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ECONOMIC ANALYSIS OF FERTILIZER APPLICATION
IN PUNJAB-PAKISTAN

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

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ABSTRACT

Pakistan has achieved a breakthrough in farm production in recent years. It has been mainly due to increased acreage under high yielding varieties of foodgrains and other crops, improved irrigation supplies and the increased use of purchased inputs such as chemical fertilizers, pesticides and farm machinery.

In this era of world wide food and fertilizer shortages it is important to identify as well as quantify the contribution of various farm inputs and particularly that of fertilizers to farm production. This would be useful in providing alternatives for increasing farm production in the short run under given technological conditions.

This study was designed in an attempt to estimate the contribution of fertilizers and other farm inputs to the production of major crops in Punjab province of Pakistan. The crops included were Mexi-Pak wheat, local wheat, Basmati rice, IRRI rice, Jhonna rice, maize, cotton and sugarcane. The other objectives of the study were to compare the levels of fertilizer application among various farm categories, to determine the sources of financing fertilizer purchases and fertilizer supplies and to analyse the factors responsible for the inadequate use of fertilizers where that situation exists. The study was also designed to determine the influence of various agro-economic factors on the use of fertilizers in the province from time-series data.

The primary data for the study were collected through a farm survey conducted in the fall of 1973. The data pertained to the cropping year 1972-73. In all, 192 farmers were interviewed. These were located in 16 villages in Gujranwala and Sahiwal districts. These two districts

represent the typical wheat-rice and wheat-cotton cropping patterns; the major cropping patterns followed in the canal irrigated districts of the province.

The production function has been the major analytical tool used in this study in the analysis of cross-sectional data. The ordinary least squares method of multiple regression was used to estimate the coefficients of production functions for the crops under study. This method was also used to analyse the impact of agro-economic factors on fertilizer use from the time-series data.

The production function analysis suggests that the use of chemical fertilizers is highly profitable on Mexi-Pak and local wheat, Jhonna rice and cotton. There is considerable potential for increasing farm production of these crops through the increased use of fertilizers. From the analysis also, it appears that there is scope for increasing production of certain crops through increased use of labor. Higher farm output of sugarcane and maize was associated with the greater use of nitrogenous fertilizers. However, the analysis was not conclusive for Basmati and IRRI rice in this regard.

The average per acre use of chemical fertilizers for the Mexi-Pak wheat, Basmati rice, cotton and sugarcane was higher on small farms as compared to medium and large farms. Urea was the most popular fertilizer with the farmers. Personal savings of the farmers and non institutional sources of credit were the major sources for financing the farmers' use of fertilizers. The commission agents and local dealers were cited as the chief suppliers of fertilizers by the farmers. High prices of fertilizers, lack of financial resources and the non-availability of

fertilizers were the main reasons given by the farmers for the inadequate use of these materials.

The analysis of time-series data suggests that the relative price of nitrogenous fertilizers has been quite important in influencing the use of these fertilizers in the province during the period of 1959-60 to 1972-73. Another important factor in this regard has been the increase in acreage under major crops, especially high yielding varieties of food grain crops. The use of fertilizers has been increasing over time. This has been probably due to increased information in the agricultural sector regarding the importance of fertilizers, and increased supplies and various market development activities of the private and public sectors.

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CHAPTER I

INTRODUCTION

Organization of the Study

This is a study of the economics of fertilizer use on selected major crops in Punjab province of Pakistan during the year of 1972-73. These crops are "Mexi-pak" wheat, "Local" wheat, "Basmati" rice, "IRRI" rice, "Jhonna" rice, maize (corn), cotton and sugarcane. Both cross sectional and time series data have been utilized. The ordinary least squares method of regression analysis has been the major analytical tool used to estimate the coefficients of "performance" functions as well as those of per acre production functions, from the cross sectional data. These data were collected through a farm survey during the fall of 1973. For the analysis of time-series data, ordinary least squares regression analysis was used to determine the effect of various agro-economic factors on the consumption of nitrogenous fertilizers in the province. The data for this analysis were obtained from several documentary sources.

The study is organized in seven chapters. Chapter I, on Introduction, describes the setting and objectives of this study. Relevant literature is also reviewed in this Chapter.

Chapter II is designed to provide an overview of the socio-economic situation (with emphasis on agriculture) prevailing in Pakistan. This chapter also reviews the production, distribution and consumption of commercial fertilizers in the country.

Chapter III describes the theoretical framework of analysis used in this study. Economic specification of the production function and

different types of production function used in the analysis of data are discussed. Design of the sample survey and methods of data collection are also discussed in this chapter.

The results of empirical production function analysis are discussed in Chapter IV. This chapter is divided into two sections. Section one of this chapter explains the various factor inputs used in estimating production functions. The results of empirical production function analysis are discussed in section two of this chapter.

Chapter V explains the general features of fertilizer use among the farmers interviewed.

Chapter VI discusses the effect of various agro-economic factors on the use of nitrogenous fertilizers in Punjab province. This analysis is based on the time-series data.

Finally, summary of conclusions and recommendations based on this study are given in Chapter VII.

Problem Setting

Rapid increase in demand for farm products caused by burgeoning population, rising incomes and what Hayami and Ruttan (16, p.2), have called "pathological" growth of urban centers, have focussed attention on increasing agricultural production, especially in the developing countries. With increasing world demand for food and other farm products, the constraints on the efforts to increase agricultural production are becoming apparent. The supplies of farm products can be increased either through the expansion of cultivated area or through increasing the productivity of land and other resources already committed to agriculture, or through some combination of these approaches.

Increasing farm production by bringing more area under cultivation offers limited potential in the short run and would require huge amounts of capital investment in the long run, if at all possible. Some of the countries are even facing a net reduction in the cultivated area due to increasing competition for land use posed by industrial development, recreation and housing, etc.

To quote Johnston and Mellor, "There are compelling considerations, however, which suggest that the most practical and economical approach to achieving sizeable increases in agricultural productivity and output lies in enhancing the efficiency of the existing agricultural economy through introduction of modern technology on a broad front. Of particular importance are expenditures for 'development services' or 'unconventional inputs' such as agricultural research, education and extension that broaden the range of alternative production possibilities available to farm operators and strengthen their capacity to make and execute decisions on the basis of more adequate knowledge of agricultural technology" (25).

The technical seed-fertilizer "breakthrough" of the 1960s resulted in the much acclaimed "green revolution." This has created a new potential. This potential is available in those areas that are under good management; where secure water supplies can be made available in addition to judicious supplies of chemical fertilizers and insecticides.

Pakistan has achieved a breakthrough in agricultural production. This has been due to (1) increased acreage under high yielding food grain varieties and other crops; (2) improved water supplies as a consequence of private and public investment in irrigation facilities and projects;

and (3) increased use of purchased inputs of fertilizers, pesticides and farm machinery. The agricultural policy of the government has also been a positive factor in this regard.

In this era of food and fertilizer scarcities, it is important to identify as well as quantify the contribution of various farm inputs and particularly that of fertilizers. It is also important to identify the factors determining the demand for fertilizers. The present study is an attempt in this direction. The coefficients of production functions based on the cross-sectional data will be estimated. The marginal productivity and the rate of return from fertilizer application on major crops, will be derived from the estimated production functions. This information will be useful to planners and policy makers in the allocation of fertilizer supplies among various crops in their endeavors to help increase total farm production in the country. Information derived from production function analysis would also be useful for diagnostic purposes, and for credit policy formulations. This analysis will also provide general guidelines for intelligent decision making at micro and macro levels.

The analysis of various factors affecting fertilizer use in the province will be of help to the fertilizer industry as well as to the policy makers concerned with the agricultural development of Pakistan.

Objectives of the Study

1. To investigate the economics of fertilizer application on major crops (wheat, rice, maize, cotton and sugarcane) in Punjab province of Pakistan, from cross-sectional data.

2. To compare the level of fertilizer application among "small", "medium" and "large" farms.
3. If low levels of fertilizer application prevail, to analyse the factors responsible for that situation.
4. To determine the various sources of financing for fertilizer purchases and fertilizer supplies.
5. To investigate farmers understanding of and preference for various fertilizers.
6. To identify and measure the effect of various agro-economic factors on fertilizer use from time-series data.

Previous Work and Present Outlook

A number of studies dealing with different aspects of fertilizer use have been published. Some of the important studies are reviewed here. Studies dealing with demand analysis of fertilizer based on time-series data are reviewed first. This is followed by the review of general studies on fertilizers based on aggregate, experimental or survey data.

Griliches (13), in his study of the demand for fertilizer in the United States, described the change in fertilizer use with a single equation, simple econometric model. Using time-series data on fertilizer sales from 1911-1956, he observed that fertilizer use was a function of the "real" price of fertilizer, the prices paid for fertilizer relative to the prices received for farm products. Griliches concluded that the tremendous increase in the use of fertilizer, during the period resulted from a secular decline in

the prices of fertilizer, engineered by technological change in the fertilizer industry.

Heady and Yeh (19), using time-series data for the periods 1910-1956, 1926-1956 (excluding data for the period 1940-55) on total consumption of fertilizers, fitted a Cobb-Douglas type equation to estimate demand elasticity for fertilizer relative to fertilizer price, crop price and other relevant variables. They observed that decline in the fertilizer/crop price ratio was important but not the only variable causing a rapid increase in fertilizer use. Factors contributing to a more favorable price ratio included improved manufacturing technology, the advent of new fertilizers and materials and a greater competition in the manufacturing and distribution of fertilizers. They noted a significant upward shift in the demand function associated with time and concluded that overtime technical knowledge of farmers had also improved as a result of fertilizer experiments, farmers' own findings in fertilizer use and from intensive educational and sales programs by the Extension Services, Tennessee Valley Authority and commercial firms.

Hayami (15), using aggregate time-series data for Japan for the period 1833-1937, concluded that the policy of government to encourage agricultural research and extension, and to improve water control, caused upward shifts of agriculture's production function, which stimulated the use of fertilizers. He observed that decline in fertilizer prices relative to the prices of farm products, resulting from technical progress in fertilizer industry helped in increasing the fertilizer consumption in Japan.

Parikh (32), in his study of demand for nitrogenous fertilizers in India over the period 1951-1961, observed that agro-economic variables like irrigated area and relative prices did not explain the variation in consumption of fertilizer over the decade for Bihar and Orissa States. However, these factors were significant in explaining the consumption of fertilizer in Mysore and Madras States, whereas in Punjab and Kerala the only irrigated area was a significant variable.

This study fitted identical equations for all the States, which were different in so many respects, especially irrigated area in different States may be cropped with different crops, widely varying in fertilizer requirements. Moreover the analysis was based on a small number of observations.

Leonard (20), using time-series data for the period 1952-1968 for West Pakistan (present Pakistan), estimated a log linear equation using time and real price as independent variables. He remarked that growth in demand for fertilizer was a function of time--a complex variable--whereas price was not a significant variable. Leonard used the total weight of all fertilizers in terms of ammonium sulphate--converting phosphate fertilizer into ammonium sulphate and did not consider the effect of tubewells on fertilizer use.

Hsu (23), in his analysis of fertilizer demand in Taiwan, found that relative prices of fertilizer were quite important in determining the demand for nitrogen fertilizer. However, the same was not found to be true for phosphate and potash fertilizers. He concluded that

farmers response to the relative prices of various farm inputs in developing countries, is determined to a large extent by the length of their experience in using them. Once a certain threshold of experience is reached, Hsu observed that the farmers could be very rational in their economic calculations.

Williams (42), in his study on farmers' decisions in the use of fertilizer among the U.S. farmers pointed out that economic factors were only partly responsible in influencing the use of fertilizers. Psychological factors were also important in influencing the use of fertilizers. Williams observed that high fertilizer users were usually those who had larger farms, larger investments, higher education and other social and economic characteristics associated with the good farm managers.

He reported that the average farmers' knowledge about fertilizer was surprisingly limited. However, there were some inconsistencies in the reported results. Trial and error, own judgment and recommendations of other farmers were given the reasons for starting fertilizer use at one point and at another point soil testing was reported as a starting factor.

Huffman (24), in his study on the farmers' rate of adjustment, to the changes in the optimum quantity of nitrogen fertilizer in corn production by U.S. farmers observed that the rate of adjustment was positively related to the level of education of farmers, the contact between State and Federal extension staff and the acres of corn per farm. He implied that in developing countries the rate and efficiency of growth may be increased by increasing the level of

education and availability of information to the farmers. However, the important question in this regard would be how to increase the level of education of the farmers.

Janvry (25), discussed alternative fertilizer price policies and their impact on the use of fertilizer in corn and wheat production in Argentina. He argued that the comparatively high price of fertilizer which the farmers in Argentina were paying, and the substantially lower prices of food grains at the farm level, were discouraging the use of fertilizer, resulting in lower yields. He went on to argue that through importation of fertilizer from abroad or through the modernization of outdated and obsolete fertilizer producing facilities at home, fertilizer prices could be lowered significantly. The lower prices of fertilizer would, he felt, encourage fertilizer use on grain crops and expand their acreage by eliminating fallowing of land for natural recuperation. He argued, it would also encourage farmers to use chemical fertilizers on other crops.

Ryan and Perrian (37), found a considerable disequilibrium in the use of fertilizer on potatoes by the Peruvian farmers, in spite of the fact that response information and fertilizer recommendations had been available for a number of years. They argued that by adopting profit maximizing levels of fertilizers, potato producers could increase their income substantially, and this would result in considerable economic gains to the consumers as well.

The profit maximizing level of fertilizer was based on the experimental data and thus the estimated response function may not

represent typical farm conditions. Institutional factors may also be responsible for the prevailing disequilibrium in the fertilizer use.

Kim (27), in his study of fertilizer use on food grains in Korea observed that equilibrium quantities of nitrogen at the current prices of food grains and inputs were greater than those quantities applied by the farmers. He found the opposite to be true for phosphate and potash fertilizers.

Herd (21), studying resource productivity in the Indian agriculture, from aggregate data on State levels, using standard Cobb-Douglas production function analysis, found low elasticities of production for labor and education, and high production elasticity for fertilizer. The high output elasticity of fertilizer in the Indian agriculture was attributed to low levels of its application while the lower labor output elasticity was attributed to the opposite reasons. The uniform simplicity of technology characterizing Indian agriculture resulted in little direct effect of education on agricultural production. Herd noted that until Indian agriculture was technologically transformed to a much greater degree, production differences would depend upon land, labor, irrigation and fertilizer.

Herd used the number of extension workers assigned per State and the literacy rate as two alternative measures for education level. The number of extension workers per State may not be really reflecting the education level of the farmers in the State, and the same is true for literacy rate, since the literacy rate of the rural

areas would be different than that of urban areas, and there may be interstate difference in the ratio of urban and rural populations.

Sidhu (39), evaluating the change in production technology of wheat resulting from the introduction of Mexican wheat varieties in the Indian Punjab, observed that new technology was neither strongly labor nor capital saving. However, new technology was cost saving. He found an increase of 25 percent in technical efficiency and a decline of approximately 16 percent in the unit cost of wheat production due to the introduction of high yielding Mexican wheat varieties. The per acre demand for labor, fertilizer and capital inputs recorded an increase of about 25 percent, due to the introduction of Mexican wheat.

Shetty (38), studying interfarm variation in fertilizer use observed that nearly 80 percent of the variation was due to the differences among farmers in relation to farm structure and access to information supply. The study was limited in its scope to only two villages located in the monocultural coastal tract of Mysore State of India.

Singh, Raheja and Bapat (41), using data of experimental trials conducted on farmers' fields with high yielding varieties of wheat and rice in India, observed that investment in fertilizer use would be justified only if it brought a net return of 100 percent or more. They were of the view that under the then prevailing price structure in India, there was little incentive for the majority of farmers receiving marginal returns to use fertilizer on the crops under investigation.

Qureshi and Khan (35), in their study of economics of fertilizer use on wheat compared the per acre yield of fertilizer users with that of non users. They observed that per acre yield of fertilizers users was 55 percent higher than that of non users. They attributed this increase to the use of fertilizer. They concluded that it was economically beneficial for the cultivators to use fertilizer at the then prevailing prices of wheat even without any subsidy on fertilizer.

The per acre increase in wheat yield could also be on account of better management practices and higher use of other factor inputs. Since the completion of the above study (data pertains to 1966-67), numerous changes in the agricultural set up have taken place due to the rapid adoption of new wheat and rice varieties, warranting new studies.

Eckert (4), in his study of dwarf wheats in Pakistan's Punjab, observed that at the fertilization level applied to local wheat, the dwarf varieties would have given a three fold increase in marginal productivity of nitrogen. He observed that farmers had achieved the economic optimum in nitrogen application to "local" wheat varieties, while in 1968-69 farmers were still increasing nitrogen fertilization of Mexican wheat. Eckert noted wide difference between the typical farmer and the better farmers in terms of optimum fertilization and resulting yields.

The study was limited to wheat crop only, since the undertaking of this study the price structure of inputs and outputs have changed significantly following the devaluation of 1972.

The review of literature has shown that a decline in the relative prices of fertilizers have played a significant role in increasing the use of fertilizers in various countries (two of the studies were not conclusive on this point). There are indications that educational and promotional efforts of various agencies concerned with fertilizers have helped in shifting the demand function for fertilizers over time. Also, research and educational activities of the government sponsored institutions shifted the agricultural production functions upward and thus stimulated the demand for fertilizers and other productive factor inputs in Japan.

The farmers level of education and access to information are important in explaining the variation in the use of fertilizers among farmers. The level of fertilizer use is positively associated with the farm size and volume of investment. Education and access to information supply are also important in determining the farmer's rate of adjustment to the changes in the optimum quantities of fertilizers. However, there is some evidence, that in the context of traditional and static agricultural set up, the education may not be very important in influencing the farm productivity. In general it appears that the farmers are using below optimum quantities of fertilizers.

The only study analysing fertilizer demand in Pakistan does not show fertilizer prices to be important in explaining the fertilizer use. The studies concerned with the application of fertilizer indicate that the use of fertilizer is highly profitable for wheat. One of these studies pointed out that farmers were using below optimum amounts of fertilizers on the dwarf varieties while the use of fertilizer for local wheat was optimal.

In general, there is a lack of research in the area of the economics of fertilizer use on specific crops under various institutional frameworks. The present study covering the important crops of Punjab will be an important contribution in this area.

CHAPTER II

SALIENT FEATURES OF AGRICULTURE, FERTILIZER PRODUCTION, CONSUMPTION AND DISTRIBUTION IN PAKISTAN

Introduction

Pakistan has four provinces: North West Frontier province, Punjab, Sind and Baluchistan. Though the present study is mainly concerned with the economics of fertilizer use in the Punjab, a brief description of the salient features of agriculture and the people of Pakistan is given in the first section of this chapter to provide an overview of the prevailing socio-economic situation. Section 2 of this chapter deals with the production, distribution and consumption of chemical fertilizers in Pakistan.

Section 1. Salient Features of Pakistan's Agriculture

Population

According to the latest population census conducted in 1972, the total population of Pakistan was estimated at 65 million, of which about 38 million, or approximately 58 percent lived in the Punjab (9). The majority of the population lives in rural areas. The agricultural population--comprising of all persons actively engaged in agriculture and their nonworking dependents, accounts for approximately 70 percent of the total population. Only 30 percent of the entire population was classified as economically active and during 1970, 70.5 percent of the economically active population was engaged in agriculture. The comparable figure in the United States was only 4 percent (7).

Land Resources and Climate

The total geographical area of Pakistan is approximately 197 million

acres, but only about 76 million acres, approximately 38 percent of the total area, can be used for cultivation. However, only 48 million acres, nearly 24 percent of total acreage, is currently under cultivation. Table 1 provides statistics on the land utilization of Pakistan and Punjab in 1971-72.

From the total land acreage available for cultivation nearly 28 million acres cannot be brought under plough mainly due to lack of irrigation water and low natural rainfall. Of the remaining 48 million acres 42 million acres, about 88 percent, of cultivated acreage was actually cropped during 1971-72. The remaining was reported as fallow.

Figures on cultivated acreage alone are inadequate as an index of agricultural production in any region. This is especially true in the case of Pakistan. Pakistan is characterized as an arid and semi-arid region with low precipitation, marked with uncertain and uneven distribution. The average annual rainfall varies from less than 8 inches in the Sind to over 50 inches in the hilly tracts of the north (2, p. 157). In the Punjab, the average annual precipitation ranges from 10 to 25 inches. This low and uneven distribution of rainfall, coupled with shortages of irrigation, is one of the major factors limiting the expansion of cultivated area.

Approximately two thirds of Pakistan's cultivated acreage is irrigated, of which canals account for about 73 percent. Tubewells and shallow wells are two other important sources of irrigation water supplies. Table 2 provides information on irrigated areas and different sources of irrigation in Pakistan and the Punjab.

TABLE 1. LAND UTILIZATION STATISTICS OF PAKISTAN AND PUNJAB 1971-72

Land Use Categories	Pakistan	Punjab	Punjab as a Proportion of Pakistan
	(Million Acres) ⁺		(Percent)
1. Total geographical area	197	51	26
2. Area reported	132	42	32
3. Area not available for cultivation (a) Forest area	6	1	17
(b) Other area	50	7	14
4. Total area available for cultivation (2-3)	76	34	45
5. Uncultivated area	28	7	25
6. Total cultivated area (4-5)	48	27	56
7. Current fallow	12	3	25
8. Net area sown	36	25	69
9. Area sown more than once	6	4	67
10. Total cropped area	43	29	67
11. Cropping intensity*	89	105	

⁺ 1 Acre = 0.405 hectare

* Cropping intensity = $\frac{\text{Cropped area} \times 100}{\text{Total cultivated area}}$

Source: Government of Pakistan, Ministry of Food and Agriculture, Year Book of Agricultural Statistics, 1972-73 (Supplement) 1974.

TABLE 2. AREA IRRIGATED BY DIFFERENT SOURCES IN PAKISTAN AND PUNJAB, 1970-71

	Cultivated Area	Total Irrigated Area	Canal Irrigated	Tubewell Irrigated	Others, Tanks & Wells, Etc.	Rainfed Cultivated Area
(Thousand Acres)						
Pakistan	47,770	32,020	23,220	5,620	3,180	15,750
Punjab	27,160	21,860	14,640	5,440	1,780	5,300
Punjab as a Proportion of Pakistan	57	68	63	97	56	34

Source: Government of Pakistan, Ministry of Food and Agriculture, Year Book of Agricultural Statistics, 1972-73 (Supplement) 1974.

Pakistan has an extensive network of canals dating from 19th century. The original canal system, as constructed by the British Indian Administration, was designed to serve as much land area as possible (31, p. 16). This was in order to obtain maximum revenue from the sale of land and from subsequent taxation (28, p. 69). Since partition of the Sub-continent and the independence of Pakistan in 1947, the government has continued to extend the original irrigation system. The high ratio of irrigable land to canal network and supplies of irrigation water gave rise to very low cropping intensities and has resulted in the twin menaces of waterlogging and salinity.

Tubewells were originally developed to fight waterlogging and salinity but have since provided an excellent source for supplementing canal water supplies. By providing secure and controllable water supplies, tubewells have played an important role in spreading a version of "the green revolution" in Pakistan. This came about by encouraging the use of chemical fertilizers and adoption of high yielding varieties of wheat, rice and maize. During 1970-71 there were 94,638 tubewells in Pakistan and nearly 87 percent of these were installed in the Punjab province alone (9). The Punjab accounts for 97 percent of the total tubewell irrigated area in the country.

Major Crops of Pakistan

The climate of Pakistan is suitable for growing a variety of crops. The cropping Pattern is quite diversified as indicated by Table 3 on the following page. However it is quite clear that only a few crops account for major proportion of the cropped area. Wheat is the leading crop, occupying 43 and 48 percent of the total area under major crops in

TABLE 3. ACREAGE UNDER IMPORTANT CROPS IN PAKISTAN AND PUNJAB, 1971-72

Crop	Pakistan	Punjab	Punjab as a proportion of Pakistan
	(Thousand Acres)		(Percent)
<u>Rabi (winter) Crops</u>			
Wheat	14,325	10,450	73
Barley	387	194	50
Gram	2,383	1,714	72
Rape & Mustard	1,389	787	72
Tobacco	125	55	44
<u>Kharif (summer) Crops</u>			
Rice	3,599	1,700	47
Bajra	1,876	1,133	60
Maize	1,253	579	46
Jowar	1,563	711	46
Cotton	4,837	3,697	76
Sesamum	103	41	40
Sugarcane	1,365	966	71
Total	33,205	22,027	66

Source: Government of Pakistan, Ministry of Food and Agriculture, Year Book of Agricultural Statistics, 1972-73 (Supplement) 1974.

Pakistan and the Punjab, respectively. Wheat is followed by cotton and rice in order of importance. Among them, these three crops have 69 and 72 percent of the acreage under major crops in Pakistan and the Punjab, respectively.

Wheat and rice are the most important food grain crops of Pakistan and sugarcane is one of the most important cash crops. Cotton and rice are a leading source of foreign exchange earnings as well.

Farm Size and the Distribution of Land Holdings

Pakistan is a country of small farms with highly uneven distribution of farmland ownership. Table 4 highlights the salient features of land distribution.

Forty-nine percent of the total farms in Pakistan have such a small size each as to aggregate to only 10 percent of the total farm area.

Only 2 percent of the total farms fall in the category of 50 acres and above. They occupy a farm area of 11.54 million acres, or 23 percent of the total farm area. It is expected that land reforms introduced during 1972 will have affected this category of farms most. According to the Year Book of Agricultural Statistics for 1974, (9) 1,897 farm owners in Pakistan were affected by these reforms. They had a total farm area of about 1,829,000 acres. These land reforms affected 873 farm owners with a total farm area of 536,000 acres in the Punjab province.

As shown in Table 4, farms falling in the category of 5 to 50 acres (approximately 49 percent of the total farms with a farming area of 67 percent) will count heavily in any strategy of agricultural development. The small farmers (owners of less than 5 acres) because of their meagre resource base are generally not in a position to experiment with new

TABLE 4. NUMBER OF FARMS AND THE DISTRIBUTION OF FARM AREA

Farm Size (Acres)	Farm Numbers		Farm Area		Cultivated Area	
	Farm Numbers	Proportion of Total	Farm Area	Proportion of Total	Cultivated Area	Proportion of Total
	(Thousand)	(Percent)	(Thousand Acres)	(Area)	(Thousand Acres)	(Percent)
Under 1.0	740	15	330	1	270	1
1.0--2.5	860	18	1,340	3	1,150	3
2.5--5.0	800	16	2,910	6	2,530	7
5.0--7.5	580	12	3,550	7	3,130	8
7.5-12.5	760	16	7,360	15	6,490	17
12.5-25.0	730	15	12,530	26	10,710	29
25.0-50.0	290	6	9,470	19	7,390	20
50--150.0	90	2	6,540	13	3,890	10
150 and over	10	*	4,900	10	1,690	5

* Less than 0.5 percent.

Source: Government of Pakistan, Ministry of Food and Agriculture, Year Book of Agricultural Statistics, 1972-73 (Supplement) 1974.

methods and inputs, since a failure will result in extraordinary hardship. The big farmers owning over 50 acres are in a relatively better position to take risks and experiment with new methods and technology. However, because of their secure financial position, and interests outside agriculture, they may not care much for farm improvements unless it further enhances their social status and prestige.

The average farm size in Pakistan is approximately 10.1 acres. Tenants operate about 42 percent of the total number of farms, cultivating a little over 19 million acres. This constitutes roughly 39 percent of the total farm area. Table 5 provides a breakdown of farm area according to tenurial arrangements.

Socio-economic features of tenancy are notorious for inhibiting initiative which is an important element in any strategy aimed at agricultural development. Therefore any future plan or program aimed at increasing agricultural production cannot afford to ignore such a major segment of the agricultural population.

Owner-cultivators operate 41 percent of the total farms, encompassing an area of 38 percent of the total farm acreage, with an average farm size of 9.4 acres. The average cultivated area on an owner operated farm is 6 acres. This section of the farming community with its ownership of land and the socio-economic status accorded to land owning classes in the agricultural societies, will likely play an ever increasing role in transforming the agricultural economy of Pakistan.

Soils of Pakistan

The soils in Pakistan are alluvial in nature with a very low organic matter content. The process of building organic matter is extremely slow

TABLE 5. NUMBER, AREA AND AVERAGE SIZE OF FARMS, CLASSIFIED BY LAND TENURE IN PAKISTAN

Type of Tenure	Number	Proportion of Total	Area	Proportion of Total	Average Size	Area	Proportion of Total	Average Size
	(Million)	(Percent)	(Thousand acres)	(Percent)	(Acres)	(Thousand acres)	(Percent)	(Acres)
Owner cultivators	2.0	41	18,700	38	9.4	12,000	32	6.0
Owner Cum Tenant	0.8	17	11,000	23	13.2	8,600	23	10.4
Tenant only	2.0	42	19,200	39	9.5	16,600	45	8.2
Total	4.8	100	48,900	100	10.1	37,200	100	7.7

Source: Government of Pakistan, Ministry of Agriculture and Works, Pakistan Census of Agriculture 1960.

under the climatic conditions prevailing in Pakistan. Consequently, the application of nitrogenous fertilizers is of paramount importance for maintaining and improving crop yields. Approximately 56 percent of Pakistani soils are classified as low in available phosphorus, 29 percent as classified as having medium available phosphorus and 15 percent as high in available phosphorus (5). Phosphorus deficient soils appear to be equally spread out throughout the agricultural tract of Pakistan. However, it is only recently that personnel concerned with agricultural research and extension have started emphasizing the use of phosphate fertilizers. There is a general consensus among experts that Pakistani soils are well supplied with potash and generally do not need potassium fertilizers (except for certain pockets particularly in the northern plains where this element is in short supply). (5).

As a by-product of the irrigation system, the twin problems of waterlogging and salinity have emerged as major obstacles, hindering agricultural development. Seepage from the canal network is the causal factor of waterlogging. Salinity is due to large salt beds underneath the Indus Valley, and poor subsurface drainage compounded by high rate of evapotranspiration and low precipitation. Pakistani soils are strongly alkaline in character. Waterlogging and salinity have adversely affected the productivity of about 25 percent soils and the menace is still growing.

Section 2. Production, Distribution and Consumption of Chemical Fertilizers in Pakistan

Production

Although chemical fertilizers were introduced into Pakistan in 1952, domestic production started in 1957 with the commissioning of an ammonium

sulphate plant at Daudkhel (34). It had an annual capacity of 50,000 tons of ammonium sulphate, which was later increased to 90,000 tons per year. Fertilizer production has continued to increase over the years, but consumption of fertilizers has expanded at a much faster pace, necessitating fertilizer imports from abroad. Table 6 provides data on domestic production and imports of fertilizers for the period of 1963-64 to 1972-73.

As is evident from Table 6, imports of fertilizers over the years have contributed substantially in meeting the total fertilizer requirements of Pakistan.

Up to 1968, the domestic production of fertilizers was confined to three public sector plants, located at Daudkhel, Multan and Lyallpur/Jaranwala. The fertilizer plant at Daudkhel has a capacity of manufacturing 90,000 tons of ammonium sulphate, while the plant at Multan is designed to produce 132,000 tons of urea and 75,500 tons of ammonium nitrate. The fertilizer plant at Lyallpur/Jaranwala has a capacity of 54,000 tons of super phosphate (9) and is the only super phosphate plant in the country. At present there are two fertilizer plants in the private sector located at Dharki and Sheikhpura. The plant at Dharki went into production in the last quarter of 1968 and has a capacity to manufacture 173,000 tons of urea. The Sheikhpura plant is designed to produce 340,000 tons of urea (9) and it started production in the last quarter of 1971.

Except for the urea plant at Dharki, which is in Sind province, all other manufacturing facilities at present are located in the Punjab.

TABLE 6. DOMESTIC PRODUCTION AND IMPORTS OF CHEMICAL FERTILIZERS
IN PAKISTAN, 1963-64 to 1972-73

Year	Domestic Production	Imports	Total Supply	Imports as Proportion of Total Supply
	(Thousand Tons)			(Percent)
1963-64	154	24	178	14
1964-65	161	15	176	9
1965-66	161	172	333	52
1966-67	171	456	627	73
1967-68	182	451	633	71
1968-69	239	331	570	58
1969-70	372	651	1,023	64
1970-71	399	301	700	43
1971-72	564	156	720	22
1972-73	703	347	1,050	33

Source: Government of Pakistan, Ministry of Food and Agriculture, Year Book of Agricultural Statistics 1972-73 (Supplement) 1974.

Distribution of Fertilizers¹

Since the first official introduction of fertilizers into Pakistan in 1952, consumption of fertilizer has increased several-fold. Up to 1961, the marketing and distribution of chemical fertilizers was exclusively handled by the provincial Departments of Agriculture. The Agricultural Development Corporation (ADC) was established in 1961, and the marketing and distribution of commercial fertilizers were entrusted to this semi-autonomous corporation. From 1967-68, ADC was solely responsible for the imports and distribution of imported fertilizers throughout the country. The Rural Supplies Co-operative Corporation (RSCC) was handling the distribution of PIDC fertilizers. In January 1968, the private sector was also allowed to enter the fertilizer business; through manufacturing, marketing and distribution. The Agricultural Development Corporation was dissolved in 1972, and the supply wing of ADC was retained and redesignated as the Agricultural Supplies Organization. During July 1973, the functions of Agricultural Supplies Organization relating to marketing and distribution of fertilizer and seeds were transferred to the four provincial governments.

As a result of this transfer, the government of the Punjab established a new organization, known as the Punjab Agricultural Development and Supplies Corporation (PASC). This new organization was authorized to make arrangements on a commercial basis for the procurement, distribution, storage and sales of fertilizers, seeds and other agricultural inputs.

¹This section draws heavily on marketing and distribution of fertilizer and seeds (34).

During August 1973, the Punjab government "nationalized" the distribution of fertilizer in the province and abolished all principal agents, dealers and commission agents. It entrusted the distribution of commercial fertilizers to the Punjab Agricultural Development and Supplies Corporation (PASC) to be performed through its own network of depots and sales outlets. The PASC has established about 600 sales depots with a bulk depot at each Tehsil headquarters. Later on, however the Punjab government allowed Dawood Herculeus, Ltd. to market 50 percent of its Baber Sher urea from the Punjab's quota in Punjab province. Eighty percent of the total production of the Esso plant is earmarked for Sind province and 14 percent for the Punjab. The share of Punjab province is marketed by the Esso dealers themselves in Bahawalpur division and Multan and Muzaffargarh districts of the Multan division.

Fertilizer Consumption in Pakistan

There has been a large increase in the consumption of chemical fertilizers in Pakistan, especially during the last ten years, although, fertilizer use per cultivated is still very small (17.18 lbs. only). Nitrogen is the most commonly used fertilizing element. It is obtained mostly from urea, ammonium sulphate and ammonium nitrate. Urea is by far the most popular fertilizer with the farmers.

During 1972-73 the total consumption of fertilizers was about 437 thousand nutrient tons, as compared to only 40 thousand nutrient tons in 1962-63. A little over two-thirds of the total fertilizer consumed in Pakistan was used in the Punjab compared to 24 and 28 percents in Sind and the Northwest Frontier Province, respectively, in the year of 1972-73 (9). Table 7 shows the consumption of different types of fertilizers in Pakistan from 1952-53 to 1972-73.

TABLE 7. CONSUMPTION OF VARIOUS CHEMICAL FERTILIZERS IN PAKISTAN
1952-53 to 1972-73

Year	Fertilizer Elements			Total
	Nitrogen (N)	Phosphorus (P)	Potash (K)	
	(Thousand Nutrient tons)			
1952-53	1.0	-	-	1.0
1953-54	14.8	-	-	14.8
1954-55	14.1	-	-	14.1
1955-56	6.6	-	-	6.6
1956-57	9.0	-	-	9.0
1957-58	16.4	-	-	16.4
1958-59	18.0	-	-	18.0
1959-60	19.3	0.1	-	19.4
1960-61	31.0	0.4	-	31.4
1961-62	37.0	0.5	-	37.5
1962-63	40.0	0.2	-	40.2
1963-64	68.0	0.7	-	68.7
1964-65	85.0	2.2	-	87.2
1965-66	69.8	1.2	-	71.0
1966-67	112.3	3.9	-	116.2
1967-68	177.7	11.3	0.2	189.2
1968-69	197.0	38.9	3.0	238.9
1969-70	273.5	35.5	1.4	310.4
1970-71	257.1	30.7	1.3	289.1
1971-72	336.4	36.4	0.7	373.5
1972-73	386.4	48.7	1.4	436.5

Source: Government of Pakistan, Ministry of Food and Agriculture, Year Book of Agricultural Statistics 1971-72.
Government of Pakistan, Ministry of Food and Agriculture, Year Book of Agricultural Statistics, 1972-73, (Supplement) 1974.

The development and the rapid spread of tubewell technology, the introduction of high yielding and fertilizer, responsive varieties of wheat, rice and maize and the favorable input-output pricing policy of the government has helped in this tremendous increase of fertilizer consumption. Private sector dealing in fertilizers has also played an important role in popularising the use of fertilizers with farmers.

Right from the introduction of chemical fertilizers, the government has maintained a cheap fertilizer policy. The fertilizer purchases by farmers have been subsidized, chiefly to encourage its use. Considerable amounts of financial, institutional and human resources have been invested in its purchase, marketing and distribution. The amount of subsidy on fertilizer has varied from 60 percent in 1952-53 to 25 percent at the end of 1964. The peak was during 1955-56 when fertilizer was subsidized to the extent of 66 percent (33). Since 1964, fertilizer subsidy has varied from 35 to 50 percent, and was only 17 percent during the later half of 1973. From January 1973 to date prices of fertilizer have been revised upward four times, with the result that prices of all kinds of fertilizers to farmers have more than doubled during the past year.

Some people have argued that the fertilizer subsidy has been meant to compensate for the high cost of production in the public sector at home. It may be true however, that the domestic production was only a part of the total fertilizer supply, even after the commissioning of manufacturing plants in the private sector. Moreover, the exchange rate in the country was considerably overvalued, before the 1972 devaluation and prior to that actual effective subsidy may have been even more.

Although the effective rate of subsidy on fertilizer for the farmers may be a debateable point, nevertheless it is certain that subsidy has played an important role in encouraging the use of fertilizers among the farmers in the initial period at least.

CHAPTER III

THEORETICAL FRAMEWORK AND DESIGN OF THE FARM SURVEY

This chapter is divided into two sections. In Section 1, the theoretical framework of the production function analysis is described. This is the major tool employed in this study. The various formulations of the production functions used in this study are also discussed in this section. In Section 2, the design of sample survey used in the present study is discussed.

Section 1. Production Function Analysis

Introduction

One way to approach the analysis of economic development is through the theory of production. The appropriate question in this regard is how to increase the yield of each factor input. Two possible alternatives are (1) changing the production surface or (2) reorganizing and reallocating factor inputs for a given production function. The first alternative implies changing the parameters of the production function usually either by introducing new kinds of factor inputs or new techniques of production. The second alternative, given the production function, output per unit may be increased by improving the allocative efficiency of the existing resources.

This study is concerned with the efficiency of resource allocation, especially that of chemical fertilizer in the production of major crops in the Punjab. In order to evaluate the efficiency of chemical fertilizer use, different types of production function for important crops have been estimated. The marginal physical products for different factor inputs

have been calculated from the estimated production functions (from per acre production functions). Finally, marginal value products of chemical fertilizer for various crops have been compared with the then prevailing prices of chemical fertilizer. However, no attempt is made to compare the marginal value products of the land and labor inputs with their opportunity costs because of the lack of factor input price data.

Production Function

The production function is a concept in physical and biological sciences, that has been widely adopted and used in economic analysis. According to Heady: "The production function refers to the relationship between the input of factor services and the output of product; product output is a function of or is 'dependent on' the input of resource services." (17, p. 30). Mathematically, a production function may be expressed as:

$$y = f(x_1, \dots, x_n)$$

$$y = \text{output (dependent factor)}$$

$$x_1, \dots, x_n = \text{factor inputs (independent factors)}$$

The production function given above, describes that output y , is determined by the factors of production specified as x_1, \dots, x_n . However, it does not specify the nature of functional relationship. The algebraic form of the function describing the nature of relationship will vary with soil, type and variety of crop under investigation. Given a functional relationship, the function describes how the average quantity of output changes with the changes of inputs.

Economic Specification of the Production Function

In formulating the economic model of the production process, the

researcher faces three problems: (1) Choice of single equation or a system of equations, (2) selection of the algebraic form of equation(s), and (3) specification of the variables. The ideally correct answers to these problems lie in the logic--economic, biological or physical underlying the production process (18, p. 197). For empirical research the model has to be not only logically sound but also computationally feasible.

Choice of Single Equation or a System of Equations

Whether to use a single equation or a set of simultaneous equations in the production function analysis depends on the relationships among the variables, availability and accuracy of data and the computational feasibility of the specified model. When a simultaneous equations model is appropriate, the use of single equation model will result in biased estimates. Nevertheless, the use of single equation model for agricultural production functions has been justified by Griliches (14). Mundlak and Hoch (29) and Zellner, Kmenta and Dreze (44), by arguing that inputs in agriculture are largely predetermined because of considerable lag in production. It is also argued that since error is largely weather determined simultaneous equation bias will be small for well specified production functions.

Selection of the Algebraic Form

A true functional relationship underlies a given production process, however the economic, physical and biological logic of the production process is usually to a large extent unknown. This is especially true of production processes involving entrepreneurial decision making. For purely mechanical production processes the problems of economic

specification may not be so great, nevertheless, difficulties arise from a lack of knowledge of entrepreneurial decision making process.

The previous researches on the subject have established a number of functional forms that are competent initial approximations of the true form. Among these, a reasonable choice of appropriate algebraic form can be made on the basis of its theoretical implications.

The various algebraic formulations used in the course of the present study are discussed below. The performance functions based on

1. Cobb-Douglas Production Function: The function has the general form:

$$y = A x_1^{b_1} \dots x_n^{b_n} U$$

y = output

A = constant

x_i = amount of factor inputs used

b_i = the elasticity of production of input i ,

U = a stochastic error term

One of the attractive properties of the Cobb-Douglas production function is that it becomes linear in the logarithms of the variables. The Cobb-Douglas function allows either increasing or decreasing or constant marginal productivity. It does not allow an input-output curve embracing all three (18, p. 75). Moreover the function assumes constant output elasticities for various factors of production over the input-output curve. The output elasticities indicate the percent change in output which would, on the average, be accompanied by one percent increase in the input concerned, while all other inputs are held constant.

The Cobb-Douglas function is not suitable for data having ranges of both increasing and decreasing marginal productivity. Neither can the

function be used satisfactorily for the data which might have positive and negative marginal products. The rate of decline in the marginal product decreases with input magnitudes, hence the curve flattens out as input increases and a maximum production point is not defined.

The Cobb-Douglas production function implies that the level of various inputs must be greater than zero, or at least some quantity of each input must have been used. However, the real world data seldom conform to this situation, since some of the sample data may have some inputs at zero levels as often happens in the production studies involving the use of fertilizers, etc. The practical computational problem arises since the log of zero is minus infinity. Heady and Dillon (18, p. 230) and Yotopolous (43, p. 179) have suggested that zero observations may be replaced by some figure of arbitrary small size. In our empirical analysis zero observations mainly that of chemical fertilizers have been assumed equal to one.

Despite these limitations, the Cobb-Douglas function has been the most popular function in farm firm studies. This algebraic model provides a compromise between (a) adequate fit of data (b) computational feasibility and (c) sufficient degrees of freedom (18, p. 228).

In this study, the Cobb-Douglas production function has been estimated for Mexi-pak wheat, Basmati rice and IRRI rice in the course of the present study. The variables used and the results obtained are discussed in the next chapter.

2. Quadratic Form: The simple quadratic function showing output to be function of only a single variable, is written as follows:

$$Y = a + bx - cx^2$$

Y = output

x = factor input

a = constant

b, c = parameters

The minus sign before c indicates diminishing marginal returns.

The quadratic form allows both a declining and negative marginal productivity but not both increasing and decreasing marginal products (18, p. 78). The marginal physical product of the x- factor input can be arrived at simply by taking the first derivative of the function with respect to the input x. The elasticity of production, which is defined as the ratio of marginal physical product to the inverse of the average product, is not constant for a quadratic function, but declines with increase in input magnitudes. The quadratic function assumes a particular characteristic in relationship between marginal physical products--that they decline by a constant absolute amount.

A modified version of the quadratic equation has been estimated for maize (corn) and sugarcane crops (on the basis of total output and total factor inputs including crop area per farm). The variables used and the results of the estimated equations are discussed in Chapter 4 under the respective crops.

3. Square Root Form: The square root equation provides a simple compromise between the exponential and quadratic forms. It allows a diminishing total product as well as marginal product which declines at a diminishing rate. In its simple form a square root equation may be expressed as below (18, p. 80):

$$Y = a - b x + c x^5$$

The output elasticity in this case declines with increase in input and output magnitudes.

In our analysis a modified form of the square root equation has been estimated for Jhonna rice and cotton crops (based on total output and total factor inputs, including crop area per farm). The variables used and the results of the analysis are reported in the next chapter.

4. Linear Equation: This is the most simple form of all the equations. The linear function implies constant marginal productivity.

The linear equation has been estimated for local wheat. The linear per acre production functions have also been estimated for maize, Jhonna rice, cotton and sugarcane.

Criteria Employed for the Selection of Appropriate Algebraic Equation

Several types of production function forms have been used in this study depending on their appropriateness and "goodness of fit." This frequently could not be determined a priori, but had to be evaluated after actual tried fits. The following criteria were used in the selection of appropriate functional form from the different estimated equations.

1. R^2 - Coefficient of multiple determination. It represents the variation of regressand explained by various regressors included in the model. The largest value of R^2 is taken to indicate the form which is most appropriate. However, as the number of regressors included in the equation increases R^2 will also increase. Therefore, this measure is not appropriate for comparing two equations having unequal number of regressors. In these situations, adjusted coefficient of determination defined as:

$$\bar{R}^2 = 1 - (1 - R^2) \frac{T - 1}{T - K - 1}$$

$$= R^2 - \frac{K}{T - K - 1} (1 - R^2) \quad \text{is a}$$

better measure (8, p. 217) and has been employed to choose from the different estimated equations.

T = total number of observations

K = number of regressors included in the model

2. Other empirical criterion used has been the F ratio:

$$F = \frac{\text{variance explained by regression}}{\text{unexplained variance}}$$

A large F ratio is taken to indicate that the model is appropriate for the set of sample observations.

3. Adequacy of the estimated function in the light of theory and logic.
4. Significance of individual coefficients in the light of t tests.

The choice among alternative functional forms involves a compromise among the several criteria, including economic theory, goodness of fit and simplicity. According to "Occam's razor" the simpler hypothesis is to be preferred to the more complicated one (8, p. 217). It is not always obvious which of the forms is simpler; but it is reasonable to assert that the smaller the number of parameters the simpler the function, and this principle has been followed throughout in the course of this study. A log linear equation has been estimated from the time-series data to determine the impact of various agro-economic factors on fertilizer use. The details of data and related factors are discussed in Chapter 6.

Economic Specification of the Production Function Variables

In order to be useful for providing guidelines in planning and policy

formulations, the production function estimated must include all the important variables effecting farm production. Economic specification, statistical estimation of production function and the collection of necessary data are not independent of each other, but each influences the other. If some of the variables relevant to the production process are omitted, the estimated function will be biased in an economic sense and would not be expected truly to depict the production process, either structurally or predictively. However, in empirical studies, it becomes frequently inevitable to compromise and use second best methods or variables, because of (1) non availability of data regarding certain variables, (2) immeasurability of certain inputs, (3) and limited resources at the disposal of a researcher. This forces the use of "proxy" variables. As Griliches (14) has pointed out, the specification errors arise because of approximations, "omissions" and "commissions" (the use of proxies, etc.) of data. The exclusion of certain variables may bias the coefficients of other variables as well as the returns to scale. Griliches (14) observed that omission of managerial inputs from the production function biased the coefficient of capital inputs upwards. Similarly, using the Cobb-Douglas type functional relationship and disregarding the quality differences in the measure of labor could lead to an upward bias in the elasticity coefficient of labor input and downward bias in the estimates of returns to scale.

The correct specification of production function is very essential, if it is to serve as a guide in policy making decisions.

Section 2. Farm Management Survey

Crop output is a function of crop area, labor input (manual and bullock labor spent on various farm operations) irrigation, fertilizer use, application of farm yard manure, type of soil, farm management quality, weather conditions prevailing during the cropping season and other related factors. In order to estimate empirical production functions, detailed quantitative information regarding various farm inputs and output is essential. To collect this information a farm management survey in 16 villages of Sahiwal and Gujranwala districts of the Punjab province was organized during the fall of 1973. In all, 192 farmers were interviewed.

Selection of Districts

The "district" in Pakistan is an administrative unit below the divisional level. All the nation building departments have offices located at the district headquarters. There are a total of 19 districts in the Punjab. The cropping pattern and the availability of irrigation water has a considerable impact on fertilizer use in each district. Since secure water supplies are the sine-qua-non for profitable application of fertilizer, therefore, only a small percentage of total fertilizer used in the province is consumed in barani areas (those areas where cultivation depends upon rainfall for irrigation) of the Punjab province; Rawalpindi, Jehlum, and Cambellpur districts. Hence, these districts were excluded from consideration for selection of farm survey on a priori basis.

Farming in the Punjab is multi-enterprise, in the sense that quite a large number of crops are grown on an average farm. However, the

agriculture of the province is characterized by two distinct cropping patterns: wheat-cotton, and wheat-rice. Therefore, it was decided to stratify the canal irrigated districts on the basis of the cropping pattern followed.

Wheat is the most important crop as indicated by the higher percentage of crop acreage under wheat in all the districts. Cotton and rice are two important kharif (summer) crops. It is evident from Table 8 that wheat and rice form the dominant cropping pattern in Gujranwala, Sialkot and Sheikhupura districts, whereas in Sahiwal, Multan, Rahim Yar Khan, Bhawalpur, Bhawalnagar, Jhang, Lyallpur, Sargodha, D. G. Khan and Muzaffargarh districts wheat and cotton is the leading cropping pattern. Major criteria for the selection of districts from each cropping zone were (a) relatively highly percentage of crop area under wheat, rice and cotton individually, (b) availability of tubewell irrigation water not constrained by saline underground water, (c) absence of special government projects like Salinity Control and Reclamation Project (SCARP), etc., (d) high aggregate fertilizer consumption in the district.

On the basis of the above specified criteria, Gujranwala district was selected to represent the wheat-rice cropping pattern. Gujranwala is an important agricultural district. It has the largest number of tubewells and the highest fertilizer consumption among those districts following the wheat-rice cropping pattern (12).

From those other districts following the wheat-cotton cropping pattern, it was originally decided to include two districts. On the basis of above discussed criteria, Sahiwal and Rahim Yar Khan were selected from this zone. Sahiwal is one of the leading districts of

TABLE 8. PERCENTAGE AREA UNDER IMPORTANT CROPS IN CANAL
IRRIGATED DISTRICTS OF THE PUNJAB 1969-70

District	Proportion of Cultivated Area under major Crops					Total Proportion under major Crops
	Wheat	Rice	Maize	Cotton	Sugarcane	
	(Percent)					
Gujrat	40	10	3	2	5	60
Sargodha	32	3	3	8	4	50
Lyallpur	40	3	7	10	12	72
Jhang	39	3	3	16	4	65
Mianwali	38	*	1	6	2	47
Sialkot	45	24	4	*	3	76
Gujranwala	36	34	1	1	2	74
Sheikhupura	39	26	4	3	4	76
Lahore	38	10	3	1	5	57
Sahiwal	35	6	3	22	4	70
Multan	36	2	2	28	2	70
Muzaffargarh	49	3	*	7	4	63
D. G. Khan	38	6	*	7	1	52
Bhawalpur	34	3	1	16	4	58
Bhawalnagar	31	3	1	9	6	50
Rahim Yar Khan	31	3	2	2	27	65

* Less than 1 percent

Source: Government of the Punjab, Agriculture Department, Season & Crop
Report of the Punjab for the year 1969-70.

Punjab in terms of agricultural production. At present it ranks second only to Multan district in terms of aggregate fertilizer consumption (12). Rahim Yar Khan district was preferred over Multan district because conditions with respect to farming are quite similar in Sahiwal and Multan. Rahim Yar Khan satisfied all the above mentioned criteria and ranked fifth in terms of total fertilizer consumption.

However, at the time the survey was about to be started in 1972, heavy floods occurred in the country and Rahim Yar Khan was one of the most heavily affected areas. Transportation and communication were disrupted. It was realized that the rehabilitation of flood affected people and the restoration of conditions leading to normal agricultural activities in the farming areas would take longer than the duration of planned survey. Therefore, Rahim Yar Khan district was dropped from the planned survey.

Selection of the Villages

Originally it was decided to select five villages from each district, yielding a total of fifteen villages from the three districts. However, because of the dropping of Rahim Yar Khan district (for reasons discussed above), eight villages from each of the remaining two districts were selected, to make up the sample size as originally planned.

A list of all the villages included in Gujranwala and Sahiwal district was prepared. The officials of the Department of Agriculture, Punjab Agricultural Development and Supplies Corporation and the Department of Local Government were consulted in the selection of representative villages. The objectives of study were carefully explained to the officials of these departments and it was emphasized

that the villages selected had to be located at least at a distance of six to eight miles from the town areas but should be accessible. However, in some cases after reaching the village it was found that the village did not represent typical rural situations, it was replaced (on a judgment basis) with a suitable village.

Selection of the Respondents

Local leaders of the villages (Lambardars,¹ ex-members and secretaries of the Union Councils) served as the first points of contact. The purpose of visiting their village and objectives of study were explained to these local leaders. While selecting farmers it was ensured that the interviewees belonged to all the pattis² of the village. If more than one ethnic group were living in the village as it often happened, the farmers were selected for interview from all these ethnic groups and care was taken that their farms were not clustered in one pocket, but were spread around the village. Before starting the actual interviews, general information about the farm location and the farmers' ethnic background was solicited from the farmer to make sure that there was no over representation of any particular farm size and/or ethnic group. However, this sometimes put the author into an awkward situation of having to decline the opportunity of interviewing a farmer who was otherwise willing to provide us information about his farming, etc.

¹Lambardar is the village headman, is customarily a hereditary position. He is entrusted with the collection of land revenue from farmers and depositing it in the Government Treasury (36, p. 32).

²A village is often subdivided into parts called "pattis." A patti is often an area existing in the minds of inhabitants, but it may have very obvious physical manifestations which differentiate the ethnic groups living in a village (36, p. 28).

In all, 192 farmers were interviewed. The survey was limited to those farmers operating farm areas of up to 50 acres.

Preparation of Questionnaire

The questionnaire for collecting data was prepared by the author in the United States, and it was discussed with his graduate advisory committee members. It was further discussed with some of the faculty members of the faculty of Agricultural Economics and Rural Sociology at the University of Agriculture, at Lyallpur, after arriving in Pakistan. Pretesting of the questionnaire was conducted in two villages of Sahiwal district, and it was modified in the light of the pretesting experience. The questionnaire is attached in the Appendix.

Interviewers

Two research assistants from the University of Agriculture, at Lyallpur, were recruited to help in conducting interviews with the farmers. Both of these were graduate students in the faculty of Agricultural Economics and Rural Sociology, who had some previous experience of conducting farm surveys.

Before going into the field for pretesting of the questionnaire, each section of the questionnaire was explained to the research assistants in detail and the questionnaires completed by them were checked and the errors were brought to their notice. After final preparation of the questionnaire (completed at Lyallpur University), the author and the two assistants conducted the interviews.

Major Problems

After the selection of villages, the location of these villages was an additional problem. Friends of the author, who were serving with the

various nation building departments in the selected districts, helped in locating these villages. Officials of the Department of Local Government in these districts were also very helpful in this regard.

Lack of adequate transportation for the research team was a constant problem throughout the survey and frequently involved two to three miles journey on foot before reaching the village. This resulted in considerable expenditure of time.

During the pretesting phase, an attempt was made to list all the farmers living in the villages along with their farm sizes for subsequent random selection of the farmers for the interviews. However, it proved to be very time consuming process and was abandoned in favor of the procedure discussed above.

The survey was conducted during a very busy farming season, fall of 1973. At that time harvesting of "kharif" and sowing of "rabi" crops was in full swing, so locating and convincing of the farmers for interviews was all the more difficult.

Summary

In order to estimate production functions for major crops, a farm survey was organized to collect the necessary data. The survey was conducted during the fall of 1973, and data collected pertained to the cropping year of 1972-73.

A total of 192 farmers were interviewed. These farmers were selected from sixteen villages of Sahiwal and Gujranwala districts, eight villages from each district.

Sahiwal district was selected from the wheat-cotton cropping area of the Punjab while Gujranwala was selected from the wheat-rice cropping area

of the province. While selecting the villages to be included in this farm survey, efforts were made that villages selected represented typical farming situations and were not located near towns to guard against the urban influence. Similarly, while selecting farmers for interviewing, it was ensured that respondents belonged to the differing ethnic farming groups of the village.

A breakdown of the sample farms according to farm size is given in Table 9. Table 10 provides information on the average farm size, minimum and maximum size of the farms in each category of our survey.

TABLE 9. BREAKDOWN OF SAMPLE FARMS ACCORDING TO FARM SIZE

Farm Size	No. of Observations	Proportion of Total Sample
		(Percent)
Up to 12.5 acres	73	38
12.6 to 25.0 acres	84	44
25.1 to 50.0 acres	35	18
Total	192	100

TABLE 10. AVERAGE, MINIMUM AND MAXIMUM ACREAGE PER FARM
UNDER DIFFERENT FARM SIZE CATEGORIES

Farm Size	Average Area per Farm	Minimum Area	Maximum Area
		(Acres)	
Up to 12.5 acres	9.2	4.0	12.5
12.6 to 25.0 acres	18.4	13.0	25.0
25.1 to 50.0 acres	35.1	26.0	50.0

CHAPTER IV

EMPIRICAL PRODUCTION FUNCTION ANALYSIS

This chapter is divided into two sections. In Section 1, explanation of the different factor inputs used in estimating empirical production functions is provided. Limitations of data are discussed at the end of this section. The results obtained from the estimation of "performance" functions (based on total output and total factor inputs including crop area under specific crop per farm), as well as per acre production functions are discussed in Section 2. The method for calculating marginal physical products is also described in this section. The marginal productivities of different factor inputs derived from the per acre production functions of the selected crops are discussed in the following order: labor (manual and bullock, fertilizers, farmyard manure, and crop area. The role of farm management in farm products is also discussed here.

Section 1. Explanation of Input-Output Factors Used in Production Function Analysis

Farm Output

Total output of each crop is measured in physical units (pounds). It is used as a dependent variable in estimating the performance functions. For calculating the coefficients of per acre production functions, average yield per acre of each crop is employed as a dependent variable or regressand.

Independent variables included in the empirical analysis are described below. Total amount of these factor inputs used for specific crops were employed as regressors in estimating the coefficients of the

performance functions. However, for per acre production function estimations the average amounts used per acre of these inputs were employed as independent variables. These were obtained by dividing the total amount of various factor inputs used for a particular crop by the acreage under that crop.

1. Area under Particular Crop. Area under each crop is measured in acres.
2. Manual Labor. Manual labor spent on various farm operations in the context of each crop is measured in hours. The farm operations included in the calculation of labor are presowing cultivation of the crop area, sowing, irrigation, fertilizer application, application of farmyard manure, interculturing of crop area, harvesting and threshing.

The problem of measurement has been resolved by collecting data on the frequency and intensity of various farm operations performed on each crop. The labor requirements of various farm operations were obtained from secondary sources (41). Total labor spent was thereby estimated individually for various farm operations, and subsequently these individual amounts were summed up to obtain total labor spent.

3. Bullock Labor. Total bullock hours spent on various farm operations on each crop under investigation has been measured in hours. The use of bullock labor is complementary with manual labor in crop production. Including manual and bullock labor as two independent variables in the production function has led to problems of collinearity in the case of those crops where the majority of farm operations performed involve the combined use of manual and bullock labor. This problem has been

especially acute where the number of observations is small.

Therefore, in these cases bullock labor as an independent variable has been dropped from the function, a procedure recommended by Heady & Dillon (17, p. 137), and Doll (3). This problem will also be pointed out in the discussion of results obtained from the production function analysis. However, in these circumstances, care must be exercised in interpreting the labor coefficient which represents not only the contribution of labor (manual) but also that of bullock labor and complementary capital items.

4. Farmyard Manure Expenses. Farmyard manure is a conventional input obtained as a by-product from farm animals and used quite extensively in crop production. Before the introduction of chemical fertilizers it was the major source of maintaining soil fertility in addition to keeping land as fallow. Its use is quite pervasive in the Punjab, especially on cash crops. To overcome problems of wide variation in quality, the opportunity cost of farmyard manure used on a particular crop is the value used in the production function analysis. The opportunity cost of farmyard manure has been estimated, using quantitative data on the amount of fertilizer used on each crop (cart loads). The prevailing price of similar kinds of farmyard manure in the community were obtained during the farm survey. The opportunity cost of farmyard manure for each crop has been estimated by multiplying these two quantities.
5. Chemical Fertilizer. Nitrogen is the most popular fertilizer element among the farmers of the Punjab. Its major sources are ammonium sulphate, ammonium nitrate and urea. Urea is by far the most popular

kind of nitrogenous fertilizer among the farmers. Out of 192 farmers interviewed, 172 (approximately 90 percent) had applied nitrogenous fertilizer to one crop or the other, under investigation. Quantity of fertilizer (nitrogenous fertilizers only) has been converted into nutrient pounds of nitrogen and this has been used as an independent variable in the estimation of production functions for various crops.

The use of phosphate fertilizers is not very common at this stage. Although, it is most widely used on wheat, still only 40 percent of the wheat growers had used it. However, its use appears to be on the increase. Due to its uncommon use among the farmers, it has been mostly represented by a dummy variable. In the case of mexi-pak wheat, total cash expenses on nitrogen and phosphate chemical fertilizers are used as an independent variable.

6. Management. A management index was constructed based on the farmer's farming practices adopted (method of crop sowing, farmer's know-how of fertilizer and improved methods of cultivation) on his farm. Farmers using improved methods of crop sowing and showing better understanding of fertilizers, etc. were rated as good farmers and the rest as average farmers. Farm management has been represented by a dummy variable in the estimation of various performance as well as production functions.

Limitations of Data

The estimated functions do not include "fixed capital" as an input factor. Under the farming conditions prevailing in the Punjab, it is the working capital in the form of bullocks, chemical fertilizers and farmyard manure which is important in crop production rather than fixed structures, etc.

Another variable, irrigation has been omitted from the analysis due to difficulties in getting an accurate measure by the survey method. However, farmers did provide information regarding the total number of irrigations applied to a particular crop, and it appears there was not much variation in the number of times a crop was irrigated among various farms. Moreover, the majority of the farmers had access to additional irrigation supplies either from their own tubewells or from the tubewells on neighboring farms. Approximately 94 percent of the farmers in the survey had access to tubewell water.

Section 2. Production Function Analysis

Estimated Output Coefficients for Major Crops in Punjab (1972-73)

The estimated coefficients and related statistics for different types of performance functions (based on total output and total factor inputs per farm, including crop area) for selected major crops are presented in Table 11. The ordinary least squares method of multiple regression analysis was used to estimate these coefficients of the performance functions as well as those of the per acre production functions, discussed later.

The size of the adjusted coefficient of multiple determination-- \bar{R}^2 suggests that a major proportion of the interfarm variation in output of these crops is explained by the observed inputs included in the performance functions. These functions are useful in terms of their predictive value, but are difficult to interpret in either behavioral or structural terms. The high value of expected as well as observed correlation between the land input and other input factors makes the interpretation of the estimated coefficients difficult if not impossible.

TABLE 11. ESTIMATED COEFFICIENTS AND RELATED PERFORMANCE FUNCTION STATISTICS FOR SELECTED CROPS, 1972-73, PUNJAB, PAKISTAN⁺

Crop	N	Intercept	x_1 Crop Acres	x_2 Man Hours	x_3 Bullock Hours	x_4 Expenses on Ferti- lizers	x_5 Pounds of Nitrogen	x_6 $(x_5)^2$	x_7 $(x_5)^3$	x_8 Expenses on FYM	x_9 Index of Manage- ment	x_{10} Phos- phate Use	\bar{R}^2	F-Ratio
Mexi-pak wheat (Cobb-Douglas)	172	0.402	- 0.208 (0.237)	+ 0.652* (0.471)	+0.609** (0.291)	+0.044** (0.014)	- -	- -	- -	- -	+0.142** (0.056)	- -	0.86	206.38
Local wheat (Linear)	24	367.40	-1694.156** (511.350)	+14.357** (2.476)	- -	- -	+ 6.785** (2.889)	- -	- -	-8.051** (3.033)	- -	- -	0.95	112.41
Basmati rice (Cobb-Douglas)	133	4.498	+ 0.396** (0.238)	+ 0.447* (0.303)	+0.113 (0.127)	- -	+ 0.004 (0.013)	- -	- -	- -	+0.162** (0.068)	- -	0.93	335.26
IRRI rice (Cobb-Douglas)	33	7.768	+ 1.022* (0.628)	- 0.340 (0.694)	+0.377** (0.219)	- -	- 0.007 (0.029)	- -	- -	- -	+0.256* (0.172)	- -	0.84	32.69
Jhonna rice (Square root in Nitrogen)	38	-102.823	+ 571.519 (1581.669)	+ 8.556 (7.864)	- -	- -	+30.760** (11.952)	- -	-333.195** (193.845)	-4.352 (8.927)	- -	- -	0.90	67.23
Maize (Quadratic in Nitrogen)	39	32.489	+ 743.045* (530.514)	+ 1.305 (2.001)	- -	- -	+11.674* (7.334)	-0.029* (0.022)	- -	- -	- -	- -	0.73	25.31
Cotton (Square root in Nitrogen)	95	1311.88	+1033.378** (566.134)	- 3.822** (1.669)	+5.900** (1.480)	- -	+10.041** (1.409)	- -	-110.835** (46.060)	+2.468* (1.581)	- -	+2.90** (1.55)	0.88	100.24
Sugarcane (Quadratic in Nitrogen)	83	-592.477	- 715.431 (2678.852)	+ 0.164 (3.509)	+6.524* (2.754)	- -	+13.428** (6.273)	-0.066** (0.018)	- -	+5.059** (2.691)	- -	- -	0.84	73.56

TABLE INDICATORS

+ The types of performance functions estimated are given under the crop name in parentheses. The primary data used are output-input figures per farm. The dependent variable has been the output of the respective crops per farm measured in physical units. Output of wheat and maize was measured in pounds of grain. Rice output was measured in pounds of unhusked paddy. Output of cotton refers to pounds of seed of cotton, while that of sugarcane to pounds of "gur" (raw sugar).

x_1 = Acres under respective crops

x_2 = Man hours spent on various farm operation for the respective crops

x_3 = Bullock hours spent on various farm operation for the respective crops

x_4 = Expenditure on nitrogenous and phosphate fertilizers applied on respective crops (rupees)

x_5 = Pounds of nitrogen nutrient applied for the respective crops

$x_6 = (x_5)^2$

$x_7 = (x_5)^5$

x_8 = Opportunity cost of the FYM (farmyard manure) used for respective crops

x_9 = Index of farm management represented by a dummy variable

x_{10} = Use of phosphate fertilizer represented by a dummy variable

N = Number of observations

() = Numbers in parenthese are the calculated standard errors of the respective coefficients

TABLE INDICATORS (Contd.)

- * = Coefficients significantly different from zero at 90 percent level of probability
- ** = Coefficients significantly different from zero at 95 percent level of probability
- = Indicates variable not included in the fitted regression

The non-starred coefficients are not statistically significant at the 90 percent level of probability

All of the F ratios are statistically significant

\bar{R}^2 = Adjusted coefficient of determination

This collinearity between land and the other input factors is the likely explanation of the unexpected negative coefficients. The behavioral and structural analysis based on per acre production functions is discussed later. Nevertheless, if we wanted to predict the performance in terms of total output of farm firms in the future under varying input combinations, the performance functions are the appropriate predictors.

The estimated coefficients of the per acre production functions for different factor inputs in the production of major crops are presented in Table 12. Average per acre yields of these crops were obtained by dividing the total output of these crops (per farm) by their respective acreages. Similarly, per acre inputs were calculated by dividing the total amount of factor inputs used for particular crops by the area under respective crops.

Average yield per acre is measured in pounds. Factor inputs used in the regression analysis were man hours, bullock hours, cash expenditure on fertilizers (nitrogenous and phosphate) or pounds of nitrogen nutrients used and the opportunity cost of farmyard manure applied to the particular crop. All these inputs are on per acre basis as discussed above.

Linear and loglinear equations (for the per acre production functions) were selected on the basis of economic and statistical criteria previously discussed. These forms were also preferred because of their computational feasibility. Some of the functions (those for IRRI rice, maize and sugarcane) were not found statistically significant (insignificant F ratio and very low \bar{R}^2). These poor fits may have resulted from: (1) lack of significant variation in per acre yields and factor inputs and small number of observations on these crops has further

TABLE 12. PRODUCTION COEFFICIENTS AND RELATED PRODUCTION FUNCTION STATISTICS[†] (ON PER ACRE BASIS) FOR SELECTED CROPS,
1972-73, PUNJAB, PAKISTAN

Crop	N	Intercept	Z ₁ Manual Labor	Z ₂ Bullock Labor	Z ₃ Expenses on Fertilizers	Z ₄ Pounds of Nitrogen	Z ₅ Expenses on FYM	Z ₆ Index of Management	Z ₇ Phosphate Use	R ²	F-Ratio
Mexi-pak wheat (Cobb-Douglas)	133	1.392	+ 0.439 (0.471)	+0.670** (0.295)	+0.048** (0.015)	-	-	+0.160** (0.057)	-	0.39	28.032
Local wheat (Linear)	24	-1032.304	+11.019** (3.288)	-	-	+11.264** (3.075)	-1.608 (2.540)	-	-	0.61	12.759
Basmati rice (Cobb-Douglas)	133	4.150	+ 0.495* (0.303)	+0.118 (0.128)	-	+ 0.012 (0.012)	-	+0.152** (0.068)	-	0.13	5.977
IRRI rice (Cobb-Douglas)	33	7.438	- 0.280 (0.678)	+0.394** (0.215)	-	- 0.011 (0.028)	-	+0.272* (0.167)	-	0.06	1.521
Jhonna rice (Linear)	38	- 893.596	+14.535** (6.956)	-	-	+ 9.747** (5.765)	-4.952 (7.311)	-	-	0.20	4.103
Maize (Linear)	39	749.331	+ 2.037 (2.731)	-	-	+ 4.358 (3.635)	+0.442 (2.175)	-	-	0.012	1.171
Cotton (Linear)	95	719.027	- 1.145 (1.301)	+2.272* (1.538)	-	+ 3.407** (1.187)	+2.812** (1.258)	-	+0.346** (0.164)	0.36	11.513
Sugarcane (Linear)	83	-1296.153	+ 3.912 (4.072)	-0.524 (2.676)	-	+ 1.119 (4.521)	+3.584 (2.923)	-	-	0.05	2.454

TABLE INDICATORS

+ The types of production functions estimated are given in parentheses under the crop names. The primary data used are the average yield per acre and average amount of various factor inputs used for the respective crops on per acre basis. Per acre yield (physical units) was obtained by dividing total output of the respective crops by the acreage under particular crop and is measured in pounds.

$Z_1 = (x_2/x_1)$ = Average number of man hours spent on per acre of respective crops

$Z_2 = (x_3/x_1)$ = Average number of bullock hours spent on per acre of respective crops

$Z_3 = (x_4/x_1)$ = Average amount (Rupees) spent on fertilizers for one acre of respective crop

$Z_4 = (x_5/x_1)$ = Average pounds of nitrogen (nutrient) applied per acre of crop

$Z_5 = (x_8/x_1)$ = Average expenses on farmyard manure (Rupees) for an acre of respective crop

Z_6 = Index of management, represented by a dummy variable

Z_7 = Use of phosphate on a particular crop represented by a dummy variable

N = Number of observations

() = Numbers in parenthesis are the calculated standard errors of the respective coefficients

*

= Coefficient significantly different from zero at 90 percent level of probability

**

= Coefficient significantly different from zero at 95 percent level of probability

-

= Indicates the variables not included in the fitted regression

TABLE INDICATORS (Contd.)

The non-starred coefficients are not statistically significant at the 90 percent level of probability. The F-ratios for mexi-pak and local wheats, Basmati rice and cotton are statistically significant at 99 percent level while that for Jhonna rice is statistically significant at 95 percent level. The F-ratios for maize, IRRI rice and sugarcane regressions were not found statistically significant.

\bar{R}^2 = Adjusted coefficient of determination

aggravated this situation; (2) some other factors not included in our production function analysis (qualitative variables such as climate, soil type etc.) are more important in explaining differences in per acre yields of these crops than those included in these models; (3) another possibility is that the technology used on these farms varied so widely that no relation between the observed behavior of the different farm firms existed; (4) the most likely explanation is that technology is constant between farms and interfarm variation in yield is small. That is the variation in total output is effectively explained by the crop area alone. This appears to be true in all cases, but especially for Basmati rice, IRRI rice, maize and sugarcane. Here it appears that the variation in other inputs explains little of the interfarm variation in per acre yields.

The marginal productivities of various factor inputs are derived only for those crops for which the estimated models were found adequate in the light of economic and statistical criteria. These crops are Mexi-Pak and local wheats, Basmati and IRRI rice and cotton.

These production functions are based on cross-sectional data, hence they define the structural relationship between the inputs utilized on a farm with high yield per acre and the inputs utilized on a farm with a low per acre yield.

Marginal Productivities

The main objective of estimating these production functions was to estimate the structural relationship between output of selected crops and various factor inputs. The marginal physical products for the factor inputs can be derived by taking the partial derivatives of the estimated linear functions with respect to these inputs. Since the production

functions are estimated from the cross-sectional data, these are the average production functions describing the production on an "average farm firm." Therefore, for log linear functions it is customary when referring to the average farm firm to compute the marginal productivities at the average mean levels of output and inputs. The following formula gives the marginal productivities of factor inputs for a Cobb-Douglas production function:

$$\text{MPP } x_i = b_i \frac{y}{x_i}$$

b_i = output elasticity of input i

y = output (average yield per acre in our case)

x_i = i th input

The geometric mean levels of output and inputs are employed in the above formula for marginal productivity computations. A geometric mean is a rough approximation for the median. Thus the computed values would tend to characterize the typical rather than the average farm. The Cobb-Douglas type of function is estimated only for Mexi-Pak wheat and Basmati rice (for IRRI rice the per acre production function was not found significant), therefore the marginal productivities for various inputs in the context of these crops are calculated by the above method. The elasticity coefficient for land area in these functions can be derived indirectly. Assuming constant returns to scale (i.e. the sum of actual output elasticities is equal to one) the elasticity coefficient for land area would be:

1 - the sum of calculated output elasticities from per acre functions

The estimated coefficients of the linear functions are the marginal productivities of the corresponding inputs, other factors held constant. In these cases the marginal product for land was calculated by first estimating the output elasticities of the various input factors and then subtracting the sum of these coefficients from one. This estimate of elasticity coefficient of land area was used to calculate the marginal productivity of land area (marginal product is equal to the product of the elasticity and the average yield).

The marginal productivities of different factor inputs in the production of selected crops are presented in Table 13.

For those per acre production functions found inadequate, it would be reasonable to assume the output elasticity of land equal to one which implies that all inputs changed proportionately with crop area changes, or technology is similar on all the farms.

The optimum allocation of resources requires that inputs be utilized up to a point where the marginal value product of input factors equals factor input prices (19, p. 68). If the ratio of marginal value product to the marginal cost is greater than one, it would indicate that less than the optimum quantity of the particular resource is being used. The opposite would be true if the ratio of marginal value product to the marginal cost is less than one.

Marginal Productivity of Labor (Manual and Bullock)

The marginal physical product for additional manual labor in Mexico wheat production is positive, but it is statistically insignificant. The lack of precision may be due to either collinearity between the manual and bullock labor or the absorption of surplus labor by the various farming operations. Though the use of manual and bullock labor is

TABLE 13. MARGINAL PRODUCTIVITIES FOR VARIOUS FACTOR INPUTS IN THE PRODUCTION OF SELECTED CROPS IN PUNJAB (1972-73) (DERIVED FROM PER ACRE PRODUCTION FUNCTION)

Crop	<u>Manual Labor</u>		<u>Bullock Labor</u>		<u>Chemical Fertilizers</u>		<u>FYM Expenses</u>	
	MPP	MVP (Rs)	MPP	MVP (Rs)	MPP ¹	MVP (Rs)	MPP	MVP (Rs)
Mexi-pak wheat	3.82*		6.45	1.68	3.91	1.02	-	
Local wheat	11.02	2.87	-		11.26	2.93	-1.61*	
Basmati rice	4.06	1.29	1.75*		2.53*		-	
Jhonna rice	14.54	3.05	-		9.75	2.05	-4.95*	
Cotton	- 1.15*		2.27	1.86	3.41	2.80	2.81	2.30

MPP = Marginal physical product. The marginal physical products of wheat, rice and cotton are in pounds of grain, unhusked paddy and seed-cotton respectively. The MPPs for Mexi-pak and Basmati rice are calculated at the geometric mean levels of output and inputs.

* = MPPs are not statistically significant

- = Indicates those factor inputs not included in the estimated equation

1 = The marginal physical product for fertilizer in the context of Mexi-pak wheat refers to cash expenses spent on nitrogenous as well as phosphate fertilizers. All other marginal physical products are for an additional pound of nitrogen nutrient

Prices per pound of wheat grain, unhusked Basmati paddy, Jhonna paddy and seed cotton were Rs 0.26, Rs 0.32, Rs 0.21, and Rs 0.82 respectively.

Price per pound of nitrogen was Rs 0.73

complementary, there are still certain farm operations such as harvesting and winnowing which are quite labor intensive and performed exclusively by manual labor. The per acre labor requirements for these operations are more or less fixed and this may be another reason for the lack of associated variation.

The marginal physical product for an additional hour of bullock labor in Mexi-Pak wheat production is quite high, and the marginal value product was estimated to be approximately Rs. 1.68. In view of relatively low opportunity cost of this factor input, it would be reasonable to conclude that the additional use of bullock labor (mainly for pre-sowing cultivation) would be economically profitable. In the light of this conclusion it should also be remembered that there is collinearity between manual and bullock labor. Since the estimated coefficient of manual labor is not statistically significant from zero, the effect of this variable may be included in the coefficient for bullock labor. However, the buying and selling of hours of bullock labor is an uncommon practice. The additional use of bullock power would require more bullocks per farm involving large amounts of capital investment which the farmers may not be able to afford.

The marginal physical product for manual labor in the production of local wheat and Jhonna rice is estimated at about 11 pounds of wheat grain and 14.5 pounds of unhusked paddy respectively for an additional hour of manual labor. In these cases bullock labor was dropped because of high correlation between manual and bullock labor, therefore this must be taken into consideration, when interpreting these marginal productivities. Nevertheless, in view of low opportunity cost of manual

labor (which does not exceed Rs. 0.75 per hour even by urban wage standards), the additional use of manual labor in the production of these crops other things remaining the same would seem warranted, remembering that this may imply increased utilization of bullock labor also.

Similarly, the marginal physical product for an additional hour of manual labor is estimated at approximately 4 pounds of Basmati paddy. However, the marginal physical product for the bullock labor was not statistically significant. This may indicate relative overuse of the bullock labor or that the variations in yield per acre of Basmati paddy is not associated with the changes in the amount of bullock labor (this could be due to the indivisible nature of bullocks).

The marginal physical product for manual labor in cotton production is not significantly different from zero. This low productivity may be inherent in the nature of various farming operations of cotton, because some of the operations such as cotton picking are very labor intensive. Hoeing of cotton, especially manual hoeing of the crop sown by broad cast method, further added to the labor requirements of cotton farming. However, the marginal physical product for the additional use of bullock labor is estimated at about 2.27 pounds of seed cotton. This provides for a marginal value product of about Rs. 1.86. Because of the substitutability nature of bullock and manual labor for certain farm operations, and the low productivity of manual labor but quite high productivity of the bullock labor, it seems that cotton production is more efficient on those farms using more bullock labor and less manual labor. Therefore, it is hypothesized that line sowing of cotton which will facilitate hoeing by the bullock driven implements and thus save

manual labor would help in increasing cotton yield. This will further economize the use of manual labor in cotton picking and stick harvesting operations. However the marginal cost of labor may be very small on some farms, which could also explain the low marginal productivity of land.

Generally speaking, the estimated coefficients for the manual and bullock labor as given in Tables 11 and 12, are quite high. The share of these two factors as indicated by these estimated coefficients are consistent with a priori expectations. For those familiar with the manual and bullock oriented agriculture practiced in the Punjab it is not surprising to find that the contribution of labor (manual and bullock), as manifested by the output coefficients, is quite high in the production of major crops.

These relatively high output coefficients for manual and bullock labor might also imply comparatively less use of these resources and more use of other input factors. However, in view of labor intensive agriculture practiced in the region this may not be true except for the circumstances discussed later in the context of low productivity for Mexi-Pak wheat area.

Chemical Fertilizers

As is evident from Table 13, the marginal physical products of chemical fertilizers for the various crops are positive and statistically significant, except for Basmati rice. The estimated coefficients of nitrogen fertilizer of the performance as well as production function for Basmati rice (Tables 11 and 12), were not only very low but also statistically insignificant. These very low coefficients for nitrogenous fertilizer point out that in Basmati production this input is not very

important. This could also indicate comparative overuse of nitrogenous fertilizers in relation to complementary inputs. Pamphlets and leaflets issued by the ESSO Fertilizer Company of Pakistan (6) show that the farmers following their program (which is basically to apply a proper combination of nitrogenous and phosphate fertilizers) have high rates of return to investment in fertilizers for all major crops including Basmati rice. In the author's discussion with the farmers during the field survey, it was found that farmers were quite concerned with the lodging of this crop. The use of nitrogenous fertilizers alone encourages vegetative growth which makes the crop more vulnerable to lodging. When lodging occurs, the crop yield is adversely affected. From the comparatively high elasticity of manual labor and practically zero elasticity for nitrogenous fertilizers in Basmati production, it may also be argued that the farmers are substituting nitrogenous fertilizers for certain farm operations involving manual labor such as weeding and hoeing.

For Mexi-Pak wheat the input of fertilizers is measured in terms of cash expenditure on both nitrogenous and phosphate fertilizers. The marginal physical product (Table 13) for an additional rupee invested in fertilizers is estimated at about 3.9 pounds of wheat grain. This gives a marginal value product of a little over one rupee. However, in the analysis wheat "bhusa" (broken wheat straw used as fodder for the farm animals), an important by product of wheat cultivation, has not been accounted for because of measurement problems. Therefore, the estimates for the output (Mexi-Pak and local wheat) may have been underestimated to that extent. Nevertheless, in view of uncertainty characterizing the domain of agriculture, the farmers' expenditure on fertilizers, appears to be approaching optimum for the Mexi-Pak wheat.

The marginal physical product for an additional pound of nitrogen in local wheat production is estimated at about 11.26 pounds of wheat grain. This gives a marginal value product of nearly three rupees for a pound of nitrogen costing only Rs. 0.73. It appears that there is considerable potential for increasing production of local wheat through the additional use of fertilizers. This also implies that the present use of nitrogenous fertilizers on local wheat is below optimal level.

With the introduction of Mexican wheat varieties in the Punjab, the area under local wheat has rapidly decreased, particularly in the canal irrigated districts. Some of the farmers have completely switched over to the high yielding dwarf Mexican wheat varieties. Of the farms surveyed, local wheat was cultivated on only 24 farms. Most of these were "small" farms (less than 12.5 acres). A few of the large farms still continue growing a few acres of local wheat for household requirements. Some of the local wheat growers were "conservative" farmers who continue growing local wheat despite the fact that Mexican wheat has outyielded local wheat. In view of these facts, special efforts and programs such as short term credit facilities for the purchase of fertilizers, etc. might be needed to encourage the use of fertilizers by farmers growing local wheat.

The marginal physical product for an additional pound of nitrogen in Jhonna rice is estimated at about 9.75 pounds of unhusked paddy. This gives a marginal value product of a little over two rupees, at an additional cost of only Rs. 0.73. This would imply relative under use of nitrogenous fertilizers in the production of this crop. The uncertainty characterizing agriculture makes exact calculations difficult. However, Jhonna rice is generally cultivated on marginal soils for reclamation

purposes. This could be the possible reason for the present below optimal level use of the nitrogenous fertilizers.

The marginal physical product for nitrogenous fertilizers in cotton production is estimated at about 3.41 pounds of seed cotton (Table 13), for an additional pound of nitrogen nutrient. This gives a marginal value product of approximately Rs. 2.8 at an additional cost of only Rs. 0.73. This indicates that there is considerable potential for increasing cotton yield through the increased use of nitrogenous fertilizers.

From the marginal value and marginal cost comparisons, fertilizer use appears to be less than optimum i.e. marginal value product is greater than the marginal cost. Many factors could be responsible for the below optimal level of fertilizer use. Important factors in this regard are the non-availability of fertilizers at the appropriate time, high prices of fertilizers and the lack of financial resources with the farmers (Chapter V). The analysis of time-series data has shown (Chapter VI) that the use of fertilizers (nitrogenous) in the province has been inversely related to the price level of these fertilizers. Uncertainty about the prices of seed cotton (the prices of seed cotton have fluctuated widely from year to year), could be another factor in this regard. Because the price of output plays an important role in determining the demand for factor inputs.

The use of phosphate fertilizers on cotton crop was represented by a dummy variable. Farm output as well as yield per acre (Tables 11 and 12) of seed cotton was higher on those farms using phosphate fertilizers, other things remaining the same.

The per acre production functions for IRRI rice, maize and sugarcane crops were found to be statistically insignificant. It appears that, crop area is the most important factor in explaining the interfarm variation of farm production of these crops and all other input factors vary proportionately with land area. Nevertheless, from the estimated coefficients of the performance functions (Table 11) it appears that output of maize and sugarcane is positively associated with the use of nitrogenous fertilizers. In both cases the coefficient of quadratic term was negative indicating diminishing returns for fertilizers, but the contribution of fertilizer on the average was still positive. The estimated coefficient for nitrogen in loglinear equation for IRRI rice, was negative but statistically insignificant. This may indicate that farm output of IRRI rice is not related to the use of nitrogenous fertilizers. But, given the high fertilizer response of IRRI rice varieties, it would be difficult to accept this argument. In view of the small number of observations on this crop (33 observations), on which the analysis was based, it is difficult to make any definite statements in this regard. This situation may be due to either the lack of some essential complementary inputs or the application of fertilizing materials at a stage in crop growth when the use of fertilizers is ineffective.

Farmyard Manure

The marginal physical product of farmyard manure expenses for Jhonna rice and local wheat (Table 13) has negative sign but the coefficients are not statistically significant. This may imply that yield per acre of these crops is not affected by farmyard manure. Probably, when both farmyard manure and nitrogenous fertilizers are applied these crops attain greater height and are more vulnerable to lodging which tends to reduce

yields. Since farmyard manure is a by product of the farm animals and has to be disposed of periodically, it may be applied in areas close to the farmstead resulting in over application on some of the crops and comparatively less application on some crops.

The marginal physical product for farmyard manure expenses in cotton production is estimated at approximately 3.4 pounds of seed cotton for an additional rupee's worth of farm manure. This provides for a marginal value product of approximately 2.8 rupees. It appears that additional use of farmyard manure for cotton crop will be highly profitable.

In the estimation of performance functions, the output coefficient for farmyard manure expenses in sugarcane production was not only positive but also statistically significant. This indicates that higher output of sugarcane is associated with a greater use of farmyard manure.

Crop Area

The marginal physical product for land area under major crops has been calculated indirectly from the per acre production functions by assuming constant returns to scale. The procedure used was to calculate output elasticity coefficients for different factor inputs, then subtract the sum of these from one. The elasticity coefficient of land area thus obtained is multiplied by the average yield per acre to obtain the marginal physical product of an additional acre of land for the respective crops. For the insignificant per acre production functions it seems reasonable to conclude that the elasticity coefficient of land is equal to unity. Since this factor is the most important in explaining variation in interfarm output. In these cases the average yield per acre

would be equal to the marginal physical product for an additional acre of the respective crops.

TABLE 14. MARGINAL PHYSICAL PRODUCT FOR CROP AREA IN PRODUCTION OF SELECTED CROPS

Crop	Marginal Physical Product For an Additional Acre of Land
Mexi-Pak wheat	- 286.0 pounds of wheat grain
Local wheat	-1032.28 pounds of wheat grain
Basmati rice	717.79 pounds of unhusked paddy
IRRI rice*	2996.46 pounds of unhusked paddy
Jhonna rice	- 893.70 pounds of unhusked paddy
Maize*	749.16 pounds of maize grain
Cotton	751.34 pounds of seed cotton
Sugarcane*	1295.95 pounds of gur

* Those crops for which per acre production function was found insignificant and elasticity of land assumed equal to unity.

As indicated in Table 11, the estimated coefficients for crop acreage under Basmati rice, IRRI rice, maize and cotton crops are positive and statistically significant. This indicates that higher farm output of these crops is associated with larger acreage under these crops. Since a larger crop area under these crops is likely to be associated with large farms, it would imply that higher output of these crops is associated with the large farms. The marginal physical products of crop area for all these crops are positive and presented in Table 14.

The estimated coefficient for crop area in sugarcane production (Table 11) is negative but statistically insignificant. It appears that the production of sugarcane on large farms is inefficient as compared to the small farms. However, the marginal physical product (calculated by the indirect method) for crop area was found positive and is given in Table 14.

The estimated coefficients for crop area for Mexi-Pak wheat and local wheat as shown in Table 11, are negative. It appears that production of these crops is more efficient on small farms as compared to the large farms.

In case of Mexi-Pak wheat (Cobb-Douglas function) the comparatively high coefficients for manual and bullock labor, relatively low elasticity coefficient for the cash expenditure and practically zero elasticity coefficient for wheat acreage (Table 11) may also indicate that variable resources of conventional inputs of farm labor and farm capital are being used too thinly over an extensive crop area.

During the field survey, it was observed that farmers continue sowing the wheat crop after the normal sowing season is over. In wheat-cotton areas, farmers continue wheat sowing after cotton harvesting sometimes as late as January, when the normal wheat sowing should not extend beyond November. After cotton harvesting there is not much time left for adequate land preparation. Farmers after broadcasting wheat seed in the fields plow these fields a couple of times. In these late sowing circumstances, farmers often apply heavy amounts of nitrogenous fertilizers. This encourages rapid vegetative growth of the crop, however, it cannot make up for the late sowing of the crop.

Similarly, in rice growing areas, there are not many crops which could be cultivated after rice harvesting. There is not much time for adequate land preparation for wheat sowing either. This is especially true after harvesting Basmati rice since, it takes a little longer to mature than other rice varieties.

It can also be argued that the government policy to increase domestic wheat production in order to attain self sufficiency in food grain production; (manifested in the "grow more wheat" campaign, which encourages farmers to cultivate wheat on the maximum possible acreage) has extended wheat cultivation to lands otherwise left for natural recuperation. This results in a low output elasticity coefficient for wheat acreage. Mexi-Pak wheat sown at the proper time with adequate use of nitrogenous and phosphate fertilizers and judicious use of irrigation water has quite high yields. It may also have encouraged farmers to extend wheat cultivation to marginal lands and to risk late sowing of the crop. It is further argued that (1) by extending wheat cultivation to marginal lands, (2) by late sowing of the crop without adequate land preparation, and (3) by using comparatively higher amounts of nitrogenous fertilizers farmers may be substituting fertilizer for manual and bullock labor. This results in higher output coefficients for manual and bullock labor and relatively low output coefficient for fertilizer expenses and land area. The negative marginal productivity of crop area in Mexi-Pak wheat production may be due to the violation of our assumption of constant returns to scale. For local wheat and Jhonna rice, the output elasticities of crop area were not estimated under the assumption of constant elasticities. Thus the assumption of constant elasticities to scale at the mean values of output may be difficult to justify.

Farm Management

The coefficient of the dummy variable representing farm management was positive and statistically significant (Tables 11 and 12) for Mexi-Pak wheat, Basmati and IRRI rice. This indicates that higher outputs as well as higher per acre yield of these crops is associated with "better" management.

Summary

Different types of performance functions based on total output and total factor inputs used in the production of selected major crops were estimated. The ones giving the "best fit" were selected to describe the relationship between the farm output and various factors used in the production of respective crops. Production functions based on average yield per acre were also estimated to estimate the resource productivity as prevailing on the average farm firm. Marginal productivities of various factors were derived from the per acre production functions.

The per acre production functions for IRRI rice, maize and sugarcane were not found statistically significant. From this it appears that interfarm variation in yield per acre is small or technology is similar on all the farms. From the wide difference in the values of \bar{R}^2 , for the performance and per acre production functions, and statistically insignificant F ratios for some per acre production functions, it seems reasonable to conclude that variation in total output of some crops is effectively explained by the crop area alone. This is especially true for Basmati rice, IRRI rice, maize and sugarcane. It appears that variation in other inputs explains little of the interfarm variation in per acre yields.

Generally speaking the estimated coefficients for the manual and bullock labor as previously discussed were positive and consistent with a priori expectations. Farm output of Mexi-Pak wheat, Basmati rice and IRRI rice was higher on farms having better managers. Higher per acre yields of Mexi-Pak wheat and Basmati rice were also associated with better management. Nevertheless, from the performance function it appears that Mexi-Pak, local wheat and sugarcane are produced more efficiently on the small farms as compared to large farms.

The marginal value products of fertilizers in the production of selected crops are presented in Table 15. The rate of return realized from investment in fertilizing various crops is also given in this Table.

TABLE 15. MARGINAL VALUE PRODUCTS AND RATE OF RETURN FROM INVESTMENT IN FERTILIZERS FOR SELECTED CROPS IN PUNJAB (DERIVED FROM PER ACRE PRODUCTION FUNCTIONS) 1972-73

Crop	Marginal Value Product	Rate of Return**
	(Rupees)	
Mexi-Pak wheat	1.02*	1.02
Local wheat	2.93	4.01
Basmati rice	-	-
Jhonna rice	2.05	2.81
Cotton	2.80	3.84

* Marginal value product for one rupee spent on fertilizers (nitrogenous and phosphate). All other marginal value products are for a pound of nitrogen.

** Rate of Return = Marginal value product/price per pound of nitrogen.

The use of chemical fertilizers on Mexi-Pak and local wheat, Jhonna rice and cotton is highly profitable as shown by high rates of return presented in Table 15. There seems considerable potential for increasing farm production of these crops through increased use of fertilizers.

From the estimated coefficients of the performance functions (Table 11), it is clear that the farm output is positively related with the use of fertilizers for all the major crops. The coefficient of fertilizer for IRRI rice was not positive, however it was not statistically significant. In view of small number of observations it is difficult to make any definite statements in this regard. Since per acre production functions for IRRI rice, maize and sugarcane, as previously discussed, were not found appropriate. It appears that in these crops, crop area is the most important factor in explaining variation in farm output on different farms, and all other inputs vary proportionately with land area. In case of Basmati rice the yield per acre of unhusked paddy is positively associated with the per acre use of nitrogenous fertilizers, however, the evidence is not very strong.

Miscellaneous pamphlets and leaflets issued by the ESSO Fertilizer Company of Pakistan, indicate that the farmers following their program of instructions (which is basically to apply a proper combination of nitrogenous and phosphate fertilizers), have high rates of return from investment in fertilizers for major crops including rice crops. However this analysis failed to establish a significant positive relationship between per acre yield of Basmati paddy and use of nitrogenous fertilizers. This may have been due to the overuse of nitrogenous fertilizers and inadequate use of other fertilizer elements or the lack of variation in

per acre use of fertilizers among various farms.

Eckert in his study (4) on dwarf wheat varieties in Punjab, (based on field survey in single district), had concluded that the farmers were using optimum quantities of fertilizers on local wheat, but below optimum quantities for the Mexican wheats. The results of present analysis indicates the opposite (i.e. almost optimum expenditure on fertilizers for the Mexi-Pak wheat and below optimum use of nitrogenous fertilizers on the local wheat). When Eckert undertook his study in 1968-69, farmers were still experimenting with the newly introduced Mexican wheats. However, by 1972-73, the Mexican wheat varieties had become extremely popular with farmers in the canal irrigated districts of the province and only a minority of the farmers were cultivating local wheat varieties. It is argued that over the years farmers' experience with Mexican wheats and fertilizers have increased and they have become aware of the profitability of fertilizer use on these wheats and therefore, using optimum quantities of fertilizers.

CHAPTER V

GENERAL FEATURES OF FERTILIZER USE IN THE FARM SURVEY

Introduction

This chapter describes the general characteristics about the fertilizer use, as found in this farm survey. The average use of fertilizer on major crops is compared among "small," "medium" and "large" farms. This is followed by a discussion of the sources used by farmers in supplying and financing fertilizer use. The reasons for the inadequate use of fertilizers are also discussed. The chapter also reviews the question of the availability or non-availability of fertilizers. Finally, a brief description and discussion about the farmers' use of fertilizers and familiarity with fertilizers is given.

Average Use of Fertilizer on Major Crops

It has been emphasized in the earlier chapters that fertilizer consumption has increased tremendously in recent years. The majority of the farmers interviewed had applied fertilizer for one crop or another. Out of the 192 farmers interviewed, approximately 90 percent had used fertilizer for at least one crop. Another important feature of fertilizer use is the imbalance in the use of fertilizer elements. Nitrogen dominates the scene. The use of phosphate fertilizers is limited to a minority of the farming population. None of the farmers interviewed had used any potassium fertilizers. The following Table provides a breakdown of nitrogen and phosphate users for various crops.

It is evident from Table 16 that an overwhelming majority of the farmers rely just on nitrogen for their fertilizer requirements and only a small percentage of the farmers apply both nitrogen and phosphate fertilizers. The use of phosphate fertilizer was most common for Mexican

TABLE 16. NUMBER OF FARMERS USING NITROGEN AND PHOSPHATE
FERTILIZER FOR VARIOUS CROPS

	Total No. of Growers	Nitrogen Users		Phosphate Users	
		Number	Percentage	Number	Percentage
Mexican wheat	172	153	89	68	40
Local wheat	24	10	42	1	4
IRRI rice	33	22	67	6	18
Basmati rice	133	95	71	21	16
Jhonna	38	23	61	6	16
Maize	39	36	92	3	8
Cotton	95	79	83	25	26
Sugarcane	83	77	93	7	8

wheat. Forty percent of the growers of Mexican varieties of wheat applied phosphate fertilizers in addition to using nitrogen. In the production function analysis of various crops it has been revealed that a stage has already been reached especially for certain crops such as Basmati and IRRI rice, where the use of nitrogen alone no longer appears to be economical. It is expected that objectives of agricultural development would be better served by the more balanced use of both nitrogen and phosphate fertilizers. This has become especially important in view of the rapidly rising prices of chemical fertilizers.

Tables 17 and 18 provide information on the per acre use of nitrogen and phosphate fertilizers on small, medium and large farms for selected food grain and cash crops, respectively.

TABLE 17. FERTILIZER USE PER ACRE ON SELECTED FOOD GRAIN CROPS

		Small Farms (up to 12.5 acres)	Medium Farms (12.6 to 25.0 acres)	Large Farms (25.1 to 50.0 acres)
		(Pounds of Nitrogen)		
A	Mexican wheat	54	48	50
	Basmati rice	67	46	60
		(Pounds of Phosphorus)		
B	Mexican wheat	48	39	38
	Basmati rice	63	45	39

TABLE 18. FERTILIZER USE PER ACRE ON SELECTED CASH CROPS

Crop	Small Farms (up to 12.5 acres)	Farms 12.6 to 50 acres
(Pounds of Nitrogen)		
Cotton	56	51
Sugarcane	73	65
(Pounds of Phosphorus)		
Cotton	46	39

It is interesting to note that the per acre use of nitrogenous as well as phosphate fertilizer on these crops is considerably higher on the "small" category of farms than that on "medium" and "large" categories of farms. It may be that because of meagre land resources, these farmers

are trying to supplement their land resources with modern inputs of chemical fertilizers. However, when comparing the percentage of fertilizer users for various crops no clear-cut picture emerges.

TABLE 19. PERCENTAGE OF FERTILIZER USERS UNDER VARIOUS FARM CATEGORIES

Crop	Small Farms (up to 12.5 acres)	Medium Farms (12.6 to 25 acres)	Large Farms (25.1 to 50.0 acres)
	(Percentage of Nitrogenous Fertilizer Users)		
Wheat (Mexican)	87	94	91
Basmati rice	76	68	51
Cotton	79	88	
Sugarcane	91	94	

Sources of Financing Fertilizer Use

Chemical fertilizer is one of the major inputs which the farmers purchase from the nonfarm sector. Knowledge about various sources of credit and their importance in financing fertilizer use assumes special importance in this era of fertilizer scarcities and rising prices. Such information could be helpful for formulating credit policies and other special programs which may be needed in this direction. Farmers were asked about their sources of financing fertilizer and the information is tabulated below.

As is shown in Table 20, personal savings and noninstitutional sources of credit (friends, relatives, village shopkeepers and commission agents) are the most important sources of finance for the purchase of

TABLE 20. SOURCES OF FERTILIZERS FINANCING FOR VARIOUS CATEGORIES OF FARMS

Source of Finance	Small Farms	Medium Farms	Large Farms	Total	Percentage of Users
1. Non Users	9	6	4	19	
2. Personal savings	18	23	10	51	30
Personal savings and noninstitutional credit sources	38	41	17	96	56
3. Personal savings and institutional credit sources	6	14	2	22	13
4. Personal savings, institutional and noninstitutional sources of credit	2	0	2	4	2
Total	73	84	35	192	

fertilizer by the farmers of all the categories irrespective of the farm size. The institutional sources of credit did not count heavily in financing the investment in fertilizers. There are many reasons for this. Most of the institutional sources of credit are located in the urban centers. They concentrate on industrial ventures and have neglected the agricultural sector until recently. Only the Agricultural Development Bank was providing credit for agricultural purposes. Their loans are mostly for medium and long term use. Moreover, farmers have to pay interest on their institutional loans and farmers are very reluctant to borrow on interest mainly for religious reasons. In borrowing from the Agricultural Development Bank and other institutions, farmers have to go through various government departments. This is a time consuming process. On the other hand, they could borrow easily from their friends, relatives and commission agents for short term use.

Sources of Fertilizer Supply

Prior to the "nationalization" of fertilizer distribution in Punjab province in 1973, there were a number of fertilizer suppliers at the retail level. Prominent among these were the commission agents and local dealers. In addition to these, the Agricultural Development Corporation also had its agents. There were some rural co-op societies in the business as well.

Commission agents are located in the market towns and provide product marketing services to the farming community. Private companies dealing in fertilizers had also appointed some of these commission agents as their agents for marketing of fertilizers.

Local dealers are defined as those persons who were located in the

villages or nearby important centers and were dealing in fertilizers either exclusively or in addition to other commodities. However, most of them were village shopkeepers.

TABLE 21. VARIOUS SOURCES OF FERTILIZER SUPPLY

Supply Source	No. of Farmers Served	Percentage of Fertilizer Users
Commission agents	66	38.2
Local dealers	55	31.8
Commission agents and local dealers	26	15.00
Landlord	4	2.3
Commission agents and local dealers and landlords	6	2.5
Co-op, Agricultural Development Corporation agents	16	9.2
Total	173	100.0

It is evident from the above Table that the overwhelming majority of farmers purchased their fertilizer requirements from commission agents and local dealers. These two sources accounted for the supplies to 85 percent of the fertilizer users in our sample. This was due mainly to the fact that local dealers were located in the community and farmers could buy fertilizer from them even at odd times and sometimes on short term credit as well. The main reason for buying from commission agents according to the respondents was that farmers dispose of their farm

products through these intermediaries and are well acquainted with them. Moreover, the provision of credit without going through various bureaucratic procedures was an additional reason for their popularity.

Reasons for the Inadequate Use of Fertilizer

Farmers were asked whether their fertilizer use was adequate or inadequate. If judged inadequate they were asked the reasons for inadequate use. A total of 132 farmers responded to this question and their answers are tabulated in Table 22.

Out of the 132 responding farmers, 54 replied that their use of fertilizer was adequate under the prevailing circumstances at that time. They were not willing to change their fertilizer use, assuming ceteris paribus conditions. Among the other farmers, the major reasons given for the perceived inadequate use were non-availability of fertilizer at the appropriate time, lack of funds and the high prices of fertilizer. There does not seem to be any difference in the distribution of reasons by size of holdings.

Availability or Non-availability of Fertilizer

Availability of purchased farm inputs at convenient locations and the appropriate times can make the difference in economical and the uneconomical use of the inputs. Farmers were asked whether the fertilizers were available at the time they needed them for their crops. Forty-eight percent of the farmers using fertilizers reported that supplies were not available when they needed them most. Another 44.5 percent of the farmers did not experience any problem or difficulty in acquiring their fertilizer requirements. Again there was no difference that may have been ascribed to size of holdings.

TABLE 22. REASONS FOR INADEQUATE FERTILIZER USE ACCORDING
TO FARM SIZE

Reason for Inadequate Use (Farmers Response)	Small Farms	Medium Farms	Large Farms	Total
1. High price and lack of funds	1	1	2	4
2. Lack of water	5	5	2	12
3. Non-availability of fertilizer	2	1	1	4
4. Lack of funds and water	7	5	2	14
5. High prices, lack of funds and non- availability	10	19	5	34
6. Lack of water and supply of fertilizer	3	6	1	10
Adequate use	20	22	12	54
Total	48	59	25	132

TABLE 23. AVAILABILITY OR NON-AVAILABILITY OF FERTILIZERS

	Small Farms	Medium Farms	Large Farms	Total	Proportion of Fertilizer Users (Percent)
1. Fertilizer not available at the appropriate time	34	35	14	83	48.0
2. Available but with difficulty	2	7	4	13	7.5
3. Available when needed	28	36	13	77	44.5
Total	64	78	31	173	100.0

Discussion About the Use of Fertilizers

Farmers were asked regarding the individuals or groups with which they discussed fertilizer use and related questions. Neither the fertilizer suppliers nor extension agents were important sources of discussion. The majority of the farmers referred to other farmers for consultations regarding their fertilizer use and related problems. An overwhelming majority of the farmers interviewed also held discussions among their family members on the use of fertilizer for their crops.

In response to another question, farmers indicated that they considered the radio extension broadcasts sponsored by the Department of Agriculture as the most important source of information regarding fertilizers, other inputs and improved methods of cultivation. This program was very popular among the farmers interviewed. However, the

local extension agents of the Department of Agriculture, did not rank very high among the farmers as a source of information.

Farmers Familiarity with Fertilizers

Though fertilizer consumption has increased substantially in Pakistan over the years, the same does not appear to be true about the farmers familiarity with various types of fertilizers. The majority of the farmers interviewed still did not know much about the effect of fertilizers. A little over 19 percent of the farmers said that they were using fertilizer (nitrogen) simply because it changed the color of crop into dark green. Twenty percent indicated they thought it was necessary to use fertilizer although they could not say specifically how it would affect their crops. A great many of the farmers seemed to be substituting fertilizer for the better preparation of seed beds and inter-culturing of the crops. In short, they seemed to be substituting fertilizers for manual and bullock labor.

As far as the popularity of various brands of fertilizers is concerned, urea was the choice indicated by an overwhelming majority of the farmers. Approximately 88 percent of the farmers using fertilizers ranked urea as their first choice among the various types of the fertilizers available. It was observed that use of Diammonium Phosphate, a compound fertilizer, was becoming quite popular. This augurs well for the balanced use of chemical fertilizers in the province.

Summary

Summarizing the results of this chapter; (1) per acre use of fertilizer on major crops (nitrogen as well as phosphate) is higher on small farms (farms up to 12.5 acres) as compared to medium (farms 12.6 to 25.0 acres) and large (farms over 25.0 acres) farms; (2) the majority of

the farmers applying fertilizer rely on nitrogenous fertilizers for the fertilizer requirements of their crops and only a limited number of farmers are using phosphate fertilizer; (3) the use of phosphate is most common for Mexican wheat; and (4) urea by far is the most popular nitrogenous fertilizer among the farmers.

Personal savings and short term borrowing from friends, relatives and commission agents are the major sources of financing fertilizer use mentioned by the farmers. Commission agents and the local dealers were the major suppliers of fertilizer requirements of the farmers. The major reasons for the inadequate use of fertilizer given by the farmers were high prices, lack of funds and the non-availability of fertilizers at the appropriate time. Despite considerable experience of fertilizer use, the average farmer's knowledge of fertilizer and its effects was poor.

CHAPTER VI

FACTORS AFFECTING FERTILIZER USE-ANALYSIS OF TIME SERIES DATA

Introduction

There has been a significant increase in fertilizer consumption in Pakistan over the years, 1959-60 to 1972-73. During this period fertilizer consumption in Pakistan increased from 19.4 thousand nutrient tons to 436.5 thousand nutrient tons (a growth of approximately 2150 percent). Almost 90 percent of the total fertilizer used in Pakistan has been nitrogenous. Approximately 70 percent of the total fertilizer consumption has been used in the Punjab, the most prosperous agricultural region of the country. Fertilizer use has been growing rapidly and considerable public and private resources have been invested in the production, imports, marketing and distribution of chemical fertilizers. The sale of fertilizer has been subsidized at considerable public expense. It is therefore important not only to identify factors influencing the fertilizer use but also to quantify their individual and collective impact on fertilizer consumption. This information will be useful in planning domestic production and imports of fertilizer in this era of fertilizer scarcities and food grain shortages.

Methodology

The analysis is limited to the nitrogenous fertilizers used in the Punjab from 1959-60 to 1972-73. This limitation is due to various constraints imposed by the non-availability of data.

It is difficult to specify an exact model for the farmers decision making for various inputs. This is due to price uncertainty, weather conditions characterizing the domain of agriculture, and a lack of factual

information regarding various economic variables needed for decision making. Nevertheless, it could be argued reasonably that fertilizer use is a function of its price, the area under the major crop, and the income of farmers. A time variable is also relevant in the case of new inputs like fertilizer to represent unmeasurables as the level of technology and the level of information in the agricultural sector.

The ordinary least squares method was used to estimate the coefficients of the following model.

$$\ln y_t = \ln b_0 + b_1 \ln x_{1t} + b_2 \ln x_{2t-1} + b_3 \ln x_{3t} + b_4 \ln x_{4t} + b_5 x_{5t} + e$$

y_t = consumption of nitrogenous fertilizer in Punjab in year t
(nutrient tons of nitrogen)

x_{1t} = relative price per ton of nitrogen
= price per ton of nitrogen/price index of major crops $\times 100$

x_{2t-1} = price index of major crops in $t-1$ year

x_{3t} = number of tubewells in the province

x_{4t} = total acreage under major crops (thousand acres)

x_{5t} = time variable

b_0 = constant

e_t = error term

Different modifications of this model were tried by replacing "total acreage under major crops" by "irrigated acreage," "cultivated acreage" and "total cropped acreage" successively. However, the model using acreage under major crops turned out to have greater explanatory power in the light of economic and statistical criteria.

Explanations of the Variables Included in the Model and Availability of Data Regarding these Variables

While testing various models and hypotheses, economists are often confronted with problems posed by lack of data. Moreover, economists frequently exercise little control over their variables. Besides these problems, economists working in developing countries often do not get reliable data. In this type of situation, the job of the economist and researcher is to make the best use of what is available and sound a warning note about the validity and interpretation of the results.

The variables used in the model specified previously, are discussed below.

Fertilizer Consumption of Nitrogen Tons in Punjab (y_t)

Data for Punjab province was available only for the period of 1962-63 to 1972-73 (from the Food and Agricultural Section of the Planning Commission of Pakistan). From the available data on fertilizer consumption in Pakistan, Punjab's share averaged about 70.73 percent of the total fertilizer used in the country. This figure was used to estimate the share of Punjab's consumption of fertilizer from the total for the years of 1959-60 to 1961-62.

Prices of Fertilizer (x_{1t})

Data on fertilizer prices were available on a gross weight basis for various kinds of nitrogenous fertilizers (i.e. ammonium sulphate, ammonium nitrate and urea, etc.) and not as price per ton of nitrogen. Besides, prices of various kinds of fertilizers varied within a given year. In order to overcome this problem the weighted average of the prices prevailing during the year for each category of fertilizer was calculated. This price was used to estimate the price per ton of nitrogen

separately for each kind of nitrogen fertilizer. In order to calculate a common price for a nutrient ton of nitrogen from these prices, a weighted average of these prices would have been ideal. However, due to lack of data on fertilizer sales for each category in a given year, a simple average of the fertilizer prices had to be used. Happily, there was not much difference in the prices of various fertilizers when calculated on a nutrient basis, since the prices of various brands are determined on the basis of their nutrient contents.

Price Index of Major Crops in t-1 year (x_{2t-1})

This variable was used as a proxy for farm income. While constructing this price index, two factors were considered for the selection of crops to be included in this index. (a) Contribution of the included crop to the cash income of the farmer and (b) consumption of fertilizer. On the basis of these criteria, rice, wheat, cotton, sugarcane and oil seeds were included in the construction of our index. A weighted average price index was constructed by multiplying the production of each crop included with its price index in a given year. After summation of these products the total sum of output of all the crops to estimate a weighted average indices.

Number of Tubewells in the Province (x_{3t})

Secure and controllable water supplies are very important for the economical use of fertilizers. The development of tubewell technology and its rapid spread has gone a long way in increasing the irrigation supplies in the province. Therefore this variable is included in the model.

Total Acreage under Major Crops (x_{4t})

Crop acreage under rice, wheat, maize, jowar, cotton, sugarcane, tobacco, potatoes and other vegetables is included under this category.

Time Variable (x_{5t})

Results of the estimated equation in double logarithms (except for time variable) are discussed below.

$$\ln y_t = \ln b_0 + b_1 \ln x_{1t} + b_2 \ln x_{2t-1} + b_3 \ln x_{3t} + b_4 \ln x_{4t} + b_5 x_5$$

-9.175	-0.522**	-0.582	+0.155	+2.079*	+0.152**
	(0.273) ⁰	(0.490)	(0.155)	(1.272)	(0.041)

$R^2 = 0.9888$ $\bar{R}^2 = 0.98$

$$F = 141.104$$

$$N = 14$$

0 Numbers in parentheses are standard error of the respective coefficients

* coefficient significantly different from zero at 90 percent level of probability

** coefficient significantly different from zero at 95 percent level of probability

N Number of observations

We hypothesize in the light of economic theory that price elasticity of demand for fertilizer is negative indicating that the use of fertilizers will increase when prices fall and vice versa and other things remaining the same. Similarly, we would expect the use of fertilizers to be positively related to the acreage under major crops, the number of tube-wells supplementing irrigation supplies. We would also expect the use of

fertilizer to be directly related to the farmers' income or some proxy for that.

The coefficient of relative fertilizer price (price elasticity of demand) is negative and significantly different from zero at the 95 percent probability level. This states that the decline in the relative prices of fertilizer over the years (mainly as a result of increase in the prices of major crops) has helped in the increase of fertilizer use in the province for the period under study.

The coefficient for the proxy for farm income has a negative sign contrary to what we would have expected. However the coefficient is not statistically significant.

The coefficient with respect to total acreage under major crops is positive and significantly different from zero at 90 percent level of probability. This shows that the use of fertilizer in the province has been positively affected by the increase in the acreage under major crops over the years under consideration. Major crops acreage has included acreage under those crops which are important from fertilizer consumption point of view. It includes area under rice, wheat, maize, jowar, cotton, sugarcane, tobacco, potatoes and other vegetables. Acreage under these crops is more important in explaining the use of fertilizer than total cultivated area or total cropped acreage. With the introduction of varieties of wheat, rice and maize, etc. the acreage under these crops has increased considerably. This has been mainly at the cost of grams, oilseeds and barley, etc. This is especially true for the canal irrigated districts of the province and these crops were not important from the fertilizer consumption point of view.

The coefficient of tubewells is positive indicating a positive influence of tubewells on the use of fertilizers in the province. Nevertheless the coefficient is not significantly different from zero at 90 percent probability level. This may be, because over time both the total acreage under major crops and the number of tubewells in the province have been increasing.

The coefficient of the time variable is not only positive but also statistically significant. Probably, fertilizer use has been increasing over time as a result of farmers' experience with fertilizer, and an accumulating level of information in the agricultural sector about fertilizer. However, it could also be argued that since supplies of fertilizer; which are determined by various institutional factors such as import policy, availability of fertilizers from donor countries or from the international market or under some aid projects in addition to domestic production which is also influenced by various institutional constraints; have been increasing over the years. Therefore, on account of various promotional programs initiated by the private and public agencies dealing fertilizers and interested in raising the farm production in the country the farmers have been responding to the increased supplies.

Leonard (29), in his study of fertilizer demand in west Pakistan had concluded that price of fertilizer was not a significant variable in influencing fertilizer demand. However the results of this analysis indicate that prices of fertilizer are an important factor in explaining the variation in fertilizer use, and the use of nitrogenous fertilizers in the Punjab has been inversely related to the relative prices of fertilizer.

Summary

From the analysis of time-series data on fertilizer use, it has been observed that the relative prices of nitrogenous fertilizers have been quite important in influencing the use of these fertilizers during the period of 1959-60 to 1972-73. Another factor in this regard has been the increased acreage under major crops, especially high yielding varieties of food grain crops. The coefficient of the time variable -- a complex variable indeed, indicates that over the years the use of nitrogenous fertilizers has been increasing. This could result from various factors such as increase in the level of information in the agricultural sector regarding the fertilizers, farmers experience, and awareness about the profitability of the use of fertilizers. However, it could also be argued that since supplies of fertilizers are determined to a considerable extent by the institutional factors and have been increasing over the years. Therefore, on account of various promotional programs initiated by the private and public agencies dealing in fertilizers, the farmers have been responding to the increased supplies.

CHAPTER VII

SUMMARY OF CONCLUSIONS AND POLICY RECOMMENDATIONS

The main objectives of this study were, (1) to investigate the economics of fertilizer application on the selected major crops: Mexi-Pak wheat, local wheat, Basmati rice, IRRI rice, Jhonna rice, maize, cotton and sugarcane in the canal irrigated areas of Punjab province of Pakistan, (2) to compare the level of fertilizer application among small (up to 12.5 acres), medium (12.6 to 25.0 acres) and large (25.1 to 50.0 acres) farms, (3) to analyse the factors responsible for low levels of fertilizer application where that situation exists, (4) to determine the various sources of financing fertilizer purchases and fertilizer supplies, (5) to investigate farmers understanding and preference for various types of fertilizers and (6) to identify and measure the effect of various agro-economic factors on fertilizer use in the Punjab from time-series data.

Data for the study pertaining to the cropping year of 1972-73 were collected through a farm survey in the fall of 1973. In all, 192 farmers were interviewed. These farmers were located in 16 villages of Gujranwala and Sahiwal districts of Punjab province. These two districts represent the typical cropping patterns of the wheat-rice and wheat-cotton growing districts of the province, respectively. The data were collected by the author with the help of two research assistants.

The ordinary least squares method of multiple regression analysis has been the major analytical tool used to estimate the coefficients of performance as well as per acre production functions. The same method has been employed to analyse the time-series data to estimate the effect

of various factors on the use of nitrogenous fertilizers in the province.

It should be pointed out that a production function estimated from the cross-sectional data is an average production function describing the structural relationship between inputs and output on an average farm firm. Nevertheless, useful policy implications can be derived from the average production functions. Different types of production functions were estimated. The ones giving the "best fit" were used to estimate the resource productivity of various factors among various crops. The productivity of inorganic fertilizers (mainly nitrogenous) was derived and used to calculate the marginal value product and the rate of return from fertilizer investment on various crops.

The results of the analysis have been discussed in detail in the preceding chapters. A summary of the conclusions is presented here. Table 24 provides a summary of the marginal productivities of various factor inputs for the crops under study. The policy recommendations are given after discussing the conclusions.

Economics of Fertilizer Use on the Selected Crops

Out of the 192 farmers interviewed, approximately 90 percent had applied fertilizer to at least one of the crops under study. However, the use of fertilizer was very much lopsided, with nitrogen dominating the scene. Phosphate fertilizers were used by only a minority of the farmers.

Mexi-Pak Wheat

Approximately 89 percent of the Mexi-Pak wheat growers had applied nitrogenous fertilizers and only 40 percent of the growers applied phosphate fertilizers. The incidence of phosphate fertilizer use was

TABLE 24. SUMMARY OF MARGINAL PRODUCTIVITIES OF VARIOUS FACTOR INPUTS

Crop	Land [@] (acres)	Man Hours	Bullock Hours	Fertilizer (Pounds of Nitrogen)	Fertilizer Expenditure (Rupees)	Farmyard Manure Expenses (Rupees)
(Marginal Physical Products in Pounds)						
Mexi-Pak wheat	- 286.00	3.82*	6.45	-	3.91	-
Local wheat	-1032.28	11.02	-	11.26	-	-1.61*
Basmati rice	717.79	4.06	1.75*	2.53	-	-
IRRI rice +	2996.46					
Jhonna rice	- 893.70	14.54	-	9.75	-	-4.95*
Maize +	749.16					
Cotton	751.34	- 1.15*	2.27	3.41	-	2.81
Sugarcane +	1295.95					

@ The marginal physical product for land derived indirectly from the per acre production functions (Chapter IV)

* The starred marginal physical products are statistically insignificant

- Indicates those factors not included in the estimated production functions

The marginal physical products for wheat and maize refer to pounds of grain. The marginal physical product of rice crops is measured in pounds of unhusked paddy, that of cotton in pounds of seed cotton. The marginal physical product of sugarcane refers to pounds of gur (raw sugar)

+ The marginal physical products of factors other than land not estimated for these crops (For details refer to Chapter IV)

highest on Mexi-Pak wheat than on any other crop in this study.

The marginal physical product for one rupee's investment in chemical fertilizers is estimated at about 3.9 pounds of wheat grain (point estimation at the geometric mean level of output and input). This provides for a marginal value product of Rs. 1.02 for an additional rupee spent on fertilizers. The farmers' expenditure on fertilizers, on the average, appears to be approaching optimum for the Mexi-Pak wheat.

As far as the level of fertilizer application is concerned, the per acre use of both nitrogenous and phosphate fertilizers was higher on small (up to 12.5 acres) farms as compared to medium (12.6 to 25.0 acres) and large (25.1 to 50.0 acres) farms on this crop. On the average, small farmers applied 54 pounds of nitrogen (N) and 48 pounds of phosphorus (P) per acre of Mexi-Pak wheat. Medium farmers applied 48 pounds of nitrogen and 39 pounds of phosphorus. Large farmers applied 50 pounds of nitrogen and 38 pounds of phosphorus.

The marginal physical product for an additional hour of bullock labor is estimated at 6.5 pounds of wheat grain. The marginal physical product for manual labor, though positive was however, statistically insignificant. Given the low cost of bullock labor in the region, the additional use of bullock labor, if available, mainly for pre-sowing cultivation could help in increasing the wheat production. Nevertheless, the gains would have to be carefully weighed against the additional cost and compared against the alternative uses of the bullock labor.

The insignificant estimated coefficient for land in the performance function might be indicative of the inefficient land use on large farms. It is also hypothesized that the late sowing of this crop, which is also characterized by inadequate land preparation and higher use of nitrogenous

fertilizers, may be resulting in low productivity of land resources. This is because the variable resources in such situations are applied too thinly over an extensive acreage.

Local Wheat

There were only 24 farmers growing local wheat in the sample. The majority of these farmers were small cultivators. Only 42 percent of the local wheat growers applied nitrogenous fertilizers on this crop. The marginal physical product of nitrogenous fertilizer was estimated at approximately 11.3 pounds of wheat grain, valued at Rs. 2.9, for an additional pound of nitrogen costing only Rs. 0.73. The use of fertilizer on local wheat does not appear to be optimal. This could be on account of several reasons. Local wheat is mainly grown for household requirements and farmers do not want to use much fertilizer on this crop. Local wheat, being a tall variety, tends to lodge under higher use of fertilizer. However, the below optimal use of fertilizer could also be due to the "conservatism" of these cultivators who are still cultivating local wheat varieties despite the fact that Mexi-Pak wheat has outyielded them. Some combination of these factors may be responsible for the relative low use of fertilizer on local wheat.

From the high marginal productivity of manual labor, it appears that the additional use of labor could be an important source for increasing production of this crop.

Basmati Rice

Out of 133 growers of Basmati rice, approximately 72 percent applied nitrogenous fertilizers. The use of phosphate fertilizers was limited to only 16 percent of the growers. The marginal physical product of land

area was estimated at about 717.8 pounds of unhusked paddy for an acre of Basmati rice. The marginal physical product of manual labor was estimated at about four pounds of unhusked paddy. The marginal physical product for bullock labor though positive was however statistically insignificant. In view of the low opportunity cost of manual labor the additional use of manual labor on this would seem justified. The marginal physical productivity of nitrogenous fertilizers though positive is not statistically significant. This insignificant marginal productivity may be due to overuse of nitrogenous fertilizers. Basmati rice, being a tall growing rice variety tends to lodge under high use of nitrogenous fertilizers alone. When lodging occurs, it adversely affects crop yields. The application of fertilizers at inappropriate time may be another factor for the insignificant contribution of nitrogenous fertilizers.

The per acre use of nitrogenous fertilizers on an average was found to be higher on small farms as compared to medium and large farms for this crop.

IRRI Rice

Approximately 75 percent of the 33 growers of IRRI rice applied nitrogenous fertilizers to their crop. The use of phosphate fertilizers was limited to only 18 percent of growers of this crop.

The per acre production function for IRRI rice was not found statistically significant. From the wide differences in the value of \bar{R}^2 , for the performance and per acre production functions and statistically insignificant F ratio for the per acre production function, (Tables 11 and 12) it appears that variation in total output of IRRI rice is effectively explained by the crop area alone. It also implies that yield per

acre is fairly constant on various farms. This may be due to similar farm technology on all the farms.

In the performance function the coefficient of nitrogen fertilizer though negative, was however, statistically insignificant. This may indicate that variation in farm output of IRRI rice is not related to the variation in the use of nitrogenous fertilizers. But given the high response of IRRI rice varieties to fertilizer use, it is difficult to accept this argument. Because of the small number of observations, on which the analysis was based, it is difficult to make any definite statement in this regard. Probably this situation may be due to either the lack of some essential complementary inputs or the application of fertilizers at a stage in crop growth when the use of fertilizers is ineffective.

Jhonna Rice

About 61 percent of the 38 Jhonna rice growers in the sample had applied nitrogenous fertilizers to their crop. The use of phosphate fertilizers was limited to only 16 percent of the growers. The marginal physical product for nitrogen was estimated at 9.8 pounds of paddy for an additional pound of nitrogen. This provides for a marginal value product of approximately two rupees for an additional cost of only Rs. 0.73. The marginal physical product of manual labor was estimated at about 14.5 pounds of unhusked paddy, providing for a marginal value product of over three rupees for an additional hour of labor. Given the low opportunity cost of manual labor, additional use of manual labor would seem justified. However, it may be pointed out that it will also involve the use of bullock labor which was excluded from the production

function analysis on account of high correlation between the manual and bullock labor.

The use of nitrogenous fertilizer appears to be below optimal level. This may be because Jhonna is mainly grown for the reclamation of the marginal lands and crop output is not the immediate goal in this case.

Maize

Out of a total of 39 growers of maize, 92 percent applied nitrogenous fertilizers. The use of phosphate fertilizers was confined to only 8 percent of the total growers of this crop.

The per acre production function for this crop was not found to be significant in the light of economic and statistical criteria. From this it appears that variation in farm output of maize is effectively explained by the variation in land area alone and other input factors vary proportionately with the area under maize crop. Nevertheless, from the estimated coefficient of performance function it appears that variation in maize output is positively associated with the variation in the use of nitrogenous fertilizers.

Cotton

A total of 95 farmers had cultivated cotton in the sample. Eighty-three percent of these farmers applied nitrogenous fertilizers. The use of phosphate fertilizers was limited to only 25 percent of these growers. Forty-seven percent of these farmers also applied organic fertilizers such as farmyard manure.

From the per acre production function, the marginal physical product for nitrogenous fertilizers was estimated to be about 3.4 pounds of seed

cotton for an additional pound of nitrogen. This provides for a marginal value product of approximately 2.8 rupees for an additional investment of only Rs. 0.73. The per acre yield of seed cotton was higher on farms using phosphate fertilizers in addition to nitrogenous fertilizers, other things being equal. The use of fertilizers appears to be below optimum. Many factors could be responsible for the below optimum level use of fertilizer. Important among these are the alleged non-availability of fertilizers at the appropriate time, high prices of fertilizers, and the lack of financial resources among the farmers. General uncertainty characterizing the domain of agriculture and particularly the uncertainty about the prices of seed cotton (the prices of seed cotton have fluctuated widely from year to year) could also be a factor in this regard, since the prices of output play an important role in determining the demand for factor inputs.

The marginal physical product for an additional rupee's worth of farmyard manure was estimated at approximately two rupees. The marginal physical product for manual labor in cotton production is not significantly different from zero. This may be because some of the farming operations in cotton farming such as cotton picking and manual hoeing (for broad cast sown crop particularly) are very labor intensive. This low productivity for manual labor may be inherent in the nature of these farming operations. Nevertheless, the marginal physical product for the additional use of bullock labor is estimated at about 2.27 pounds of seed cotton. This provides for a marginal value product of about Rs. 1.86. Because of the substitutability of bullock and manual labor for certain operations, from the low productivity of manual labor but quite high

productivity of bullock labor it seems that cotton production is more efficient on those farms using more bullock labor and less manual labor. Therefore, it is hypothesized that line sowing of cotton which will facilitate hoeing by the bullock driven implements and thus save manual labor would help in increasing cotton yields. This will further economize the use of manual labor in cotton picking and stick harvesting operations.

The per acre use of fertilizer application was higher on small farms as compared to medium and large farms.

Sugarcane

There were a total of 83 farmers growing sugarcane on an average of 1.2 acres per farm. Ninety-three percent of these growers applied nitrogenous fertilizers and only 8 percent of these farmers used phosphate fertilizers on their sugarcane crop.

The per acre production function for sugarcane was not found to be statistically significant. From this it appears that interfarm variation in per acre yield of sugarcane is small or technology is constant. From the wide differences in the value of \bar{R}^2 , for the performance and per acre production functions and statistically insignificant F ratio (Tables 11 and 12), it appears that variation in farm output of sugarcane is effectively explained by the crop area alone. It also appears that other factors vary proportionately with the variation in land area. In the performance function the coefficient of nitrogenous fertilizer was found to be positively associated with output of sugarcane, and so was the coefficient of organic manures.

Source of Financing Fertilizer Purchases and Fertilizer Supplies

According to interview responses, personal savings and non-institutional sources of credit were the most important sources of finance for the purchase of fertilizers by the farmers. (Non-institutional sources of credit include friends, relatives, village shop keepers and commission agents). This was true for all the categories of farms irrespective of the farm size. Institutional sources of credit supported the fertilizer investment of less than 15 percent of fertilizer users.

The commission agents and local dealers of fertilizers were cited as accounting for the fertilizer supplies of 85 percent of the farmers using fertilizers in the survey.

Farmers Familiarity with Fertilizers

The average farmer's knowledge about fertilizer appeared to be poor. The majority of the farmers interviewed told that they did not know much about the effect of fertilizers. Twenty percent of the farmers thought it was necessary to use fertilizers although they could not specifically say how it would affect their crops. A little over 19 percent of the farmers said that they were using fertilizer (nitrogen) because it could change the crop color into dark green. Farmers seemed to be unaware of the importance of other fertilizer nutrients.

Among various nitrogen fertilizers, urea was the choice indicated by an overwhelming majority of the farmers. The use of Diammonium phosphate, a double carrier of nitrogen and phosphate nutrients appear to be on the increase.

An overwhelming majority of the farmers who applied fertilizers

reported having discussed the use of fertilizers with other categories of people. The most frequently consulted groups were the following (in order of frequency): family members, neighboring farmers, local extension agents and fertilizer suppliers. Farmers also reported that they considered the radio extension broadcasts, sponsored by the Department of Agriculture as the most important and valuable source of information regarding fertilizers, other inputs and improved practices of cultivation and new crop varieties. Nevertheless, the local extension agents posted in the villages did not rank very high among farmers as source of information. This may be due to the inadequate professional training and knowledge of these agents or because of the poor contacts among the farmers and the local extension agent or some combination of these.

Factors Affecting the Use of Fertilizers (Nitrogenous)

From the analysis of time-series data, it has been observed that the relative prices of nitrogenous fertilizers have been quite important in influencing the use of these fertilizers during the period of 1959-60 to 1972-73. Another important factor in this regard has been the increase in acreage under major crops, especially high yielding varieties of food grain crops. The coefficient of the time variable -- a complex variable indeed, indicates that over the years use of nitrogenous fertilizers has been increasing, probably, as a result of increase in the level of information in the agricultural sector regarding the fertilizers, farmers' experience and awareness about the profitability about the use of fertilizers. However, it could also be argued that since supplies of fertilizers; which are determined by various institutional factors such

as import policy, availability of fertilizers from friendly donor countries or from the international market; in addition to domestic production which is also influenced by various institutional constraints; have been increasing over the years. Therefore, on account of various promotional programs initiated by the private and public agencies dealing in fertilizers and interested in raising the farm production in the province, the farmers have been responding to the increased supplies.

Policy Recommendations

The following discussion should be considered in the light of the findings reported in the preceding chapters. These recommendations are presented with the basic desire of providing various alternatives and guidelines for increasing the agricultural productivity at the micro as well as macro levels. Since the study was conducted in the most prosperous agricultural region of the country the reader is cautioned against the temptation of over-generalising from these findings. This is especially so for the findings on IRRI rice, maize and sugarcane since the analysis based on per acre production function was not conclusive, due to small number of observations. The scope of this study was limited to the canal irrigated districts of the province, therefore, the results may not be applicable for the rainfed areas. Since, the sample was not a random sample, it may suffer from some limitations on this account. Nevertheless, the author is satisfied about the representativeness of the farmers interviewed, and the findings of the survey faithfully describe the general agricultural situation and structure of the farming in the canal irrigated areas of the Punjab.

The results of this study indicate that the use of fertilizer (nitrogen) on local wheat, Jhonna rice and cotton is below optimum i.e. the marginal value product per pound of nitrogen is considerably higher than the price per pound of nitrogen fertilizer. The output of maize and sugarcane were positively associated with the use of these fertilizers. It appears that there is considerable potential for increasing farm output by increasing the use of fertilizer on these crops. It is the author's view that the crop yields could be much higher if the use of nitrogen fertilizers was accompanied by other complementary inputs such as phosphate fertilizers and pesticides. The data in this study have shown, fertilizer usage by farmers has emphasized a single nutrient element, nitrogen.

The below optimum use of fertilizer on various crops may be because of price uncertainty. If price uncertainty of the crops is a problem, it would be desirable to guarantee the minimum prices. Experience in Pakistan with the Mexi-Pak, where minimum prices are ensured by the government, is suggestive in this regard. The present analysis shows that fertilizer expenditure on Mexi-Pak wheat approximates the optimum allocation. The guaranteed floor prices are especially recommended for cotton and sugarcane, because these are important cash crops and have considerable influence on the farmers purchasing power.

The non-availability of fertilizer supplies at the appropriate time is another reason for the below optimum use of fertilizers. Timely supplies of fertilizers must be ensured.

In the light of this analysis, the recent price hikes of fertilizers (Chapter II) though justified due to price increases in the international market, are likely to slow down the use of fertilizers. This will

adversely affect the production of farm crops. Since many farmers have very limited capital, therefore, it is recommended that short term loans for the purchase of fertilizers be provided to the farmers. The fertilizer loans in kind might be even better to avoid the misuse of cash loans. Efforts should be made to minimize the bureaucratic procedures involved in obtaining these loans.

Special educational programs should be launched to educate farmers on the method and timings of fertilizer application on various crops in order to increase the efficiency of fertilizing materials.

In this period of world-wide fertilizer shortages, it is important to find alternatives. Organic fertilizers such as farmyard manure should be substituted for chemical fertilizers wherever possible. The use of farmyard manure was found highly profitable on cotton and crop. During the field survey it was observed that not much attention was being paid to the proper storage of this material. This generally results in considerable loss of its valuable nutrients during the rainy season. Moreover a considerable portion of cow-dung is used as a household fuel. This could be saved if there were adequate fuel substitutes. The extension wing of the Agricultural Department should launch campaigns to educate the farmers on the methods of proper storage of organic fertilizers.

It is recommended that the possibilities for the use of other cheap sources of nitrogen fertilizers such as anhydrous ammonia be explored. The use of this is very common in advanced countries like United States of America. However this is not to say since it is being used in the United States, it would be also advisable to use it in Pakistan.

Nevertheless the pros and cons of its use should be weighed.

The use of phosphate fertilizers is in its early stages and there is evidence (6) that farmers using a combination of nitrogen and phosphate nutrients achieved substantially higher crop yield than those using nitrogen only. The author's own discussion with some progressive farmers during the field survey indicated that the combined use of these nutrients resulted in higher yields. It is, therefore, recommended that subsidy on the phosphate fertilizer be continued to popularise its use with the farmers.

The outlay on fertilizers on Mexi-Pak wheat (nitrogen and phosphate) appears to be nearly optimal. However, there are indications that the "grow more wheat campaigns" organized every year by the government during the wheat sowing season overemphasize the expansion of acreage. In the light of this analysis this does not seem warranted. It is suggested that the cultivation of short duration crops such as Maize (sown in spring) should be encouraged especially in wheat-cotton areas. This will take some of the pressure off of farmers for late sowing of wheat (after harvesting of cotton crop). Research should also be stepped up to evolve wheat varieties which could thrive well under conditions of late sowing. Early maturing cotton varieties should be evolved.

In view of the low productivity of nitrogenous fertilizers on Basmati and IRRI rice varieties, it is recommended that further research on the agronomic practices of these crops be carried out to find out the causes of this low productivity. This low productivity could possibly be due to the lack of some trace elements which are limiting the efficiency of fertilizing nutrients.

Only a few of the interviewed farmers had soil samples from their farms analysed to determine the nutrient status of their soils and the fertilizer requirements of their crops. It is recommended that the soil testing laboratories be established, at least at each of the district headquarters. Farmers should be educated about the importance of having soil samples analysed in order to have a proper combination of fertilizing elements for their soils. A detailed soil survey should be undertaken to determine the nutrient status of the soils in the country.

It is recommended that similar farm management studies on a larger scale should be conducted in all the districts of the province and the country, to determine the resource productivity of various factor inputs under different farming conditions. The studies will also provide information regarding the structure of country's farming industry. This would be helpful in formulating strategies and programs for increasing farm production in the country. It is also recommended that agro-economic studies, to determine the optimal cropping patterns for different regions of the country, be carried out.

Though the present study was concerned with the use of fertilizers however, in side discussions, of the author, with the farmers, during the field survey, it was noticed that the farmers were very much concerned about the damage to their crops caused by the pests. It is recommended that future research programs should include studies on the profitability of pesticide uses on different crops.

In view of considerable potential for increasing farm production through the increased use of fertilizers, it is strongly recommended that the domestic production of fertilizers be stepped up. During 1974, there

were signs that some countries, including Pakistan, would be unable to obtain the needed amounts of fertilizers regardless of prices (22, p. 69). Pakistan has abundant resources of natural gas, a basic material in the manufacturing of fertilizers. Moreover, at present the cost of purchasing urea in Pakistan is less than 25 percent of imported urea (1). The increased production of fertilizers would not only provide secure supplies of fertilizers at lower costs, but also provide forward and backward linkages for the development in other sectors of the economy.

APPENDICES

APPENDIX A

GLOSSARY OF INDIGENOUS TERMS

- 1 Acre : 0.45 hectare.
- Rupee : The local standard currency. One rupee is equivalent to approximately 10 cents. The term Rs. often used in the text means rupees.
- Rabi : Winter cropping season.
- Kharif : Summer cropping season.
- Mexi-Pak: The term commonly used for Mexican wheat varieties in Pakistan.
- Bhusa : Wheat straw used as fodder.
- Paddy : Unhusked rice. Cleaned rice is about two-thirds of paddy.
- Gur : Raw sugar.

APPENDIX B

QUESTIONNAIRE FOR FARM SURVEY

Identification: Serial No. _____
 Interviewer _____
 Village Name/No. _____ Tehsil _____
 District _____
 Respondent's Name _____ Age _____
 Formal Education (School years) _____
 No. of work years spent on the farm in present locality _____
 Total No. of work years on the farm _____

Tenure:

i) Owner Operator _____ ii) Tenant _____
 iii) Owner cum Tenant _____ iv) Other (specify) _____

If Tenant, please indicate what is the share of the Landlord in the followings:

i) Total Produce _____
 ii) Cost of Farm Operation:
 a) Fertilizer _____ b) Seed _____
 c) Hired labour _____ d) Land revenue & water charges _____
 e) Tractor services _____ f) Miscellaneous _____

Farm Size:

Units of land measurement used _____
 Local units in terms of Acres _____

	Total area owned	Area owned in this village	Area taken on rent in this village	Area given on rent	Net Area operated
Local Units					
Standard units/Acres					

- i) Area not available for cultivation _____
- ii) Area Cropped once _____ iii) Area double cropped _____
- iv) Area left fallow _____ v) Total Cropped Area _____
- vi) Cropping intensity _____

Soil Type:

Heavy _____ Medium _____ Poor _____

If you were to buy your present farm, how much would you be willing to pay for the farm?

Total _____

Farm building (Including Tubewell) _____

Farm land _____

Source of Irrigation:

- i) Canal _____ ii) Canal cum Tubewell _____
- iii) Tubewell _____
- Discharge of the Moga _____
- Water tune weekly _____ or bi-weekly _____
- Total hours available per turn _____

Total water turns used last year _____

General weather condition during Cropping season of 1972-73:

Normal _____

Above normal _____

Below normal _____

CROPS GROWN, ACREAGE AND YIELDS

Crop	Area (Local units)	Acres	Total Yields (mds)	Average Yield (mds)	Retained for household requirements (mds)	Sold in local market	Price/unit (Rs./md)	Sold in town market	Price/unit (Rs./md)	Remarks
<u>Cotton</u>										
i. Desi										
ii. American										
<u>Maize</u>										
i. Local										
ii. Hybrid										
iii. Neelam										
<u>Rice</u>										
i. Basmati										
ii. Irri										
iii. Jhona										
Kh. Fodder										
Kh. Vegetables										
Misc.										
<u>Sugarcane</u>										
Rabi Crops										
<u>Wheat</u>										
i. Desi										
ii. Mexi										
iii. S.A.-42										
Gram										
Oil Seeds										
Rabi Fodder										
Rabi Vegetables										
Corn										
Miscellaneous										

METHOD OF SOWING AND HOEING OF CROPS

Crops	Area	Acres	No. of pre-sowing Plowing			Total	Preparatory Plowing (After Rauni)		Seed Rate/ Acre	Method of Sowing		Hoeing & Weeding		Sown after what crop	Remarks
			With furrow turning plow	With tractor	With ordinary plow		Tractor	Ordinary		Broad cast	Line sow- ing	Manual No.	With animals No.		
American Cotton															
<u>Maize</u>															
i. Local															
ii. Hybrid															
iii. J-1															
iv. Neelam															
<u>Wheat</u>															
i. Desi															
ii. Mexi															
iii. S.A.-42															
<u>Rice</u>															
i. Basmati															
ii. Irri															
iii. Jhona															
<u>Sugarcane</u>															
i. Fresh															
ii. Ratoon															

IRRIGATION OF CROPS

Crops	Area	Acres	Rauni		No. of Irrigations			Total No. of Irrigations	Tube well hours required to irrigated a Crop Acre	Canal hours required to irrigate a Crop Acre	Remarks
			Light	Heavy	Canal	Tube-well	Canal cum Tube well				
American Cotton											
Maize											
i. Local											
ii. Hybrid											
iii. J-1											
iv. Neelam											
Wheat											
i. Desi											
ii. Mexi											
iii. S.A.-42											
Rice											
i. Basmati											
ii. Irri-Pak											
iii. Jhona											
Sugarcane											
i. Fresh											
ii. Ratoon											

APPLICATION OF FARM YARD MANURE

EDITOR'S USE

Crops	Area	Acres	Area Manured	Total cart loads of F.Y.M.used	Price/cart load (Rs.)	Total cost (Rs.)	Conversion ratio for Nitrogen	Conversion ratio for P ₂ O ₅	Pounds of N	Pounds of P ₂ O ₅	Remarks
<u>American</u>											
<u>Cotton</u>											
<u>Maize</u>											
i. Local											
ii. Hybrid											
iii. J-1											
iv. Neelam											
<u>Wheat</u>											
i. Local											
ii. Mexi											
iii. S.A.-42											
<u>Rice</u>											
i. Basmati											
ii. Irri-Pak											
iii. Jhona											
<u>Sugarcane</u>											
i. Fresh											
ii. Ratoon											

NITROGENOUS FERTILIZERS

EDITOR'S USE

Crops	Area	Acres	Area Fertilized	Total No. of Bags used	Brand	Size of the Bag (Weight)	Price per Bag (Rs.)	Total cost (Rs.)	Total Wt. used	Nutrient Pounds	Price per lb. of N	Remarks
American Cotton												
Maize												
i. Local												
ii. Hybrid												
iii. J-1												
iv. Neelam												
Wheat												
i. Local												
ii. Mexi												
iii. S.A.-42												
Rice												
i. Basmati												
ii. Irri-Pak												
iii. Jhona												
Sugarcane												
i. Fresh												
ii. Ratoon												

CONSUMPTION OF PHOSPHATIC AND COMPOUND FERTILIZERS

FOR EDITOR'S USE

Crops	Area	Acres	Area to which P ₂ O ₅ used	Total No. of Bags used	Brand	Size of the Bag	Price per Bag (Rs.)	Total Amount spent (Rs.)	Total Weight used	Nutrient Pounds	Price per Nutrient Pound (Rs.)	Remarks
<u>American Cotton</u>												
<u>Maize</u>												
i. Local												
ii. Hybrid												
iii. J-1												
iv. Neelam												
<u>Wheat</u>												
i. Local												
ii. Mexi												
iii. S.A.-42												
<u>Rice</u>												
i. Basmati												
ii. Irri-Pak												
iii. Jhona												
<u>Sugarcane</u>												
i. Fresh												
ii. Ratoon												

Please provide the following information:

Kind of Fertilizer	Total No. of bags used (Overall)	Size of bag/weight per bag	Expenses on Fertilizer				Total	Av./bag (Rs.)
			Price/bag (Rs.)	Transportation/bag (Rs.)	Cost of fertilizer			
<u>Nitrogenous</u>								
1. Ammonium sulphate								
2. Am. Nitrate								
3. Urea								
4. Amm. sul.- Nitrate								
5. Other								
<u>Phosphatic</u>								
1. Single								
2. Double								
3. Triple								
<u>Compound</u>								
1. D.A.P.								
2. Nitrophos								
3. Others								

Please provide the following information:

Major crops fertilized	Method of fertilizer use	Time of application	Recommendation of the Agri. Dept. on fertilizer application		
			Dose	Method	Time
Wheat					
Rice					
Sugarcane					
Maize					
Cotton					
Other (specify)					

SOURCE OF FERTILIZER SUPPLYPrivate Agencies

1. P.N.O. _____ 2. Dawood. _____ 3. Esso. _____
 4. Jaffar _____ 5. Commission agents _____
 6. Village shop keeper _____ 7. Land lord _____
 8. Local dealer _____

Govt./Semi. Govt. Agencies

1. A.D.C. _____ 2. R.S.C. _____ 3. Farm guide _____
 4. Other (specify) _____

Q. Why do you prefer the above source?

Ans. _____

Q. Does the agency from which you buy your fertilizers advise you on the method, time and dose of fertilizer?

Yes _____ No _____

Q. Do you discuss the use of fertilizer with the following?

	Yes	No
Family members	_____	_____
Fellow farmers	_____	_____
Village extension worker	_____	_____
Fertilizer Suppliers	_____	_____
Land lord (in case of tenant)	_____	_____

Q. Is fertilizer generally available to you when you need?

~~Yes~~ _____ No _____

1. If not, in what season the supplies are lacking.

Kharif _____ Rabi _____ Both _____

If no, is fertilizer available in black market?

Yes _____ No _____

Q. Do you think, you are using adequate amount of fertilizer?

Yes _____ No _____

If no, then what are the reason for this inadequacy?

Nonavailability _____ Lack of Water _____

Lack of Funds _____ Price of Fertilizer _____

Other (specify) _____

Q. If the price of fertilizer is increased, would you reduce the amount of fertilizer applied?

Yes _____ No _____

If yes, for which crop?

Cotton _____ Wheat _____ Rice _____ Maize _____

Sugarcane _____ Other (specify) _____

Q. If prices of major crops increase, will you use more fertilizers in the following season?

Yes _____ No _____

Q. How far the present price increase of fertilizer is going to affect the use of fertilizer on your farm and for what crop?

Ans. _____

Q. Is fertilizer available to you on credit or is credit available to you for fertilizer?

Yes _____ No _____

Q. If yes, what are the sources and terms of this credit?

	Sources	Terms	
		(1) Interest rate	(2) Repayment period
1.	_____	_____	_____
2.	_____	_____	_____
3.	_____	_____	_____

Q. From what sources do you finance your fertilizer purchases?

Own saving _____

Borrowing from Friends/Relatives _____

Credit from A.D.B.P. _____

Credit from Co-op Society _____

Any other _____

Q. If cash credit was available to you, would you use more fertilizer?

Yes _____ No _____

If yes, for what crops _____

How much _____

Q. If kind-credit was available to you, would you use more fertilizer?

Yes _____ No _____

If yes, for what crops 1. _____ 2. _____ 3. _____

How much _____

Q. With the present increase in fertilizer price, would you require more credit to finance the purchase of fertilizer?

Ans. _____

Q. What agencies and institutions in your area advise farmers on the use of fertilizer?

Agri. Dept. _____ A.D.C. _____

Farm guide _____ Private fertilizer agencies _____

Radio _____ Miscellaneous _____

Q. Do you have access to radio?

Yes _____

No _____

If yes, of what kind?

Personal _____

Friends _____

Q. Are these instructions for:

(a) Particular fertilizer (specify) _____

(b) All Fertilizer _____

Q. Are these instructions for (a) Particular Crop _____

(b) Major Crops _____

Q. What is the nature of these instructions?

Institutions/ Organizations	Verbal	Demonstration	Audio Visual
Agri. Dept.			
A.D.C.			
Farm guide			
Private agencies			

Q. What is your opinion about these instructions?

Useful _____ Useless _____ No opinion _____

Suggestions for improvement _____

Q. Did these instructions have any influence on the use of fertilizer
by you?

Ans. Please specify_____

Q. Did you have your soil samples analysed?

Yes _____ No _____

Q. Are there any facilities available for this?

Q. What fertilizers do you prefer?

Phosphatic _____ Nitrogeneous _____

Reasons _____

Please specify the brand in each category and give reasons for
your preference _____

Q. Do you think nationalization of fertilizer will be of help to the
farmers?

Ans. _____

FAMILY LABOUR

Member of household & their relationship to the head of family (Farmer)	Sex M/F	Age (Yrs)	Educa- (No. of school yrs)	Occupation		Working on Farm			
				Prin- cipal	Sec- ond- ary	Full time	Half time	Quar- ter time	Other speci- fy
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									

PERMANENT HIRED LABOUR

	Age	Employ- ment period	Wage in cash (Rs.)	Wage in kind grains Clothes Shoes (Rs.)	Wage inputed for meals & housing etc. (Rs.)	Total cost (calcula- ted) (Rs.)
1.						
2.						
3.						
4.						
5.						

Investigator's Remarks for Family & Hired Labour:

Family _____

Hired _____

CASUALLY HIRED LABOUR

Crop & Operations	No. of men hired	Days of employ- ment	Total man days	Wages in cash/man (Rs.)	Wages in kind/man	Total cost of Operation
<u>Wheat</u>						
Preparatory tillage						
Sowing						
Hoeing, weeding						
Fertilizing						
Harvesting						
Threshing, etc.						
Winnowing, etc.						
<u>Rice</u>						
Sowing (Transplanting)						
Hoeing, weeding						
Fertilizing						
Harvesting						
Threshing						
<u>Cotton</u>						
Sowing						
Hoeing, weeding						
Fertilizing						
Picking						
Stick harvesting						

CASUALLY HIRED LABOUR (Contd.)

Crop & Operations	No.of men hired	Days of employ- ment	Total man days	Wages in cash/man (Rs.)	Wages in kind/man	Total cost of Operation
<u>Maize</u>						
Sowing						
Hoeing, weeding						
Fertilizing						
Harvesting						
<u>Threshing</u>						
<u>Sugarcane</u>						
Sowing						
Hoeing, weeding						
Fertilizing						
Harvesting						
Cane crushing						
<u>Gur/Sugar making</u>						

Remarks by Research Investigator:

Cotton pickers wages etc:

Rice wages/acre to be asked:

Capital items on the Farm:

Q. Do you have a tubewell on your farm? Yes _____ No _____

Q. If yes, please give the year of installment? 19____

Q. If no, do you purchase tubewell/canal water from other tubewell owners? Yes _____ No _____

Q. If yes, for what Crop?

1. _____ 2. _____ 3. _____ 4. _____
5. _____

Q. What is the rate of water charges? _____

Q. How much did you spend on buying water last year (1972-73)
if you have tubewell on the farm, how much did you pay for
electric, diesel expenses during the last year (July 1972 to
June 1973).

Is this tubewell:

Single owned _____ Partnership _____

Q. If partnership please specify the number of partners and share of
partners:

No. of partners _____ Shares _____

Q. How much water did you sell last year? _____

Q. Is there any change in the use of fertilizer after installing/
availability of tubewell water, on your farm.

Increase _____

Decrease _____

No. _____

Please give reason for change. _____

Q. Do you have a Tractor? Yes _____ No _____

If yes, please give year of purchase, type and horse power of
Tractor. _____

If no, do you hire tractor services for farm operations.

Yes _____ No _____ Price of Tractor _____

If yes, for what operation did you hire tractor last year.

Crop	Operation	Rate	Total charges paid
1.			
2.			
3.			
4.			

Q. If owner of a tractor, please indicate the operational charges during last year (July 1972 to June 1973). Diesel, operator's salary maintenance.

Do you have trolly? Yes _____ No _____

Q. Please indicate the proportion of time tractor services sold.

Q. Is there any change in your fertilizer use after buying/availability of tractor services. Increase _____

Decrease _____

No _____

Q. In case of change please give reasons?

Miscellaneous Capital Items

Capital item	No	Price/ unit (Rs.)	Total value (Rs.)	Life years	Editor's calculations
--------------	----	-------------------------	-------------------------	------------	--------------------------

Animal shedFodder cutterCane crusherCart

Wheat Thresher

1. Animal

2. Mechanical

Ordinary PloughFurrow TurningHoesSeed drillSohagaMiscellaneous

Remarks

LABOUR REQUIREMENTS FOR DIFFERENT OPERATION OF MAJOR CROPS

Crops	Hours required for preparatory tillage of one acre with one pair of bullocks	Man hours required for sow- ing one acre with a pair of bullocks		Man hours required for hoe- ing with a pair of bullocks per acre	Man hours required for manual hoeing one acre	Man hours required for fertilizing one acre	Man hours required for har- vesting/ picking of cotton one acre	Man hours required for thre- shing/ cane cru- shing and gur mak- ing with a pair of bullocks	Man hours required for winnow- ing of one acre crop/ cotton stick har- vesting	Remarks
		B.C.	Kara							
Wheat										
Rice										
Maize										
Cotton										
Sugarcane										

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