intensity factor of 130 per cent, irrigated cropped acreage would be about 39 million in 1975. If expansion of irrigated land by 1985 does not exceed the 30 million acres recommended by the World Bank, the additional water which will become available after 1975 may be expected to lead to further

[6] The singular dependence of West Pakistan agriculture on irrigation water is well documented. The Revelle Report on Land and Water Development in the Indus Basin (*50*) has been followed by even more detailed studies by the World Bank and by consultant firms working under the auspices of the Bank. Ghulam Mohammad has called attention to the importance of the rapid expansion of private tubewells since 1959, and he has argued for concentrating government efforts on the expansion of water supplies and on increased use of fertilizers (*20*). Michel provides an excellent historical account of the development of irrigation and also a summary account of plans for further expansion of irrigation facilities (*38*).

[7] Current estimates put private tubewell numbers at over 60,000 in the Indus Basin. These wells generally have a capacity of about one cubic foot per second or enough supplemental water to irrigate about 100 acres on an annual basis (*32*).

[8] These estimates are calculated on the basis of 10 per cent losses in watercourses and 30 per cent losses in the fields. A net addition of 6.3 million acre feet is supplied by annual rainfall (*24*, p. 63).

significant increases in multiple cropping.[9] Assuming a commanded area of 30 million acres and an increase in the intensity of irrigated land use to 150 per cent by 1985, the irrigated cropped area would amount to nearly 45 million acres.

A probable increase of these magnitudes in water availability and in total irrigated area makes it most unlikely that water will be a constraint on the projected acreage increases for wheat and rice. It is true that the interaction effects between water and fertilizer at high levels of fertilizer application are significant, and that farmers will probably find it profitable to increase the per acre application of water as they increase that of fertilizer. Nevertheless, the increases in yields and cropped acreage assumed in the projections seem entirely consistent with the likely availability of irrigation water.

Important questions remain, however, concerning the magnitude of the increase in requirements for nonhuman power that are implied by the alternative expansion paths considered here. Those issues and the related questions concerning the profitability for West Pakistan of producing such large amounts of foodgrains are discussed in the following section.

IMPLICATIONS OF THE PROJECTIONS

The projections of this study have implications for many of the questions which must be considered by economic planners in West Pakistan.

Interdependence Between Agriculture and Other Sectors

The implications of these output projections for West Pakistan should be considered in conjunction with the interrelationships between the agricultural sector and the rest of the economy. Three aspects of this sectoral interdependence are of particular importance in determining efficient sequences for a strategy of agricultural development: (1) the size and rates of growth of population and labor force in agriculture and in nonagriculture; (2) the interdependence between farm cash income (and how it is distributed) and the use of purchased inputs; and (3) the likely impact on overall economic growth of alternative strategies for agricultural development.[10]

Size and rates of growth of population and labor force.—Population and labor force are growing rapidly in most of the less developed countries, and in this respect Pakistan is typical. Furthermore, the relative sizes of the agricultural and nonagricultural population ensure that the former will, for some time, continue to grow in absolute size even while the latter grows at a more rapid rate. However, there are marked variations among the less developed countries in the extent to which structural change has led to a decline in agriculture's share of the total labor force and the gross national product. In fact, there is a considerable contrast between East and West Pakistan in this respect, and the experiences of the two regions pretty well bracket those of the less developed world as a whole.

[9] The World Bank group's recommendation indicates that although water may not be a binding constraint on production in the current period, it can be expected to become a limiting factor in the future. The Bank's recommendation therefore is to intensify cropping on a 30 million acre land base over the Perspective Plan period (1965–85) rather than to expand total irrigated area (*24*, p. 28).

[10] The sectoral interdependence between agriculture and the nonfarm sectors is examined more fully in *29* and *30*.

The phenomenally rapid expansion in the post-Partition period of nonagricultural investment and output in West Pakistan was associated with rapid growth in nonfarm employment, and the share of agriculture in the total labor force declined from 65 to 59 per cent between 1951 and 1961 (*8*, p. 385). Nonfarm employment increased during that period at a rate of 4.5 per cent, a rate of increase which, in the post–World War II period, appears to have been exceeded only by Taiwan (*28*, p. 274). Increases in the capital intensity of investment and in industrial productivity may have resulted in a slowing in the rate of expansion of nonfarm employment since 1961, and particularly during the past few years in which industrial growth has been less rapid. Data are not available for testing that supposition, however, and we have therefore based our projections on the optimistic assumption that nonfarm employment in West Pakistan would continue to grow at the 4.5 per cent rate until 1985. On that basis nonfarm employment would increase nearly threefold from the 1961 census figure of 5.3 million to 15.1 million in 1985. The projected increase in the total labor force is from 12.9 million in 1961 to 27.4 million in 1985, implying an increase in the farm labor force of 60 per cent from 7.7 million to 12.2 million.[11] (The 42 per cent increase in the farm labor force mentioned earlier relates to the increase from 1968/69 to 1984/85.)

Interdependence between farm cash income and the use of purchased inputs.—The ability of the agricultural sector to obtain purchased inputs from the nonagricultural sector is, of course, limited by the cash income received by farmers (although the time horizon of this constraint can be shifted by the availability of credit). Total cash income of the agricultural sector is, in turn, determined by exports and by domestic sales to the nonagricultural sector. Receipts from the former will depend on world market conditions as well as on Pakistani output. The uncertainties of future world demand are discussed below. Growth of domestic sales to the nonagricultural sector will be limited by the growth of employment and cash income in that sector. Limitations on these are also discussed below. What is important here is that the potential cash income of the agricultural sector may, in the near future, be restricted more sharply by limitations of demand than by the ability of the agricultural sector to expand output. However, it is

[11] The calculations were based on the population projections and labor force participation rates given in *7* and *8*. (The unrounded 1961 figures, in millions, used in making the projections were 12.904, 7.652, and 5.252 for total, farm, and nonfarm labor force respectively.) It is worth noting that the increase in the size of the farm labor force in West Pakistan will not be as large as in East Pakistan. The rate of change in the farm labor force (L'_A) depends on agriculture's initial share in the total labor force (L_A L_T) as well as on the extent to which the rate of growth of nonfarm employment (L'_N) exceeds the rate of growth of the total labor force (L'_T). On the assumption that the change in the size of the farm labor force is determined as a residual, we have

$$L'_A \equiv \frac{L_T}{L_A} L'_T - \frac{L_N}{L_A} L'_N .$$

As a result of the adverse effects of Partition on the economy of East Pakistan, the growth of nonfarm output in employment was relatively slow. In fact, nonfarm employment increased at about the same rate as the farm labor force between 1951 and 1961. Consequently, there was no decline in agriculture's share of the labor force which was 85 per cent of the total in the latter year. Efforts to foster industrial expansion in East Pakistan have no doubt accelerated the rate of increase in nonfarm employment, but if the farm and nonfarm labor force in East Pakistan were both to continue to grow at the same rate as the total labor force, the farm labor force would increase from 14.3 million in 1961 to a little over 30 million in 1985, giving rise to severe problems in an agricultural economy where the average farm unit is already extremely small.

not only the total volume of agricultural cash receipts or purchased inputs which is of interest; the kinds of inputs purchased will also play a role in determining the course of a nation's agricultural and economic growth. If the agricultural sector is characterized by the "dual-size structure" so often found in Latin American countries, a relatively small group of large-scale farmers will employ capital-intensive methods and will purchase large quantities of such inputs as tractors and other heavy machinery. It follows, however, that the majority of the agricultural labor force, concentrated on small-scale farms, will find their ability to command such purchased inputs as chemical fertilizers correspondingly lessened (unless exports can be expanded fast enough so that effective demand does not act as a constraint on the growth of output).

The impact of agricultural development strategies on overall economic growth.—Development strategies for agriculture in West Pakistan should, of course, attempt to ensure that the benefits of the seed-fertilizer revolution have the maximum possible positive impact on the total economy. Strategies to be implemented by government policy must assess the *social* benefits and costs of alternatives, and should seek to discourage (for example) patterns of investment which might be advantageous for a relatively few large farm operators but wasteful from the point of view of the economy as a whole. A specific possible example is examined in detail in the following discussion of nonhuman power sources.

Alternative Approaches to Meeting Increased Power Requirements

Because of its relevance to the three areas of interdependence mentioned above and to the choice of strategy for agricultural development, the mechanization issue has been analyzed as it pertains to agriculture in West Pakistan in some detail. This analysis has necessarily been done subject to the limitations of available data, and in some cases these are severe. Nevertheless, we believe that even our preliminary analysis serves to clarify some of the crucial questions that need to be considered with care by policymakers and economists.

Labor requirements for some operations are almost entirely a function of the planted area; for these activities the increase in labor requirements, in the absence of any changes in equipment or technique, would be proportional to the increase in cropped area assumed to occur by 1984/85—only 20 per cent (wheat) and 30 per cent (rice) under the low A assumption but 52 per cent (wheat) and 65 per cent (rice) under the B expansion path that assumes rapid mechanization. At the opposite extreme, labor requirements for operations such as transportation and storage (again in the absence of changes in equipment or technique) are nearly proportional to output. Labor requirements for threshing are closely related to the size of the harvest, and a strong demand for power threshers has been a direct consequence of the introduction of the dwarf wheat. Most operations fall somewhere between the two extremes in their effect on labor requirements. For reasons already noted, the per acre requirements for seedbed preparation, planting, weeding, and plant protection will increase because a higher standard is required to realize the yield potential of the new varieties. Labor requirements for harvesting are increased because of the heavier yield, but the increase is not proportional; the new varieties are easier to reap because there is very little lodging and the plants are closely spaced.

The approach adopted here is to bracket a broad spectrum of possible approaches to mechanization by considering three alternatives. All three mechanization alternatives are related to the assumption that the "stock" of farm labor will increase by approximately 42 per cent between 1968/69 and 1984/85 because the size of the farm labor force has been projected as a residual from assumed rates of growth of the total labor force and of nonfarm employment.

Continuation of the present situation in which virtually all farmers carry out their field operations with bullocks and the traditional "stick plow" and very little auxiliary equipment should not be viewed as the only alternative to tractor mechanization. The increased incentive to carry out operations such as seedbed preparation and weed control more efficiently than is possible with the traditional yoke and stick plow means that many farmers will have a keen interest in equipping themselves with better implements. And the rapid increase in farm cash incomes that can be expected during the next few years as enlarged domestic sales are substituted for foodgrain imports means that a considerable number of farmers will have the purchasing power to make this demand effective. Thus the really interesting questions concern the extent to which Pakistani farmers will move in the direction of upgrading the quality and range of bullock-drawn equipment as compared to the alternative of all-out mechanization with tractors. We were unable to examine the possible role of single-axle tractors (power tillers) in meeting power requirements in West Pakistan because of the lack of information concerning the costs and performance characteristics of such units.[12]

We have made a very rough and tentative comparison of the costs associated with three mechanization alternatives as described in Table 3. The first alternative is based on the assumption that the labor requirements associated with the low A expansion path could be satisfied by fairly rapid spread of improved equipment such as moldboard plows, seed drill-fertilizer spreader units, improved bullock harness, and simple rotary threshers. At the opposite extreme, we have made rough calculations of the cost of implementing a program of rapid tractor mechanization. The rough cost comparisons summarized in Chart 1, and described in greater detail in Appendix B, are based on estimates of the annual costs associated, respectively, with the "improved bullock equipment package" and the "tractor package" listed in Table 4; the total cost of each alternative in each year was calculated on the basis of the number of such "packages" in that year for each mechanization alternative. The costs of the high A alternative were estimated

[12] It would seem desirable to include analysis of power tillers or small tractors in the 5 to 15 horsepower range in future research. As Giles points out in his report, both the initial cost per horsepower and the operating cost per horsepower are higher for the smaller tractors (*22*, p. 20). Although larger tractors have a clear advantage in technical efficiency, additional elements would have to be assessed to arrive at a valid judgment concerning their economic efficiency. The smaller tractors and power tillers have obvious advantages on the small fields which characterize much of the irrigated area in West Pakistan. More than 75 per cent of the farm holdings in West Pakistan are less than 12.5 acres, and most holdings consist of several different plots (*44*, p. 12). Although nearly two-thirds of the cultivated area is in holdings of more than 12.5 acres, many of these are farmed by tenants in smaller units. Moreover, the large and growing farm labor force in West Pakistan means that the cultivated acreage per farm worker will continue to be small. As is pointed out below, setting up large "economic" units to facilitate mechanization with larger tractors necessarily implies that the remaining holdings will be reduced accordingly. Small tractors and power tillers also have the related advantage that they are within the financial means of farmers cultivating a small acreage—5 to 10 acres according to studies carried out by the International Rice Research Institute in the Philippines (*26*; *27*).

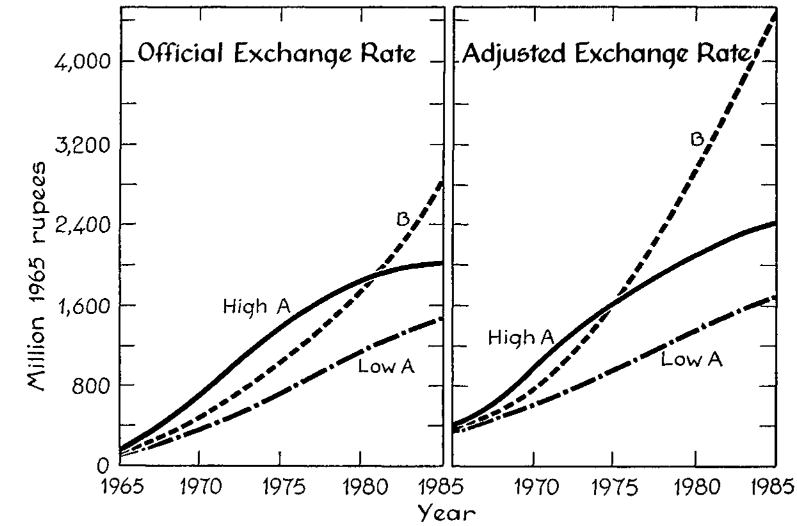
Table 3.—Assumptions Underlying the Alternative Approaches to the Expansion of Agricultural Power*

Method	Low A	High A	B
Improved bullock package	Increase in improved bullock package numbers to cover 50 per cent of total bullock acreage by 1978 and 70 per cent by 1985.	Increase in improved bullock package numbers to cover 80 per cent of total bullock acreage by 1978.	Increase in improved bullock package numbers to cover 40 per cent of total bullock acreage by 1978.
Tractors	No increase in tractors.	Increase in tractors on farms of 5 per cent per year throughout period.	Increase in tractors on farms of 15 per cent per year throughout period.
Description	Moderately heavy emphasis on improved bullock technology with slight commitment to use of tractors.	Heavy emphasis on expansion of improved bullock technology with moderate increase in number of tractors.	Primarily tractor-type modernization program with only limited spread of improved bullock technology.

* These alternatives are briefly described in the Machinery column of Table 1.

As explained in the text, these mechanization alternatives are intended to meet the power requirements associated with the expansion paths described in Table 1 and the corresponding output projections in Table 2.

CHART 1.—APPROXIMATIONS OF TOTAL ANNUAL COSTS OF MECHANIZATION ALTERNATIVES EXPRESSED AT OFFICIAL AND ADJUSTED RATES OF EXCHANGE (CONSTANT 1965 PRICES)*



* Data from Appendix Table B-3.

in the same way but on the assumption that the number of "packages" of improved bullock equipment would increase more rapidly than under the low A alternative and that there would be a 5 per cent annual increase in the number of "tractor packages" (compared to the 15 per cent rate under the B alternative of rapid tractor mechanization). In addition to the cost calculations based on the official exchange rate approximations of the costs of the mechanization alternatives are given calculated on the assumption that the official rate is overvalued by 100 per cent.

Clearly these estimates must be regarded as merely giving a rough indication of the order of magnitude of the costs associated with alternative approaches to mechanization. The most critical lack of knowledge concerns the extent to which power requirements will be increased as a result of increases in cropped area and the substantial increases in yield and output that are in prospect. On the basis of exceedingly limited evidence we judge that the increases in output associated with the low A alternative would probably be feasible with a substantial increase in the quality and range of bullock implements along the lines suggested in Table 4, given the growth of the farm labor force that is in prospect and the fairly moderate increases in cropped area assumed in that expansion path. The evidence that is available for West Pakistan suggests that the increased prevalence of multiple cropping that is to be expected is likely to lead to an increase in labor inputs in a flow sense greater than the anticipated growth of the total farm labor force and also to fuller utilization of the existing stock of bullocks. Ghulam Mohammad's survey comparing the cropping patterns of tubewell and non-tubewell farmers indicates that there is considerable scope for increasing the rate of utilization of both farm labor and bullocks; cropped acreage on farms

TABLE 4.—COMPONENTS OF ALTERNATIVE MECHANIZATION PACKAGES*

Improved bullock equipment package	Tractor package
One pair of bullocks	35 HP diesel wheel tractor
Adjustable moldboard plow	Straight shank cultivator
Spiketooth or comb harrow	Disc plow
Seed drill-fertilizer combination	Spiketooth harrow
Ridger	Drill and fertilizer applicator
Hand-operated rotary weeder	Tractor mounted rototiller
Pedal thresher	Tractor-drawn six-foot harvester
Improved bullock harness	Tractor-drawn land plane

* Bullock package assumed to be most effectively utilized on a 12½-acre farming unit.
Tractor package assumed to be most effectively utilized on a 100-acre farming unit. The cost calculations are based on the assumption that only half of the farms with the "tractor package" will have rototillers and that only one-third of the mechanized farms will have a harvester.

served by tubewells averaged roughly 10 acres per man and 17 to 20 acres per team of bullocks. Depending on the district, these represented increases of 30 to 50 per cent per man and per team of bullocks as compared to the acreage on non-tubewell units (*21*, pp. 22–24).

Rapid tractor mechanization, as assumed under the B alternative, would naturally permit more rapid expansion of the area planted to wheat and rice and a substantially larger increase in output. G. W. Giles recommended that the number of tractors be expanded at the rate of 15 per cent a year (our B alternative), and asserted that pursuit of such a program "even with borrowed monies should return handsomely in the future with exports of wheat, rice and maize to help satisfy the world's food grain needs" (*22*, p. 6). If export demand for wheat and rice should prove to be as buoyant as assumed by Giles, the foreign exchange costs associated with the B expansion path would not be a serious disadvantage; rapid mechanization would make it possible to expand foodgrain exports more rapidly and reach even higher levels of exportable surplus than implied by Table 5 where supplies associated with the low A expansion path are compared with projected domestic requirements.

If it turns out, however, that world demand for foodgrain imports is not so elastic, the high foreign exchange cost of the B alternative represents a social cost that is greater than the cost of tractors, associated materials, and equipment at the official exchange rate, especially if the official rate is overvalued. And it seems likely that the official rate may be overvalued by as much as 100 per cent. If the expansion of foreign exchange earnings as a result of enlarged foodgrain exports were sufficiently great, however, it is conceivable that the existing imbalance between the supply and demand of foreign exchange might be corrected. But in light of the world supply and demand prospects for foodgrains, discussed briefly in the following section, it seems unlikely that Pakistan will be able to expand its foreign exchange earnings rapidly enough to eliminate the present overvaluation of the rupee. In any event, if Pakistan is to export wheat and rice at competitive prices, it will have to pay an export subsidy or, more likely, permit grain exports under the bonus voucher system so that exporters can obtain rupees on terms more favorable than the official rate (*6*).

TABLE 5.—FOODGRAINS IN WEST PAKISTAN: SUPPLY AND DOMESTIC DEMAND*
(*Millions long tons*)

Year	Wheat		Rice	
	Low A supply	Projected demand[a]	Low A supply	Projected demand[b]
1964/65	4.2	4.8	1.3	1.0
1969/70	6.1	5.8	2.0	1.2
1974/75	9.3	7.2	3.2	1.5
1979/80	13.0	8.6	4.9	1.8
1984/85	15.9	10.3	6.2	2.1

* Low A supply from Table 2.

[a] Growth of demand at 4.1 per cent per year is assumed through 1970/71. Annual growth rate then tapers off to 3.5 per cent by 1984/85 because of an assumed decline in income elasticity of demand for foodgrains.

[b] Estimates through 1969/70 are from the 1966 annual progress report on the accelerated rice research program (R. B. M. Abbasi, Mohammad Shafi, Sulyman Khan, and Kenneth Mueller, *Annual Progress Report on Accelerated Rice Research Program, West Pakistan, 1968* (Planning Cell, Agr. Dept., Govt. of West Pakistan, Lahore, December 1966, Appendix E). Rate of growth of demand is assumed to taper off from 4.0 per cent (maintained through 1972/73) to 3.5 per cent in 1984/85 as in the case of wheat.

Demand Projections

Even with full allowance for their tentative character, the present projections eliminate any doubt about the ability of West Pakistan to become self-sufficient in foodgrain production. In fact, preliminary reports on the 1969 harvest indicate that self-sufficiency in wheat production has already been reached; and the region already exports significant amounts of the premium quality *basmati* rice. The domestic demand for these crops will increase throughout the 1970's and 1980's, but the projections of Table 5 indicate that a large and growing exportable surplus will emerge.

One of the key questions facing policymakers in West Pakistan is whether in fact an expansion path for foodgrains implying such a huge exportable surplus would represent an optimal use of the region's agricultural resources. East Pakistan may for a time absorb much of the West Pakistan surplus, but East Pakistan will most likely be moving toward regional self-sufficiency even as the potential surpluses in the West continue to grow. Thus it will be to West Pakistan's advantage to exploit fully her capacity to produce foodgrains only if the world market will absorb surpluses at prices which make production profitable.

Recent allegations concerning an impending world food crisis have encouraged a tendency to justify investment in mechanization on the assumption that the demand for agricultural products is unlimited. Given that climate of opinion, it is not surprising that Giles advised the Government of West Pakistan to pursue a program of rapid tractor mechanization not only because grain exports "should pay off handsomely in monetary returns" but also because Pakistan has "the added responsibility and opportunity to contribute to the world's growing food needs" (22, p. 14). The rapid expansion of world foodgrain exports (from 33 million tons in 1955 to 66 million tons in 1964) also might engender confidence that the demand for exports will remain extremely buoyant. A recent report by the Secretary General of the Organization for Economic Cooperation and Development (OECD) argues, on the basis of projecting these recent trends, that the less developed countries face growing food import deficits and that the developed countries must therefore ensure that increased supplies of food aid will be available (*43*, p. 26). In his criticism of this report, Schultz has pointed out that projections derived from the growth of food imports during that period are almost certain to mislead because those changes were the result of a disequilibrium situation that is now being modified drastically (*47*, pp. 14–16). There is clearly an important need for revised world projections of import demands and exportable surpluses that take account of the magnitude of the probable impact of the seed-fertilizer revolution. That the projections currently available are misleading is underscored by the fact that West Pakistan itself is included among the less developed countries expected to encounter growing food deficits. That view is indeed consistent with the C and D expansion paths shown in Table 2, but happily the potential for expanded output that is now available makes such a view obsolete. Admittedly, West Pakistan is in an unusually favorable position to take advantage of the high-yielding varieties of rice and wheat, but there is no doubt that their impact will also alter the prospects for domestic production in a number of deficit countries. The Philippines, for many years a net importer, has already begun to export rice as a result of the spread of IR-8 and other high-yielding varieties. And Kenya, to cite an African example involving hybrid and synthetic varieties of maize, seems destined to emerge as a fairly important exporter. Kenya's late Minister for Economic Planning and Development, T. J. Mboya, even argued that the United Nations should purchase surpluses in certain developing countries so that they could participate in food aid programs (*39*, p. 11). It seems most unlikely that the developed countries would show much enthusiasm for financing any sizable food aid programs unrelated to their own farm price support programs, but Mboya's statement is an interesting indication of how rapidly conditions are changing since Kenya was a recipient of food aid under P.L. 480 as recently as 1966.

West Pakistan's ability to compete advantageously for a share of the world's grain trade will depend on a number of factors that we are unable to assess. The extent to which world grain prices are likely to decline will be influenced by government policies in the major grain exporting and importing countries as well as the underlying cost conditions. West Pakistan now has a large potential for relatively low-cost expansion of foodgrain production and exports based to a considerable extent on more effective utilization of its existing on-farm resources of labor and land and the capital represented by its irrigation systems and stock of bullocks. It would seem to be evident, however, that before West Pakistan commits sizable amounts of resources to tractor mechanization (thus increasing its exportable surplus *above* that implied by Table 5), the alternative uses for such resources should be weighed carefully.

Although detailed consideration of alternative investment opportunities is beyond the scope of this paper, recent studies of wheat and rice marketing problems in West Pakistan suggest that very high priority should be given to measures to rapidly improve the capacity and quality of facilities for storing, processing, grading, and shipping these commodities (*5*; *14*; *15*; *16*; *37*; *51*). The present marketing system will be totally inadequate to handle the increased volume of foodgrains that will be entering the market. The seriousness of this situation is particularly acute as it affects Pakistan's ability to compete efficiently on international markets as a major exporter of foodgrains. It has been estimated, to cite an important example, that investment in improved rice milling plants would yield a 39 per cent return on capital and pay for the foreign exchange component of the initial investment within the first year of operation (*16*, pp. 19–20).[18] The fundamental proposition, however, is that substantial investments in enlarging and upgrading facilities for drying, storage, processing, and handling are indispensable if Pakistan is to become a successful grain exporter. Investments in tractor mechanization, on the other hand, would simply accelerate the rate at which Pakistan could emerge as a major exporter and permit a somewhat higher level of foodgrain exports, provided that world demand conditions are such as to make it profitable to expand exports at the rate implied by the B expansion path.

Another important alternative within the agricultural sector that merits serious consideration relates to the potential gains to be realized from changes in the composition of agricultural output in West Pakistan. As in most countries, income elasticities of demand for such expensive but highly esteemed commodities as fruit and vegetables and livestock products are considerably higher than for cereals (*31*). To what extent should the improved production possibilities that now exist be utilized to achieve a fairly rapid improvement in the economic and nutritional quality of Pakistani diets rather than attaining a maximum exportable surplus of foodgrains? That is obviously a difficult question, but to the extent that there is a trend toward such diversification the justification for rapid tractor mechanization would be reduced. With respect to the balance between agricultural and other economic sectors, the importance of allocating scarce resources of capital and foreign exchange to enlarging the manufacturing sector and related infrastructure is widely recognized. Its importance to Pakistan is accentuated, however, by the magnitude of the labor force absorption problem that is dealt with in the following section.

The rate of growth of demand is also relevant to another argument frequently made on behalf of tractor mechanization. Proponents of tractor mechanization commonly emphasize that the replacement of bullocks will permit a significant reduction in the acreage devoted to fodder production, thereby permitting increased production of foodgrains and other crops. At the present time approximately 20 per cent of the total cropped acreage is devoted to production of fodder crops so that the potential for "releasing" acres is fairly substantial (*24*, p. 19).

Bose and Clark have examined this aspect of the problem in considerable detail and have undertaken to estimate the cost of rearing and maintaining bullocks (*9*). We will limit ourselves to a few observations pertinent to the present analysis. It is apparent from the foregoing discussion that the opportunity cost of fodder production depends in part on the demand for the alternative outputs that could be produced on land now devoted to feed crops. In view of the possibility that an exportable surplus of foodgrains of nearly 10 million tons could be

[18] Efferson and Wimberly estimate that the exportable surplus of rice will reach three million tons by 1975, a volume considerably larger than is indicated by Table 5 and slightly larger than that implied by our high A and B projections of output.

attained without a reduction in fodder crop acreage and without concomitant heavy investment in tractor mechanization, it seems almost certain that capital and foreign exchange required for such a program could be better employed.

It should also be mentioned that the reduction in bullock numbers might in fact be fairly limited even with a rapid increase in the use of tractors on the larger farm units. As noted in the following section, rapid tractor mechanization when the total farm labor force is increasing could mean that most of the farm population would be concentrated in a bullock-powered subsector; this subsector might well be characterized by increased underemployment of both human labor and bullock power. To the extent that the large-scale, mechanized farm units accounted for the bulk of the commercial sales of agricultural products, many farmers in the small-scale subsector might lack the purchasing power to upgrade their bullock-drawn equipment and expand their use of fertilizers. For small units with limited cash income from commercial sales, there is clearly a very significant difference in the ability to acquire external inputs that must be purchased and internal inputs that can be produced with the on-farm resources of labor and land. There is in fact considerable scope for increasing fodder crop yields in West Pakistan by the application of fertilizers and associated changes in farm practices. Hence, the fodder area required to support a given bullock population could be reduced substantially if the farmers maintaining bullocks are in a position to adopt technical innovations in fodder production.

Agricultural Development Strategies and the Labor Force Absorption Problem

Comparison of alternative strategies as illustrated by the low A and B expansion paths considered here should include consideration of some of the more significant interrelationships between agriculture and overall economic growth. Most pertinent in the present context is whether the agricultural development strategy that is pursued will lead toward a "bimodal" pattern of agricultural development or a "unimodal" pattern. Elsewhere these alternatives have been described as the Mexican or Japanese models of agricultural development, since the Mexican and Japanese "success stories" serve as excellent examples of the "bimodal" and "unimodal" patterns respectively (*28*, pp. 285–88). In contrast with the Japanese experience in which high levels of productivity were achieved by most of the nation's farmers, the increases in productivity and output in Mexican agriculture have been concentrated to a large extent in a subsector of large-scale, capital-intensive farm enterprises that have accounted for an especially high percentage of the commercialized production.

In West Pakistan (and still more is this true of East Pakistan), the "arithmetic of population growth and structural transformation" makes it clear that the farm labor force will continue to grow throughout the Perspective Plan period—and considerably longer unless there is a remarkably speedy reduction in birthrates. Under these conditions a rapid increase in tractor numbers of 15 per cent per year would almost inevitably mean that a "bimodal" agricultural structure would evolve. Even on the most optimistic assessment with respect to the growth of demand for agricultural output, a rapid increase in the use of tractors by the larger land owners would mean that many tenants would be displaced.[14] And the opportunities for productive employment in the large-scale, capital-intensive subsector would be limited. Inasmuch as the rate of growth of employment opportunities outside of agriculture will also be limited, the probable result would be that virtually all of the increase in the farm labor force would remain in agriculture as family workers or hired laborers in the bullock-oriented subsector. Table 6 summarizes some of the implications of the B expansion path. The rather substantial increase in cropped area over the 20-year period would correspond closely with the increase in the tractor commanded area, but the increase in farm workers employed on such units would represent only a fairly small fraction of the total increase in the farm labor force. In consequence, the land/labor ratio in the traditional subsector would decrease substantially as a result of this bi-polarization of the agricultural economy. Even if demand conditions permitted the extremely large increase in foodgrain output implied by the B projection, the ability of farm workers outside the mechanized subsector to share in the potential gains would be limited because the cropped area per worker would decline from slightly more than four acres in 1965 to less than three acres in 1985.

The uncritical assumption is sometimes made that mechanization that "releases" farm labor will necessarily mean a more rapid increase in nonfarm employment. But in the situation that confronts Pakistan over at least the next two decades, the growth of nonfarm employment will be determined mainly by the rate of capital formation in the nonfarm sector, the average capital intensity of that investment, and the availability of foreign exchange for imported capital equipment and materials required for efficient industrial expansion.

It seems probable that an agricultural expansion path that relies mainly on greatly expanded use of an improved and wider range of bullock implements and other inexpensive equipment would lead to more rapid increase of nonfarm output and employment than the rapid mechanization alternative. Increased demand for farm inputs by large-scale, capital-intensive units will to a considerable extent be directed toward imports of farm machinery. While establishment of local assembly plants gives an illusion of impressive industrial progress, the tractor assembly plants are unlikely to make a very significant contribution to domestic value added. The effect of such plants on job opportunities in the nonfarm sector will be small, and the foreign exchange requirements for imported components will, of course, be very large. In contrast, an agricultural development strategy that involves a large increase in demand for inexpensive farm equip-

[14] In his analysis of the economic implications of the "Green Revolution" in West Pakistan, Kaneda makes an important additional point. He rightly emphasizes that the present rapid increase in tractor numbers is encouraged by a favorable level of foodgrain prices that the government will not be able to maintain as supplies increase beyond the absorptive capacity of the domestic market. With a sharp decline in prices to world levels, the bulk of the nation's farmers "will face a decline in their net incomes due to the worsened terms of trade for their small marketable surpluses. Large farmers will find that in order to cut the costs of operation per acre their operating acreage has to be further expanded and their operations made more commercially oriented" (*32*, p. 132). The investments now being made in tractors and associated equipment will then be fixed costs and hence will not affect their short-run supply functions. Profit maximization for large farmers will therefore dictate acreage and output expansion so long as product prices cover variable costs. The consequences for small farmers and tenants are likely to be particularly serious. They are more vulnerable because nearly all of their costs are variable, and the expansion of acreage by large farmers will to a considerable extent be realized by taking over land formerly cultivated by tenants or small farmers.

TABLE 6.—POLARIZATION OF AGRICULTURAL LABOR FORCE ACCOMPANYING A STRATEGY OF AGRICULTURAL DEVELOPMENT EMPLOYING AN ASSUMED 15 PER CENT ANNUAL INCREASE IN TRACTOR UNITS (ALTERNATIVE B)*

Year	Total farm labor force (*millions*) (1)	Labor employed on tractor units (*millions*) (2)	Labor employed on bullock units (*millions*) (3)	Tractor-commanded acres (*millions*) (4)	Bullock-commanded acres (*millions*) (5)	Land/labor ratio on bullock units (*acres/man*) (6)	Per cent of farm labor force on tractor units (7)
1965	8.205	.084	8.121	1.050	33.039	4.068	1.02
1970	9.026	.169	8.857	2.112	34.135	3.854	1.87
1975	9.987	.340	9.647	4.248	35.743	3.705	3.40
1980	11.120	.684	10.436	8.544	35.736	3.424	6.15
1985	12.249	1.375	10.874	17.185	32.004	2.943	11.22

* Assumptions: The labor force on tractor units shown in Column (2) is estimated at eight men per 100 acres using the acreage figures in Column (4). Bullock-commanded acres consist of those utilizing improved and traditional cultural practices and equipment. Data on labor force based on L. L. Bean, M. R. Khan, and A. R. Rukanuddin, *Population Projections for Pakistan: 1960–2000* (Pakistan Institute of Development Economics, Monographs in the Economics of Development No. 17, Karachi, January 1968), and S. R. Bose, "Labour Force and Employment in Pakistan, 1961–86: A Preliminary Analysis," *Pakistan Development Review* (Karachi), Autumn 1963. Land area taken from the projection under alternative B, Appendix Table B-3.

As explained in the text, the size of the total farm labor force is assumed to be the same in all three alternatives since it is computed as a residual on the basis of the estimated growth of the total labor force and an annual increase of nonfarm employment of 4.5 per cent. Column (3) above, Labor employed on bullock units, is also computed as a residual by subtracting Column (2) from Column (1).

ment—well suited to local manufacture by small- and medium-scale rural workshops which employ capital-saving, labor-intensive techniques—can be expected to contribute much more to the expansion of nonfarm output and employment.

The potential for developing the local manufacture of a widening range of improved farm implements cheap enough to enter into general use appears to be large. Although past efforts to replace the traditional plow with an improved furrow-turning plow have met with only limited success, a rise in cash income is increasing the ability of Pakistani farmers to purchase such implements. Furthermore, the incentive to do so has been increased because the yield advantage of more adequate seed bed preparation and greater precision in executing other operations is so much greater with the new varieties. A systematic program to screen, test, and design prototypes of promising items of equipment, such as the bullock-drawn seed-fertilizer drill, a Japanese type of rotary weeder, and an inexpensive thresher could, therefore, be instrumental in promoting local manufacture and widespread use of such items.[15] Emphasis on an agricultural development strategy that generates demand for this type of equipment appears to have two important advantages. Such equipment lends itself to widespread use and is essentially complementary to the abundant farm labor; it serves to break seasonal labor bottlenecks and, therefore, results in more productive utilization of labor rather than massive displacement of farm workers. And the relatively unimportant technological economies of scale in the type of metalworking industry that produces this type of equipment can be offset fairly easily by the lower wages that generally prevail in small-scale firms. Rural-based workshops also appear to have an advantage in being able to draw upon local sources of capital and entrepreneurial talent that the modern, large-scale industrial sector is not capable of tapping.

The impact on local manufacturing firms of the rapid expansion of private tubewells in West Pakistan is a notable example of the potential importance of this type of positive interaction between agricultural and industrial development. The remarkable expansion of production of pumps, diesel engines, strainers, and similar items produced in workshops in rural areas has contributed to the expansion of output and employment opportunities outside of agriculture, and the import content of such production is much less than in the public tubewell program that is based on larger bore tubewells and more sophisticated equipment (*17*).

Finally, it seems likely that efforts to promote the spread of family planning in Pakistan will achieve more rapid and substantial results if the benefits and dynamic stimulus toward socio-economic change made possible by the seed-fertilizer revolution are spread as widely as possible rather than being concentrated in a large-scale, capital-intensive subsector. The projections in Table 6 suggest that such a subsector could embrace only a small fraction of the farm population and labor force.

[15] As an example, a drum-type power thresher recently developed at the International Rice Research Institute would seem to be capable of overcoming threshing bottlenecks likely to arise with the rapid spread of the new varieties of rice, and it is reported that this thresher "makes maximum use of the locally available components and is simple enough to encourage local manufacture and to facilitate operation and service" (*25*).

CONCLUDING COMMENTS

Many other policy questions merit serious attention in the light of the new production possibilities opened up by the seed-fertilizer revolution. Although attention here has been focused on wheat and rice because of their importance in the West Pakistan agricultural economy, high-yielding synthetic varieties of maize are showing good results and are being planted quite widely. Should research programs and extension activities give greater attention to promoting maize production and exports? Maize gives a higher yield of grain per acre foot of water than wheat or rice, and being a feed grain it probably has better export potential. What priority should be given to developing yield-increasing innovations for fodder crops, cotton, oilseeds, and other major field crops? Striking progress in other cotton growing areas of the world in raising cotton yields has thus far had little effect on the varieties available to Pakistani farmers, and there seems no doubt that a crop improvement program for cotton could yield large returns. To what extent should the composition of farm output in West Pakistan be shifted toward the more expensive foods such as meat, dairy products, fruits, and vegetables, for which the income elasticity of demand is much higher than for foodgrains? Is continued subsidization of irrigation water and fertilizer an appropriate use of government funds available for development purposes? And most complex and controversial of all, does the rapid growth of farm cash income that is in prospect warrant an increase in the land (revenue) tax so that agriculture will contribute more to meeting the fiscal needs for broader development of the country's economy?[16]

Difficult decisions remain to be made. Although it is clear that the seed-fertilizer revolution is giving to Pakistan a degree of economic freedom which she would not otherwise enjoy, this freedom will not last indefinitely. The advantages of improved seeds and additional fertilizers will probably have been realized throughout the agricultural sector by the early 1980's. If rapid economic growth is to continue after that time, other sectors will have to grow increasingly rapidly; this only serves to reemphasize the need for allocating capital carefully in the interim, and for avoiding unnecessarily heavy expenditures on agricultural mechanization.

It has been noted that the output projections summarized in Table 2 are in no sense predictions of what agricultural production actually will be. However, they give a useful indication of potential growth rates for the principal foodgrain crops, and growth rates calculated from Table 2 illustrate the point made in the

[16] In his 1965 study of domestic resources and fiscal policy in Pakistan's Second and Third Plans, S. R. Lewis argued that "improvements in the means of imposing relatively equitable income-elastic taxes in the agricultural sector command even greater urgency than they did in 1960" (*36*, p. 472). He notes that an important goal of the country's Perspective Plan is to reduce and eventually to eliminate foreign assistance. If this goal is to be attained, taxation must increase more rapidly than government expenditure, since a considerable proportion of government expenditure is now covered by foreign assistance. Thus, to make progress toward the goal of eliminating foreign assistance, while maintaining or increasing the proportion of income invested, domestic saving must rise more rapidly than investment and exports must increase more rapidly than imports. Lewis concludes that the ability to maintain high rates of saving, investment, and economic growth is likely to hinge to a considerable extent on whether the necessary steps are taken to realize "the potential for additional taxation out of rapidly rising income in sectors like agriculture" (*36*, p. 470). This conclusion has now become considerably more relevant since the availability of the new plant varieties has accelerated the increase of agricultural output.

preceding paragraph. The compound annual growth rates implied by the A and B expansion paths range as follows:

1964/65–1969/70	8–12 per cent
1969/70–1974/75	9–13 per cent
1974/75–1979/80	5– 9 per cent
1979/80–1984/85	4– 7 per cent

If the growth rates above were translated into per capita terms, the declines after 1975 would be even more dramatic. Despite the many uncertainties inherent in the results of the present study, one central conclusion seems inescapable: the enormous potential benefits of the seed-fertilizer revolution must be exploited as widely and efficiently as possible if the revolution is to lay the foundation for sustained and rapid economic growth in Pakistan. Any misuse of these benefits could easily lead in the "medium run" to economic stagnation and to political and social frustration. At the very least, such misuse would inevitably and unnecessarily dim Pakistan's bright prospects for economic growth.

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APPENDIX A

The details of the assumptions used in making the projections for Cases A through D are shown in Tables A-1 through A-5 below.

The calculation for a given year, crop, land type (irrigated or rainfed, improved or local), variety of seed can be described in general terms by the equation:

OUTPUT = [BASE YIELD + (FERTILIZER RESPONSE RATIO) × (FERTILIZER APPLICATION ABOVE BASE)] × [(ACREAGE FOR CROP) × (FRACTION OF ACREAGE FOR VARIETY)]

In more detail for a given expansion path in a given year the total output of wheat is calculated as follows:

$$w = (y_1a_1 + y_2a_2 + y_4a_4 + y_5a_5) \ / \ 2{,}240$$
$$y_i = Y_i + n_i(f_i - F_i)$$
$$a_1 = a_3p \quad a_2 = a_3(1-p) \quad a_4 = a_6q \quad a_5 = a_6(1-q)$$

where

w = total output, in long tons
y = yield, in pounds per acre
a = area, in acres
Y = base[1] yield, in pounds per acre
n = fertilizer response ratio, weight basis
f = fertilizer application in pounds per acre
F = basic fertilizer application in pounds per acre
p = proportion of irrigated crop acreage sown to improved varieties
q = proportion of rainfed acreage sown to improved varieties

[1] Does not vary over time.

and the subscript i ($i = 1, 2 \ldots 6$) is defined as follows:

1 irrigated improved	2 irrigated local	3 total irrigated
4 rainfed improved	5 rainfed local	6 total rainfed

For rice the calculation is the same except that the variables for rainfed cultivation are not required.

The base yields and "basic" fertilizer applications are shown in Table A-1; the assumed rates of fertilizer application for the various expansion paths are shown in Table A-3; and the fertilizer response ratios, i.e., the additional grain produced per pound of fertilizer above the "basic" amounts, are shown in Table A-5. The annual figures for planted area, percentage of area planted to improved varieties, grain output under the alternative projections, and the projections of total fertilizer use are shown in Tables A-2, A-4, A-6, and A-7.

The average yield figures (pounds per acre) implied by the low A projection together with the assumed yields for improved varieties are shown below for selected years. The increase in yield for the improved varieties results from the rising level of fertilizer application and the assumed rise in the response coefficient.

	Average yield		Yield of improved varieties	
	Wheat	Rice	Wheat[a]	Rice
1964/65	771	939	1,650	1,600
1969/70	1,078	1,333	2,079	2,144
1974/75	1,583	1,990	2,460	2,440
1979/80	2,130	2,808	2,904	2,808
1984/85	2,513	3,290	3,410	3,290

[a] Applies to irrigated wheat only. The yield increase for rainfed wheat would be much less because it is assumed that under those conditions improved varieties receive 20 pounds per acre throughout the period.

TABLE A-1.—BASE YIELDS AND "BASIC" FERTILIZER APPLICATIONS*

	Irrigated		Rainfed
	Wheat	Rice[a]	wheat
A. BASE YIELDS IN POUNDS PER ACRE			
Local	940	940	480
Improved	1,650	1,600	700
B. BASIC APPLICATIONS OF FERTILIZERS, PRESUMED IN BASE YIELD FIGURES, IN POUNDS OF CONTAINED NUTRIENTS PER ACRE			
Local	10	10	0
Improved	0	0	20

* Yields per acre for the various cropping conditions are computed as the sum of these base yield figures and an increment which is a response to the application of fertilizer over and above that assumed in the base yield figure.

[a] All quantity figures for rice are for "clean" rice (estimated at 65 per cent of paddy weight) unless otherwise specified.

TABLE A-2.—PLANTED AREA ASSUMED FOR ALTERNATIVE PROJECTIONS*

(Million irrigated acres)

	Low A and High C		High A		B and D		Low C	
Year	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice
1964/65	7.74	3.10	7.74	3.10	7.74	3.10	7.74	3.10
1965/66	7.83	3.15	7.83	3.15	7.83	3.15	7.83	3.15
1966/67	7.92	3.20	7.92	3.20	7.92	3.20	7.92	3.20
1967/68	8.00	3.25	8.00	3.25	8.00	3.25	8.00	3.25
1968/69	8.09	3.30	8.16	3.30	8.20	3.30	8.05	3.30
1969/70	8.18	3.35	8.32	3.39	8.41	3.41	8.10	3.33
1970/71	8.27	3.41	8.49	3.47	8.62	3.52	8.15	3.37
1971/72	8.36	3.46	8.66	3.56	8.83	3.63	8.19	3.40
1972/73	8.45	3.52	8.83	3.66	9.05	3.74	8.24	3.43
1973/74	8.54	3.57	9.01	3.75	9.28	3.86	8.29	3.47
1974/75	8.64	3.63	9.19	3.85	9.51	3.99	8.34	3.50
1975/76	8.73	3.69	9.37	3.95	9.75	4.11	8.39	3.54
1976/77	8.83	3.75	9.56	4.05	9.99	4.25	8.44	3.57
1977/78	8.93	3.81	9.75	4.16	10.24	4.38	8.49	3.61
1978/79	9.02	3.87	9.95	4.27	10.50	4.52	8.54	3.65
1979/80	9.12	3.93	10.15	4.38	10.76	4.67	8.60	3.68
1980/81	9.22	3.99	10.35	4.49	11.03	4.82	8.65	3.72
1981/82	9.32	4.06	10.56	4.61	11.30	4.97	8.70	3.76
1982/83	9.43	4.12	10.77	4.73	11.59	5.13	8.75	3.79
1983/84	9.53	4.19	10.98	4.85	11.88	5.29	8.80	3.83
1984/85	9.63	4.25	11.20	4.98	12.17	5.46	8.86	3.87

* Under all projections 4.5 million acres of rainfed land are planted to wheat each year, in addition to the irrigated acres shown above. See Table 1 for description of alternatives.

TABLE A-3.—FERTILIZER PER ACRE ASSUMPTIONS FOR ALTERNATIVE PROJECTIONS*
(Pounds of contained nutrients per acre on irrigated land)

Year	A and B				C and D	
	Improved		Local		Local	
	Wheat	Rice	Wheat	Rice	Wheat	Rice
1964/65	—	—	10	10	10	10
1965/66	—	—	10	10	10	10
1966/67	—	—	10	10	10	10
1967/68	30	100	10	10	10	10
1968/69	30	60	10	10	10	10
1969/70	35	64	10	10	11	10
1970/71	40	68	10	10	12	11
1971/72	45	72	10	10	13	12
1972/73	50	76	10	10	14	13
1973/74	55	80	10	10	15	14
1974/75	60	84	10	10	16	15
1975/76	65	88	10	10	17	16
1976/77	70	92	10	10	18	17
1977/78	75	96	10	10	19	18
1978/79	80	100	10	10	20	19
1979/80	85	105	10	10	21	20
1980/81	90	110	10	10	22	21
1981/82	95	115	10	10	23	22
1982/83	100	120	10	10	24	23
1983/84	105	125	10	10	25	24
1984/85	110	130	10	10	25	25

* Under all projections improved varieties of wheat on rainfed land receive 20 pounds per acre of fertilizer nutrients each year. Local varieties on rainfed land are not fertilized. See Table 1 for description of alternatives.

TABLE A-4.—ADOPTION OF IMPROVED VARIETIES*
(Percentage of crop acreage planted to improved varieties)

	Irrigated				
	Low A		High A and B		Rainfed A and B
Year	Wheat	Rice	Wheat	Rice	Wheat
1964/65	0	0	0	0	0
1965/66	0	0	0	0	0
1966/67	0	0	0	0	0
1967/68	25.0	0.3	35.0	0.3	0
1968/69	32.5	25.0	48.0	35.0	5
1969/70	40.0	32.5	61.0	48.0	10
1970/71	47.5	40.0	74.0	61.0	15
1971/72	55.0	47.5	87.0	74.0	20
1972/73	62.5	55.0	100.0	87.0	25
1973/74	70.0	62.5	100.0	100.0	30
1974/75	77.5	70.0	100.0	100.0	35
1975/76	85.0	77.5	100.0	100.0	40
1976/77	92.5	85.0	100.0	100.0	45
1977/78	100.0	92.5	100.0	100.0	50
1978/79	100.0	100.0	100.0	100.0	50
1979/80	100.0	100.0	100.0	100.0	50
1980/81	100.0	100.0	100.0	100.0	50
1981/82	100.0	100.0	100.0	100.0	50
1982/83	100.0	100.0	100.0	100.0	50
1983/84	100.0	100.0	100.0	100.0	50
1984/85	100.0	100.0	100.0	100.0	50

* See Table 1 for description of alternatives.

TABLE A-5.—FERTILIZER RESPONSE RATIO*
(*Grain/nutrient, by weight*)

Year	Improved		Local	
	Wheat	Rice[a]	Wheat	Rice
1964/65	—	—	—	—
1965/66	—	—	—	—
1966/67	—	—	—	—
1967/68	12.00	8.0	—	—
1968/69	12.00	8.2	—	—
1969/70	12.25	8.5	8.0	—
1970/71	12.50	8.8	8.0	8.0
1971/72	12.75	9.1	8.0	8.0
1972/73	13.00	9.4	8.0	8.0
1973/74	13.25	9.7	8.0	8.0
1974/75	13.50	10.0	8.0	8.0
1975/76	13.75	10.3	8.0	8.0
1976/77	14.00	10.6	8.0	8.0
1977/78	14.25	10.9	8.0	8.0
1978/79	14.50	11.2	8.0	8.0
1979/80	14.75	11.5	8.0	8.0
1980/81	15.00	11.8	8.0	8.0
1981/82	15.25	12.1	8.0	8.0
1982/83	15.50	12.4	8.0	8.0
1983/84	15.75	12.7	8.0	8.0
1984/85	16.00	13.0	8.0	8.0

* Additional grain produced by fertilizer applications in excess of the "basic" amounts shown in Table A-1.

[a] In terms of paddy, the response coefficient rises from approximately 12 to 20.

Table A-6.—Summary: Alternative Projections of Grain Output*

(Million long tons)

Year	Low A		High A		B		Low C		High C		D	
	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice
1964/65	4.213	1.300	4.213	1.300	4.213	1.300	4.213	1.300	4.213	1.300	4.213	1.300
1965/66	4.249	1.321	4.249	1.321	4.249	1.321	4.249	1.321	4.249	1.321	4.249	1.321
1966/67	4.285	1.342	4.285	1.342	4.285	1.342	4.285	1.342	4.285	1.342	4.285	1.342
1967/68	5.277	1.369	5.659	1.369	5.659	1.369	4.321	1.363	4.321	1.363	4.321	1.363
1968/69	5.636	1.809	6.282	1.979	6.308	1.979	4.358	1.385	4.342	1.385	4.405	1.385
1969/70	6.103	1.993	7.082	2.294	7.142	2.308	4.396	1.407	4.362	1.399	4.491	1.429
1970/71	6.621	2.195	7.987	2.648	8.089	2.680	4.463	1.442	4.411	1.425	4.610	1.488
1971/72	7.195	2.418	9.004	3.044	9.161	3.098	4.531	1.477	4.461	1.451	4.733	1.548
1972/73	7.827	2.662	10.144	3.487	10.368	3.569	4.601	1.513	4.512	1.478	4.859	1.611
1973/74	8.522	2.931	10.665	3.980	10.950	4.098	4.671	1.550	4.562	1.505	4.990	1.676
1974/75	9.286	3.225	11.212	4.193	11.563	4.342	4.743	1.588	4.614	1.533	5.125	1.744
1975/76	10.119	3.546	11.786	4.419	12.210	4.603	4.816	1.627	4.666	1.561	5.263	1.815
1976/77	11.029	3.897	12.389	4.658	12.894	4.881	4.890	1.666	4.718	1.589	5.407	1.888
1977/78	12.018	4.279	13.022	4.912	13.615	5.176	4.965	1.706	4.771	1.618	5.554	1.964
1978/79	12.504	4.697	13.663	5.180	14.353	5.491	5.041	1.748	4.824	1.647	5.707	2.043
1979/80	13.010	4.926	14.338	5.485	15.132	5.849	5.118	1.790	4.878	1.677	5.863	2.125
1980/81	13.536	5.165	15.046	5.809	15.955	6.231	5.197	1.832	4.933	1.706	6.025	2.210
1981/82	14.084	5.417	15.788	6.153	16.823	6.637	5.277	1.876	4.988	1.737	6.192	2.299
1982/83	14.651	5.681	16.567	6.517	17.737	7.071	5.357	1.921	5.043	1.768	6.364	2.390
1983/84	15.241	5.958	17.382	6.902	18.701	7.532	5.440	1.966	5.099	1.799	6.542	2.486
1984/85	15.853	6.248	18.238	7.308	19.716	8.022	5.524	2.013	5.155	1.831	6.725	2.585

* See text Table 1 for description of alternatives.

Table A-7.—Summary: Alternative Projections of Fertilizer Input*

(Million long tons of contained nutrients)

Year	Low A		High A		B		High C		Low C		D	
	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice
1964/65	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014
1965/66	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014
1966/67	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014	0.035	0.014
1967/68	0.054	0.015	0.061	0.015	0.061	0.015	0.036	0.014	0.036	0.014	0.036	0.014
1968/69	0.062	0.033	0.073	0.041	0.074	0.041	0.036	0.015	0.036	0.015	0.037	0.015
1969/70	0.077	0.041	0.098	0.054	0.099	0.055	0.037	0.015	0.036	0.015	0.038	0.015
1970/71	0.096	0.050	0.128	0.070	0.130	0.071	0.041	0.017	0.040	0.017	0.042	0.017
1971/72	0.117	0.061	0.164	0.089	0.167	0.090	0.045	0.019	0.044	0.018	0.047	0.019
1972/73	0.142	0.073	0.207	0.110	0.212	0.113	0.049	0.020	0.048	0.020	0.053	0.022
1973/74	0.170	0.086	0.233	0.134	0.240	0.138	0.053	0.022	0.052	0.022	0.058	0.024
1974/75	0.202	0.100	0.260	0.144	0.269	0.149	0.058	0.024	0.056	0.023	0.064	0.027
1975/76	0.237	0.116	0.288	0.155	0.299	0.162	0.062	0.026	0.060	0.025	0.070	0.029
1976/77	0.276	0.133	0.317	0.166	0.330	0.174	0.067	0.028	0.064	0.027	0.076	0.032
1977/78	0.319	0.152	0.347	0.178	0.363	0.188	0.072	0.031	0.068	0.029	0.082	0.035
1978/79	0.342	0.173	0.375	0.190	0.395	0.202	0.077	0.033	0.072	0.031	0.089	0.038
1979/80	0.366	0.184	0.405	0.205	0.428	0.219	0.081	0.035	0.077	0.033	0.096	0.042
1980/81	0.391	0.196	0.436	0.220	0.463	0.236	0.086	0.037	0.081	0.035	0.103	0.045
1981/82	0.416	0.208	0.468	0.237	0.499	0.255	0.092	0.040	0.085	0.037	0.111	0.049
1982/83	0.441	0.221	0.501	0.253	0.537	0.275	0.097	0.042	0.090	0.039	0.119	0.053
1983/84	0.467	0.234	0.535	0.271	0.557	0.295	0.102	0.045	0.094	0.041	0.127	0.057
1984/85	0.493	0.247	0.570	0.289	0.618	0.317	0.108	0.047	0.099	0.043	0.136	0.061

* Based on Tables A-2, A-3, and A.4.

APPENDIX B

This appendix contains the computations and cost estimates associated with the various approaches to mechanization discussed in the body of the paper. It must be emphasized again that this is only a preliminary exercise. It is hoped that it gives a fair approximation of the costs of the alternative approaches to mechanization, but there is clearly a need to refine both the methodology and the estimates of the technical coefficients required in such an analysis.

TABLE B-1.—ESTIMATED ANNUAL COSTS FOR TRACTOR MECHANIZATION PACKAGE AT OFFICIAL AND ADJUSTED EXCHANGE RATES

		Official	Adjusted[a]
A. 35 HP Diesel Wheel Tractor[b]			
Fixed costs			
Depreciation using 7-year life		Rs 1,710	Rs 3,428
Interest		480	1,440
Insurance and licensing fees		230	230
Tractor housing and fuel storage		100	100
Variable costs			
Fuel		3,128	6,256
Oil		660	1,320
Repairs		1,800	3,600
Total annual cost for tractor		8,108	16,374
B. Implements Associated with 35 HP Tractor[c]			
a. Cultivator	Rs 1,500		
b. Disc plow	2,500		
c. Spiketooth harrow	800		
d. Drill and fertilizer applicator	2,500		
e. Tractor-mounted rototiller	2,000		
f. Tractor-drawn harvester	15,000		
g. Tractor-drawn land plane	500		
Total initial outlay	13,800[d]		
Fixed costs			
Depreciation		1,971	3,943
Interest		552	1,656
Variable costs			
Repairs and maintenance		2,070	4,140
Total annual cost for implements		4,593	9,739
Total annual mechanized package costs		12,700	26,113

[a] The adjusted rate of exchange assumes a 100 per cent overvaluation of the Pakistan rupee. Only those costs involving a foreign exchange component are adjusted. Interest charges are calculated at 12 per cent rather than 8 per cent as used in the calculations based on the official exchange rate.

[b] Tractor has the following characteristics: initial cost Rs 12,000 at official rate of exchange; 7 to 8 years useful life; 1,200 hours of annual use; covers a 100 cropped acre farming unit. Cost calculations based on agricultural engineering data from G. H. Larson, G. E. Fairbanks, and F. C. Fenton, *What It Costs to Use Farm Machinery* (Kansas Agricultural Experiment Station Bulletin 417, Manhattan, 1960) and University of Nebraska, *The Nebraska Tractor Tests* (Agricultural Experiment Station, Lincoln, 1963, 1964, 1965).

[c] No attempt has been made to measure the life of each implement separately and the assumption is made that each will have a useful life of 7 years.

[d] The rototiller is considered useful only in rice production, therefore its cost is divided between 2 units of 100 acres each; the harvester's cost is divided among 3 units of 100 acres each.

TABLE B-2.—ESTIMATED ANNUAL COSTS FOR IMPROVED BULLOCK TECHNOLOGY*
(*Rupees*)

A. Initial implement costs	
a. Adjustable moldboard plow	70
b. Spiketooth or comb harrow	50
c. Seed drill-fertilizer combination	250
d. Ridger	40
e. Rotary weeder	30
f. Pedal thresher	200
g. Improved harness	50
Total initial cost	690
B. Annual costs[a]	
Depreciation using 5-year life	138
Interest	41
Feed and veterinarian care for one pair of bullocks	430
Total annual costs for bullocks	609

* The bullock package in this partial budget is assumed to be capable of cultivating a 12½-acre farm unit.

[a] Bullock purchase or rearing costs are not included in this calculation as they are considered internal to the farm firm and not applicable to decision making in a planning sense. For an explanation and detailed attempt at estimating such costs, see S. R. Bose and E. H. Clark, II, *Some Basic Considerations on Agricultural Mechanization in West Pakistan* (Pakistan Institute of Development Economics, draft manuscript, Karachi, November 1968).

THE COST BUDGETS

Table B-1 contains the detailed cost figures for the 35 HP diesel tractor and associated implements utilized in this study. Table B-2 contains similar figures for an improved bullock package. Tractor cost figures are calculated on the basis of a 1200-hour working year. This yearly figure reflects an assumed optimal allocation of tractor time and therefore implicitly assumes that the tractor will be used in those areas where year-round cropping is possible. Cost calculations are carried out at both an official rate of foreign exchange and an adjusted rate which assumes a 100 per cent overvaluation of the Pakistan rupee.

MECHANIZATION PROJECTIONS

Three strategies providing mechanization to the agricultural sector are examined. The assumptions and characteristics of these strategies were outlined in text Table 3. Calculation of tractor numbers and imports is based on the following formulas:

$$Z_t = Z_{t-1} + g(Z_{t-1})$$
$$I_t = g(Z_{t-1}) + r(Z_{t-1})$$

where

Z_t = number of on-farm tractors in year t
I_t = number of tractors imported in year t
g = growth rate of on-farm tractors
r = annual rate of replacement

Improved bullock units are calculated on the basis of the following:

$$IB_t = \frac{[\text{total cultivated acreage}_t - 100\,(Z_t)]d_t}{12.5}$$

where

IB_t = improved bullock units in year t, capable of cultivating a 12.5 acre farm unit

d_t = cumulative percentage of total bullock areas on which the improved units are utilized in year t

Costs over time are determined by multiplying the number of units (tractors or bullocks) in year t by the per unit annual costs. Aggregating the costs of tractors and bullocks gives the total annual cost for each alternative. Machinery numbers, acreage covered, and total annual costs for the three alternatives considered are given in Table B-3.

TABLE B-3.—MECHANIZATION PROJECTIONS UNDER ALTERNATIVE EXPANSION PATHS*

Year	Tractors on farms	Tractors Imported	Improved bullock units (*millions*)	Cropped area (*million acres*)			Total annual costs (*million 1965 rupees*)				
				Tractor commanded	Improved bullock commanded	Total	Tractor at official exchange	Tractor at adjusted exchange	Improved bullock cultivation	Total at official exchange	Total at adjusted exchange
				LOW A ALTERNATIVE							
1964/65	10,500	1,800	0.132	1.050	1.652	34.089	133	274	80	213	354
1969/70	10.500	1,050	0.484	1.050	6.060	35.622	133	274	295	428	569
1974/75	10,500	1,050	1.014	1.050	12.676	37.267	133	274	618	751	892
1979/80	10,500	1,050	1.700	1.050	21.252	39.000	133	274	1,035	1,168	1,309
1984/85	10,500	1,050	2.228	1.050	27.856	40.844	133	274	1,357	1,490	1,631
				HIGH A ALTERNATIVE							
1964/65	10,500	1,800	0.132	1.050	1.652	34.089	133	274	80	213	354
1969/70	13,401	1,914	0.971	1.340	12.139	36.022	170	350	591	761	941
1974/75	17,103	2,443	1.938	1.710	24.224	38.978	217	447	1,180	1,397	1,627
1979/80	21,828	3,118	2.567	2.183	32.085	42.289	277	570	1,563	1,840	2,133
1984/85	27,859	3,890	2.763	2.786	34.536	45.956	354	727	1,683	2,037	2,410
				B ALTERNATIVE							
1964/65	10,500	1,800	0.132	1.050	1.652	34.089	133	274	80	213	354
1969/70	21,119	4,591	0.355	2.112	4.438	36.247	268	551	216	484	767
1974/75	42,478	9,234	0.858	4.248	10.723	39.991	539	1,109	522	1,061	1,631
1979/80	85,439	18,574	1.144	8.544	14.294	44.280	1,085	2,231	696	1,781	2,927
1984/85	171,847	37,358	1.144	17.185	14.294	49.189	2,182	4,487	696	2,878	5,183

* In the 1964/65 period there were an estimated 10,500 tractors operating in West Pakistan. Under the Low A Alternative no increase in tractors on farms is projected; under High A the projected annual rate of increase is 5 per cent, under B, 15 per cent. The assumed annual replacement rate required in the computation of tractor imports is 10 per cent.

Total cropped area assumed in the various alternatives is calculated in relation to the projected expansion of wheat and rice acreage (shown in Table A-2) with the planted acreage in these crops assumed to be 45 per cent of the total cropped area.

The tractor commanded area is estimated at 100 acres per tractor. The bullock commanded area, estimated as the difference between the total cropped area and the tractor commanded area, is subdivided into improved and traditional with the factors described in Table 3. One adjustment in this procedure was made in the B Alternative; after 1980 the number of acres under improved bullock cultivation was assumed to remain constant.