

The Pakistan Development Review
42 : 3 (Autumn 2003) pp. 219–248

Agricultural Productivity, Efficiency, and Rural Poverty in Irrigated Pakistan: A Stochastic Production Frontier Analysis

MUNIR AHMAD

The main objective of this study is to estimate the input elasticities of production for poor and non-poor farms. The study estimates the stochastic frontier production function. The results show that the elasticities of production differ for poor and non-poor farms. The production elasticity of land is substantially higher on rich farms as compared to the farms belonging to poor farmers. This implies higher returns on investment on land by the rich farmers. The salinity/sodicity problem and the tail-end location of the plot adversely affect farm productivity and efficiency, particularly at the poor farms. Moreover, the average cost of the existence of technical inefficiencies is about 43 percent in terms of loss in output, with wide variations across farms ranging from 17 percent to 62 percent. The study further concludes that the least efficient group is not only operating far below the frontier but it also operates at the lower portion of the production frontier. Consequently, increasing access to the inputs would likely raise productivity and reduce poverty.

The results imply that the land distribution using the notion of land reforms in favour of poor/small farmers in the presence of existing farm structure, rural infrastructure, and the weak farm-supporting institutions is not expected to raise farm productivity and reduce poverty among the poor farmers. The results call for a strong and active role of the government in close partnership with the private sector to initiate income-generating activities and inputs supply chains in the rural areas to break the nexus of poverty, land degradation, and low agricultural productivity.

1. INTRODUCTION

Agriculture sectors in less developed countries like Pakistan are widely considered to play a vital role in the eradication of poverty. In spite of the importance of the sector, the production potential in agriculture in many of the

Munir Ahmad is Chief of Research at the Pakistan Institute of Development Economics, Islamabad.

Author's Note: I am grateful to Dr A. R. Kemal, Director, PIDE, Dr Muhammad Iqbal, Senior Research Economist, PIDE, and Dr Bashir Ahmad, Vice-Chancellor, University of Agriculture, Faisalabad, for technical discussions with them and for their comments on an earlier draft of this paper. I am also thankful to an anonymous referee of this journal for valuable comments and suggestions for improvements in an earlier version of this paper.

developing countries is mostly unrealised due mainly to under-investment in research and development, irrigation, rural infrastructure, rural education, and health. Consequently, the levels of productivity of the agriculture sector in these economies are far below the potential that the developed countries achieved several decades ago.

The multi-dimensional nature of the relationship between agriculture and poverty is being acknowledged more widely. Higher agricultural productivity affects family earnings and nutrition, which in turn supports labour productivity and results in better health and well-being of the people [Oshaug and Haddad (2002)]. Poor health of workers either results in the loss of working days or reduces their working capacity, leading to lower output [Croppenstedt and Muller (2000)]. Poverty is likely to affect the capacity of the farm households to avail themselves of better health and education facilities, to purchase inputs at the proper time, to hold/acquire other farm assets, to adopt new technologies and invest in conservation of their land resources, etc. The low level of these factors in turn affects agricultural productivity adversely. Therefore, poverty is not only an effect but also a cause of low agricultural productivity. Thus, it is imperative to pay more attention to this aspect of the relationship between agricultural productivity and poverty.

The performance of the agriculture sector in Pakistan has been satisfactory for over four decades. It grew at the rate of about 3.5 percent per year during the period 1959-60 to 2002-2003. The growth in the crops sub-sector remained around 3.3 percent per year, while the livestock sub-sector grew at a rate of more than 3.5 percent per annum during the same period. Despite the fact that agriculture has been growing at a reasonable rate, poverty has increased during the 1990s, in sharp contrast to its declining trend in 1970s and 1980s [Amjad and Kemal (1997); Ali and Tahir (1999); Jafri (1999); Arif, *et al.* (2001)]. In Pakistan, poverty has been generally higher in rural areas, and is mostly concentrated among the landless and the small and tenant farmers. It needs to be mentioned here that the rural indicators appeared to have improved little in recent years, demonstrating that human deprivation in the country is likely to deteriorate further in the future, forcing people to stay poor [Arif and Ahmad (2001)]. There is a great likelihood that the agricultural productivity situation will be affected adversely.

The poverty scenario in Pakistan shows that, generally, the growth in agriculture sector has not benefited the poor sections of the society. Rather, the fact is that the families which were not poor earlier have been sliding down the poverty line. It points to the possibility that the income inequality might have worsened due to the deterioration in the distribution of productive assets and access to the financial and other supporting institutions [Kemal (2003) and Timmer (1997)]. If this is true, then the per capita income has to grow at a much more rapid rate to make an impact in terms of reduction in poverty [Kakwani (2001)].

Although growth and poverty are interlinked, the above discussion highlights that the former is not a sufficient activity to reduce poverty. To understand this phenomenon in the context of Pakistan, we need to consider the main factors that acted as a driving force for triggering growth in the agriculture sector, and we need to analyse who is being benefited, and how. The key factors include: (1) the higher use of conventional inputs, (2) increase in total factor productivity (TFP), and (3) the targeted transformations in the institutional set-up that assist the agriculture sector. These sources of growth are inter-related, and who gets the benefits depends on the distribution of assets, particularly the land.

Pakistan has a highly skewed distribution of farm lands,¹ and the access to input and output markets is mainly determined by the ownership of this factor of production. It is believed that benefits of agricultural growth have also been unequally distributed. The poor small farmers under-utilise various factors of production, particularly the purchased inputs, because of financial constraints, which results in lower productivity and income. Consequently, the poor farmers seemed to be operating not only at the lower portion of the production frontier but also appeared to be realising less than the maximum achievable output with the given level of inputs. That must lead to rise in poverty.²

The key factors behind the TFP, the second source of growth, are agricultural research and extension, better rural infrastructure like roads, electricity, education, and irrigation [Fan, Hazell and Thorat (1999); Fan, Zhang and Zhang (2000); Evenson, Pray and Rosegrant (1999); Rosegrant and Evenson (1993); and Ali (2000)]. The empirical literature shows that the poor farmers have limited access to such facilities [Iqbal, Khan and Ahmad (2002) and Ahmad, Chaudhry and Iqbal (2002)]. Consequently, the poor farmers are not in a position to benefit from growth in TFP to the extent to which the rich farmers do. This results in widening the gap between the poor/small and the rich/progressive farmers. The third major factor, which could be instrumental for agricultural growth is the policy-targeted institutional changes including agricultural extension, education and credit, and

¹According to the recent agricultural census [Pakistan (2003)], about 58 percent of the farms having less than 5 acres cultivate only 16 percent of the total area, while 5 percent of the farms having 25 acres or above cultivate 37 percent of the total area in Pakistan. In Sindh, about 46 percent of the farms having lands less than 5 acres cultivate only 12 percent of the area, while large farms (≥ 25 acres) are only 7 percent, cultivating the major chunk of the area, i.e., 44 percent. In the NWFP, 79 percent of the farms having less than 5 acres cultivate 32 percent of the area, while only one percent of the farms having 25 acres or more cultivate 27 percent of the area. Land distribution in Balochistan shows that 29 percent are marginal farms (<5 acres) cultivating 3 percent of the area, while 16 percent are the large farms (≥ 25 acres) cultivating 63 percent of the total area.

²Causality in poverty-agricultural productivity relationship runs both ways. A high level of poverty results in lower productivity because of low use of inputs caused by financial constraints, and in low labour productivity because of low calorie intake and poor health, etc. On the other hand, low agricultural productivity leads to lower income that in turn affects the poverty. The relationship can be studied using the simultaneous equation model. However, the data at hand cannot be used for such a study. Moreover, the major objective of this study is to estimate elasticities of production at the poor and the non-poor farms.

improvement in the functioning of input and output markets [Saris (2001)]. These institutions have worsened the disparity between the rich/large and the poor/small farmers in rural Pakistan by offering greater access to influential and well-off farmers. Moreover, the agricultural price policies in Pakistan have remained unfriendly to producers and tended to slow down the growth [Lele (1989); Schiff and Valdes (1991) and Saris (2001)].

As part of structural adjustment and stabilisation programmes, the Government of Pakistan removed all subsidies during the 1990s, which resulted in a manifold increase in input prices and, thus, greater cost of production [Ahmad (2003)]. To compensate for the higher production cost, the Government has been following the policy of increasing the support prices of major crops. However, the increase in inputs prices has been much faster than the compensation in terms of higher output prices. Such trends in prices have been squeezing the profitability of the agriculture sector in general and of poor farmers in particular. Consequently, poverty increased among the landless, tenants, and small farmers during the 1990s. In the absence of other alternative sources of income, the poor families had to part with education and health and even failed to purchase quality inputs timely which affected their agricultural productivity adversely. As a result, the poverty situation and the social status of the families have deteriorated further.

Various studies have emphasised the link between poverty and agricultural growth using Indian data. The most important of them are Ahluwalia (1978); Gaiha (1989); Datt and Ravallian (1998, 1998a); Fan, Hazell and Thorat (2000) and De Janvry and Sadoulet (2002). These studies concluded that there is an inverse relationship between agricultural growth and rural poverty. A number of studies have also been conducted to assess the incidence of poverty using data from Pakistan, e.g., Naseem (1973); Mujahid (1978); Amjad and Irfan (1984); Ahmad and Ludlow (1989); Ercelawn (1990); Malik (1991 and 1994); Gazdar, *et al.* (1994); Anwar (1996, 1998); Amjad and Kemal (1997); Jafri (1999); Arif, *et al.* (2000); FBS (2001) and World Bank (1995, 2002).

However, there is a dearth of empirical literature that analyses the effects of poverty on the performance of agriculture.³ An exception is a study by Randrianarisoa and Minten (2001) that explores the effects of rural poverty on agricultural production using data from Madagascar. They estimate the primal production function at different poverty levels and conclude that elasticities of

³Various studies are found in the literature exploring the link between health, nutrition, and productivity. The pioneering studies include Leibenstein (1957); Stiglitz (1976) and Bliss and Stern (1978). The subsequent studies include Baldwin and Weisbrod (1974); Weisbrod and Helminiak (1977); among others. Applications are also found in the agriculture sector and provide mixed results. The list includes the work published by Pitt and Rosenweig (1986); Strauss (1986); Deolalikar (1988); Fafchamps and Quisumbing (1997); Haddad and Bouis (1991); Behrman and Deolalikar (1989); Foster and Rosenweig (1993); Thomas and Straus (1997) and Bhargava (1997), among others. However, no comprehensive work has been done using data from Pakistan.

production with respect to inputs are different at poor and non-poor farms. The study concludes that production elasticity of land is higher at the poor farms, and therefore the redistribution of land from the rich to the poor farmers may help in reducing poverty. Education, secure property rights, and better rental arrangements enhance the poor farmer's agricultural productivity, and thus these alleviate poverty.

So far, none of the studies has explored the link between agricultural production and poverty in Pakistan. The present study attempts to extend the work of Randrianarisoa and Minten (2001) and of other authors (focusing on the nutrition and productivity relationship) by estimating the frontier production (the best practice) function incorporating different levels of poverty. The remaining paper consists of three sections. Section 2 explains the data and the empirical framework. Section 3 is devoted to results and discussion. The last section concludes the paper and suggests some policy implications.

2. THE DATA AND THE METHODOLOGICAL FRAMEWORK

2.1. The Data

This study uses the 'Pakistan Rural Household Survey' (PRHS) data collected by the Pakistan Institute of Development Economics, Islamabad for the cropping year 2000-2001. This survey covers 16 districts in four provinces of the country.⁴ No agricultural household was observed in Gawadar District (in Balochistan). Two other districts, Attock in Punjab and Dir in the NWFP, are predominantly non-irrigated areas. Therefore, these three districts were excluded from the production frontier analysis. The survey covers only the rural areas, focusing on agriculture, credit, labour, and health issues. This study uses only those farm households which grow crops, fruit, and vegetables. These households in the overall sample are about 40 percent. This PRHS survey covers information regarding crops output and inputs at the plot-level. However, plot-level data were missing for a number of variables including output. Therefore, such observations have to be dropped from the analysis. Consequently, the total number of observations finally used for estimating the stochastic production frontier comes out to be 1566 regarding 1112 irrigated farms.⁵

⁴The data covers six districts in Punjab, which are Faisalabad, Attock, Hafizabad, Vehari, Muzaffargarh, and Bahawalpur. Four districts, including Badin, Nawabshah, Mirpur Khas, and Larkana, were selected from Sindh province; three districts, including Dir, Mardan and Lakimmarwat belong to the NWFP; and three districts, Loralai, Khuzdar and Gawadar, were from Balochistan. In total 23 Tehsils (sub-district) were covered in all the districts. One Tehsil was selected from each district, except Faisalabad (4 Tehsils), Attock (2 Tesils), Badin (2 Tesils), Dir (2 Tesils), and Larkana (2 Tesils). Total villages covered in all Tehsils were 151, varying from one to 10 in each Tehsil. The total number of households covered under this survey was 2726, including both farm and non-farm households.

⁵The numbers of plots they cultivate vary from 1 to 6.

2.2. Empirical Model

To quantify the impact of determinants of agricultural productivity at different poverty levels in Pakistan, we use the primal production frontier technique. Randrianarisoa and Minten (2001) is the only study which estimates the production response coefficients at different poverty levels using data from Madagascar. They applied an average production function approach using conventional and non-conventional variables in the model. The use of average production function incorporating non-conventional (socioeconomic) variables in the production function raises various questions. The inclusion of these variables in the production function has been criticised on the ground that they have ‘roundabout’ effects on production and, thus, may not be included in the model [Kalirajan (1981)]. On the other hand, the average production function, which is estimated using the OLS technique, assumes that farmers are 100 percent technically efficient, which may not be true and is considered to be a very strong assumption.⁶

Various models have been developed by the researchers that accommodate the concept of technical inefficiency on the part of farm manager, including the parametric and non-parametric models; the former uses specific functional form, while the latter does not. The parametric models can be divided further into the deterministic and the stochastic frontier models. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic modelling technique allows for statistical noise.

Aigner, Lovell, and Schmidt (1977) and Meeusen and Broeck (1977) independently developed the stochastic frontier approach that decomposes the error term into two components. One is symmetric that captures the effects of those variables which are not under the control of the producer, and the other is one-sided, representing management inefficiency. Kalirajan (1981) proposed that the predicted technical inefficiency effects then could be regressed on various observable explanatory variables involving farmer or farm-specific attributes/factors to examine the determinants of inefficiency. Various applied researchers have used this two-step procedure. However, this procedure has been criticised on the ground that it violates one of the basic assumptions, that of ‘identically independently distributed technical inefficiency effects in the stochastic frontier’ [Battese, Malik and Gill (1996)]. Battese and Coelli (1993, 1995) proposed one-stage modelling in which the technical inefficiency effects are a function of various observable variables such as age, education, access to extension services, etc.

The stochastic production frontier model incorporating inefficiency effects can be written as:

⁶The concept of technical efficiency of a firm was first introduced by Farrell in his pioneering work published in 1957. He defined it as the ratio of realised output to that of maximum achievable potential with the same level of inputs and technology.

$$Y_i = f(X_i; \beta) \exp(V_i - U_i) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (1)$$

Where Y_i represents the possible production level for the i th sample farm; $f(X_i; \beta)$ is a suitable function of the vector, X_i , of inputs for the i th farm and a vector, β , of unknown parameters—this paper uses Cobb-Douglas type function for the analysis; V_i s are assumed to be independent and identically distributed normal random errors having mean zero and variance σ_v^2 and are also independently distributed of U_i ; and U_i s are non-negative technical inefficiency effects representing management factors and are assumed to be independently distributed with mean u_i and variance σ^2 [Battese, Malik and Gill (1996)]. The i th farm exploits the full technological production potential when the value of U_i comes out to be equal to zero, and the farmer is then producing at the production frontier implying that the producer cannot produce above the production frontier. The higher the value of U_i , the farther away is the farmer from the production frontier, indicating greater operational inefficiency [Drysdale, Kalirajan and Zhao (1995)].

According to Battese and Coelli (1993), the technical inefficiency component U_i is a function that can be written as

$$U_i = Z_i \delta + w_i \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

Where Z_i is vector of explanatory variables, δ is a vector of unknown parameters to be estimated, and w_i is an unobservable random variable assuming truncated normal distribution with mean zero and variance σ_w^2 , given that U_i is non-negative (i.e., $w_i \geq -Z_i \delta$). The Z variables could be the farm- and farmer-specific variables. The technical efficiency of production at the i th farm (TE_i) can be computed as

$$TE_i = \exp(-U_i) = Y_i / Y_i^* \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

Where Y_i is the observed farm output and Y_i^* is maximum possible output using the given level of inputs.

Definitions of all the variables included in the estimated model are given in Table 1. The dependent variable, Q_{ij} , is the weighted index of output from all the k crops grown at the i th farm and the j th plot. This can be computed as

$$Q_{ij} = \sum_{k=1}^K W_{ijk} Y_{ijk} \quad (i = 1 \dots 1939, j = 1 \dots 6, \text{ and } k = 1 \dots 37.) \quad \dots \quad (4)$$

The weights are $W_{ijk} = S_{ijk} / TV$, where S_{ijk} is the share of k th crop value in total value of crops output (TV) grown at the i th farm and the j th plot, and Y_{ijk} is the quantity of k th crop output at the i th farm and j th plot.

The model includes some conventional inputs like area of the plot in *kanals*⁷ (Land), fertiliser nutrients applied per plot (NPK), hired labour cost (Hlabour),

⁷*Kanal* is equal to 1/8th of an acre.

Table 1
*Definition of Variables and Their Averages,⁸ By Poverty
 Levels of the Farming Households*

Variables		Very Poor	Poor	Rich
Ln(Q _{ij})	natural log of index of outputs produced at jth plot from kth crop grown at the ith farm;	181.63	175.35	224.35
P ₁	dummy variable assuming value of One if the household is classified to be very poor, otherwise Zero;	0.33		
P ₂	dummy variable assuming value of One if the household is classified to be poor, otherwise Zero;		0.34	
P ₃	dummy variable assuming value of One if the household is classified to be rich, otherwise Zero;			0.33
Ln (Land)	natural log of the size of the plot in kanals;	33.90	38.97	39.94
Ln (NPK)	natural log of fertiliser nutrients if NPK>0, otherwise Zero; and NPK stands for Nitrogen, Phosphorus, and Potash respectively;	282.26	322.78	420.84
RATNPK	ratio of phosphatic fertiliser nutrients to total fertiliser (NPK) used;	0.23	0.21	0.23
DNPK	dummy variable representing value equal to One if NPK is equal to Zero, and assumes Zero for positive values of NPK; ⁹	0.10	0.11	0.08
Ln(HL)	natural log of hired labour cost at the jth plot if the cost is positive, and assumes Zero value when HL=0;	1342.26	1655.28	3151.17
Ln(Twater)	natural log of tubewell water rented and own in hours when Twater>0, and assumes Zero values when Twater=0;	50.29	58.44	102.31
Ln(FI)	natural log of the family members from 14 years of age to 70 years;	6.51	7.35	5.26
Ln(Pest)	natural log of the pesticide expenditures (in rupees) when Pest>0, and assumes Zero values when Pest=0;	1467.03	2149.52	4618.38
Ln(FYM)	natural log of farm-yard-manure used on the plot (in 40kg) when FYM>0, and assumes Zero values when FYM=0;	44.98	67.56	205.45
DHL	dummy variable assuming value of One when HL=0 and takes Zero for HL>0;	0.69	0.62	0.513
DPEST	dummy variable assuming value of One when Pest=0 and takes Zero for Pest>0;	0.50	0.47	0.43
DFYM	dummy variable assuming value of One if FYM=0 and Zero for FYM>0;	0.80	0.73	0.63
DTWater	dummy variable assuming value of One when Twater=0 and takes Zero for Twater>0;	0.60	0.53	0.40
DCANAL	dummy variable assuming value of One if plot receives canal water, otherwise Zero;	0.77	0.730	0.68
%Wlogged	percentage area of the plot affected by water-logging;	4.82	2.73	3.17
%Salinity	percentage area of the plot affected by salinity/sodicity;	6.77	5.45	5.38
Rice/Crop Area	proportionate area under rice crop;	0.26	0.22	0.14
Cotton/Crop Area	proportionate area under cotton crop;	0.10	0.14	0.16
Detail	dummy variable assuming value of One if the plot is located at the tail and of the watercourse, otherwise Zero;	0.35	0.34	0.28
Tenant	dummy variable assuming value of One if the plot is rented in, otherwise Zero;	0.52	0.43	0.29
Education	education of the head of the household in years of schooling;	1.89	2.93	3.32
Age	age of the head of household in years;	48.57	49.04	49.51
Plots	number of plots a household cultivates;	1.69	1.78	1.85
Tractor	number tractors owned;	0.06	0.11	0.20
Twells	number of tubewells owned;	0.18	0.21	0.38
IFLoans	informal loans (in 000 rupees);	1558.43	2638.07	1077.74
FLoans	institutional loans (in 000 Rs).	2062.76	2187.76	10428.98

⁸Averages of all variables are in original units, not in logs.

⁹Following Battese (1997), dummies for variables have also been used that have the zero value in the data to account for different production regimes for farmers who use certain inputs, relative to those who do not. Failing to do so results in biased parameter estimates of the production function using the Cobb-Douglas/Translog functional forms.

family labour (FL),¹⁰ water used at each plot from both rented in and own tubewell (Twater), herbicide and pesticide expenditures incurred at each plot (Pest), and farm-yard-manure (FYM) used at each plot. To accommodate canal water source of irrigation, a dummy variable DCANAL is used.¹¹ The possible impact of soil quality is accounted for by using two variables, which are percentage area waterlogged (%Wlogged) and percentage area affected by salinity/sodicity (%Salinity). To see the impact of cropping pattern/double cropping on farm output, two variables are introduced in the model that are proportionate area under cotton (Cotton/Cropped Area) and proportionate area of the plot under rice crop (Rice/Cropped Area). The reasons for using these variables are threefold. First, sowing of subsequent crop, particularly wheat, is delayed and this delay reduces its productivity. Secondly, in cropping year 2000-2001, productivity of both cotton and rice crops was lower than the normal years because of shortage of canal water and attack of diseases and insects. Thirdly, both of these crops consume the highest proportion of pesticides.

The model also includes two other variables, namely, the rented in plots (Tenant) and the location of the plots at the watercourse (Dtail). These variables are observed at the plot level and, therefore, make more sense to be included in the main production function.

To assess the role of management factors on the production performance, personal characteristics of the farmers like education of the head of household (Education) and age of the head of household (Age) are included in the model. The other variables, which are expected to be influencing productivity performance are land fragmentation—number of plots a household operates (Plots), the number of tractors owned (Tractor), and the number of tubewells owned (Twell) by the household, loan from institutional sources (Floans), and loan from non-institutional sources (IFloans).

To see the impact of poverty on agricultural output and production response coefficients of conventional inputs, we have divided the data into three groups having an almost equal number of observations based on per capita food expenditures of the households. Consistent with these groups, three dummy variables are introduced in the model. These are P_1 , P_2 , and P_3 considered as very poor, poor/transitively poor, and rich, respectively.¹² Table 1 clearly demonstrates that household level use of inputs and the output they produce are considerably different

¹⁰Actual family labour given in the survey was not used in the model due to two reasons. First, the information obtained in the survey was at the household level; and secondly, the data on family labour seemed to be abnormal and many observations were missing. There are various observations where there was neither family labour nor hired labour reported. Therefore, it was decided to use male members of a household between ages of 14 years to 70 years as a proxy for permanent labour.

¹¹Data on the number of turns and hours per turn were available. However, it appeared that the information on this variable is also very crude.

¹²Average food expenditures per person for very poor, poor, and rich farm categories are observed as Rs 476.66, Rs 797.4, and Rs 1838.71, respectively.

across household categories. The main characteristics of these groups are: (1) there are relatively greater problems of waterlogging and salinity on the lands of very poor groups; (2) a greater proportion of poor farmers are located at the tail-end of the watercourses, and most of them are tenants; (3) a poor farmer owns less farm machinery and is a small farmer; (4) poor farmers are less educated; and (5) poor farmers mainly depend on getting loans from non-institutional sources, while the rich ones borrow more from the institutional sources.

The sample mean of binary variables provided in the last three columns of Table 1 is the proportions of the sample plots taking on particular qualitative attributes. For example, about 80 percent, 73 percent, and 63 percent households did not use farmyard manure at the plots belonging to very poor (P_1), poor (P_2), and non-poor (P_3) farmers respectively; and about 35 percent, 34 percent, and 28 percent of the plots are located at the tail-end of the watercourse of the very poor, poor, and non-poor farmers, respectively.

3. RESULTS AND DISCUSSION

3.1. Production Frontier Estimation and Hypotheses Testing

The maximum likelihood estimates of the parameters of the stochastic production frontier and inefficiency model are estimated using Frontier 4.1. Before proceeding to examine the parameter estimates of the production frontier, we need to investigate the validity of the model used for the analysis. The results of the tests of hypotheses are reported in Table 2. These tests are performed using generalised likelihood-ratio statistics, LR, which is defined as: $LR = -2 \ln[L(H_0)/L(H_1)]$, where $L(H_0)$ and $L(H_1)$ are the values of the log likelihood function under the specifications

Table 2

Tests of Hypotheses

Hypotheses	Log Likelihood Function	Test Statistics χ^2	Critical Value $\chi^2_{0.95}$	Decision
Model A	-2022.57			
1. $H_0: \delta_1 = \delta_2 = \dots = \delta_7 = 0$	-2025.76	6.38	15.51	Accepted
Model B (Given the above result)	-2021.49			
2. $H_0: \gamma = \mu \neq 0$	-2025.76	8.54	5.99	Rejected
3. $H_0: \mu = 0$	-2023.92	4.86	3.84	Rejected
Model B vs. Model C				
4. $H_0: \alpha_1 = \beta_1 = \beta_2 = \beta_3; \alpha_2 = \beta_4 = \beta_5 = \beta_6;$ $\alpha_3 = \beta_9 = \beta_{10} = \beta_{11}; \alpha_4 = \beta_{13} = \beta_{14} = \beta_{15};$ $\alpha_5 = \beta_{17} = \beta_{18} = \beta_{19};$ and $\alpha_5 = \beta_{20} = \beta_{21} = \beta_{22}$	-2087.17	131.36	21.03	Rejected

of null and alternate hypotheses, respectively. The LR test statistic has an asymptotic chi-square distribution with degrees of freedom equal to the difference between the number of parameters in the unrestricted and restricted models.

The first hypothesis we tested is $H_0: \delta_1 = \dots = \delta_7 = 0$, which indicates that the farm-level technical inefficiencies are not affected by the independent variables included in the model (Model A).¹³ This null hypothesis is accepted. Given the result of this hypothesis, the error component model (Model B) without technical inefficiency effects was estimated and the second null hypothesis which was performed is $H_0: \gamma = 0$ and $\mu \neq 0$.¹⁴ This hypothesis is rejected, implying that the technical inefficiency effects exist at the farm level and the stochastic frontier production function with truncated normal distribution is the appropriate model to be used for further analysis. The third test that was performed is $H_0: \mu = 0$, which indicates that the one-sided error term is half-normally distributed with mean zero. This null hypothesis was again rejected, implying that the one-sided error term does not have half-normal distribution with mean zero.

The fourth null hypothesis that we tested is that $H_0: \alpha_1 = \beta_1 = \beta_2 = \beta_3, \alpha_2 = \beta_4 = \beta_5 = \beta_6, \alpha_3 = \beta_9 = \beta_{10} = \beta_{11}, \alpha_4 = \beta_{13} = \beta_{14} = \beta_{15}, \alpha_5 = \beta_{17} = \beta_{18} = \beta_{19},$ and $\alpha_6 = \beta_{20} = \beta_{21} = \beta_{22}$, which specifies that the estimates of input elasticities of production do not differ at different levels of poverty [Model B vs. Model C]. The test rejects the specification of Model C, and therefore it is suitable to estimate a model that allows the parameter estimates to vary across the poor and non-poor household levels. Based on tests of hypotheses, we can conclude that the error component model (Model B) assuming truncated normal distribution for the one-sided error term is the most appropriate model to be used for further analysis.¹⁵

3.2. Parameter Estimates of the Production Frontier and the Issue of Poverty

The results of Model B and C are given in Table 3. In total 35 parameters were estimated in the stochastic production frontier model (Model B), including 32 in the production frontier model, and three parameters σ_s^2 , γ and μ relate to variance of the random variables, V_i and U_i . The parameter estimate of γ is 0.11 and is statistically significant at the one percent level.

Out of 35 estimated parameters, 29 are statistically significant. Among those 28 are significant at the five percent level and the one is significant at the 10 percent level. The remaining six estimates are not significant even at the 10 percent level of significance.

The coefficients of land at all the three levels—poor and non-poor—are significant and carry positive signs as expected. The coefficients that are the

¹³The maximum likelihood estimates of Model A are presented in Annexure 1.

¹⁴The parameter, γ , is defined by $\gamma = \sigma^2 / \sigma_s^2$, where $\sigma_s^2 = \sigma^2 + \sigma_v^2$ [Battese, Malik, and Gill (1996)].

¹⁵District-specific dummy variables have not been used in the model because of high collinearity with other independent variables.

elasticities of production increase with the increase in the well-being of the sampled farmers. Production elasticity of land of rich farmers is higher by 13 percent and 28 percent than the production elasticities of the very poor and poor groups of farmers, respectively. This result stipulates that at the present level of inputs use and other resources available to the poor farmers, increase in land at their disposal may not increase the farm output. The average area per plot on the poorer farmers' farms (33.90 *kanals*) is significantly lower than the area the richer farmers have (39.94 *kanals*). So is the status of the overall farm size—average farm size of the first group (very poor) is 70.37 *kanals*; second group (poor) has a farm size of 77.83 *kanals*; and the rich have an average farm size of 82.63 *kanals*. Two conclusions can be drawn from this result: (1) land is more productive at the rich farms; and (2) land distribution using the notion of land reforms in favour of poor/small farmers in the presence of prevailing farm structure, rural infrastructure, and the rural supporting institutions will not increase farm productivity and thus would not help alleviate poverty among the poor farmers. Rather, with the existing land-ownership, if the access of poor farmers to agricultural services is ensured, the agricultural productivity can be increased considerably, which in turn would help reduce poverty. The coefficients of all the four fertiliser-related variables are statistically significant and carry a positive sign. Fertiliser elasticity declined from 0.29 at the very poor farmers' farm to 0.19 at the rich farmers' farm. This indicates that farm production is more responsive to the use of fertiliser at the poor farms as compared to the rich farms. The use of fertiliser per unit of land at the poor farms is significantly lower than the use at richer farms. Therefore, encouraging the use of chemical fertiliser can increase agricultural productivity of the poor farmers. The coefficient of 'phosphate to total NPK ratio' suggests that improvement in this increases farm productivity but the impact is non-significant. The reason could be the less variation in the use of P/NPK ratio. Table 1, in the previous section, shows that the average P/NPK ratio appeared to be the same. Nonetheless, the use is not balanced since the present P/NPK ratio is $\frac{1}{4}$ against the recommended $\frac{1}{2}$. This highlights the fact that promoting greater and balanced use of fertiliser at all farms is needed in order to increase production and thus raise the well-being of the farming community.

All the parameter estimates relating to hired labour are statistically significant at the one percent level. The elasticity estimate shows that the magnitude is significantly lower at the richer farms than the value at poor farms. The reasons could be that about 70 percent of the very poor farmers do not use any hired labour, and even if they do, the use per plot is very small as compared to the use at the farms belonging to the richer farmers. The parameter estimates of the family labour are statistically significant and carry positive signs. The magnitudes of the coefficients are positively associated with the well-being of the farmers groups, e.g., the elasticity of production of very poor farmers is 0.16 while it is 0.23 for the rich farmers. However, the use of family labour is relatively less prevalent on rich farms. These

Table 3

Parameter Estimates of the Stochastic Production Frontiers

Variables		Model C		Model B	
		Coefficients	St. Error	Coefficient	St. Error
Constant	β_0	0.3747	1.0899	0.1501	0.3458
Ln (land)*P ₁	β_1			0.4954***	0.0471
Ln (land)*P ₂	β_2			0.5564***	0.0444
Ln (land)*P ₃	β_3			0.6332***	0.0448
Ln (land)	α_1	0.6418***	19.0504		
Ln (NPK)* P ₁	β_4			0.2886***	0.0338
Ln (NPK)* P ₂	β_5			0.2415***	0.0333
Ln (NPK)* P ₃	β_6			0.1883***	0.0343
Ln (NPK)* P ₃	α_2	0.0694***	3.7798		
P/NPK	β_7	0.2437	1.6647	0.0250	0.1419
DNPK	β_8	-0.0318	-0.2883	0.9031***	0.1614
Ln(HL)*P ₁	β_9			0.1735***	0.0312
Ln(HL)*P ₂	β_{10}			0.1513***	0.0311
Ln(HL)*P ₃	β_{11}			0.1421***	0.0306
Ln(HL)	α_3	0.1993***	6.5097		
DHL	β_{12}	1.0755***	4.6391	0.7865***	0.2235
Ln (TWater)*P ₁	β_{13}			0.0903**	0.0368
Ln (TWater)*P ₂	β_{14}			0.1043***	0.0362
Ln (TWater)*P ₃	β_{15}			0.1027***	0.0358
Ln (TWater)	α_4	0.1402***	4.0714		
DTwater	β_{16}	0.7250***	4.7300	0.5601***	0.1433
Ln (FL)*P ₁	β_{17}			0.1597**	0.0663
Ln (FL)*P ₂	β_{18}			0.2256***	0.0550
Ln (FL)*P ₃	β_{19}			0.2347***	0.0674
Ln (FL)	α_5	0.2328***	5.7862		
Ln (Pest)*P ₁	β_{20}			-0.0651**	0.0319
Ln (Pest)*P ₂	β_{21}			-0.0686**	0.0318
Ln (Pest)*P ₃	β_{22}			-0.0416	0.0311
Ln (Pest)	α_6	-0.0963***	-3.2157		
Dpest	β_{23}	-0.3516	-1.6138	-0.1531	0.2139
Ln(FYM)	β_{24}	0.0396	1.4244	0.0322	0.0282
DFYM	β_{25}	0.1811	1.3269	0.1516	0.1369
Dcan	β_{26}	0.3339***	4.9451	0.3704***	0.0689
%Wlogged	β_{27}	0.0002	0.0950	-0.0007	0.0016
%Salinity	β_{28}	-0.0083***	-5.2201	-0.0070***	0.0015
Rice/Cropped Area	β_{29}	-0.2917***	-3.4154	-0.4660***	0.0849
Cotton/Cropped Area	β_{30}	-0.4243***	-5.4821	-1.4495***	0.1375
Dtail	β_{31}	-0.2505***	-4.3187	-0.2421***	0.0544
Tenant	β_{32}	0.2965***	5.6755	0.2872***	0.0515
	σ^2	0.8372***	12.1043	0.7886***	0.0362
	γ	0.1051	1.3564	0.1113*	0.0612
	μ	0.5932***	3.2497	0.5927***	0.2270

Note: *Significant at the 10 percent level. **Significant at the 5 percent level, and ***Significant at the 1 percent level.

results foretell that the productivity of labour is higher at the well-off farms. This may be due to the reason that the rich farmers' farms are more mechanised, having greater capital-labour ratio than that of the poor. One conclusion that we can definitely draw from this result is that better functioning of labour markets and the reallocation of labour and capital resources could improve farm productivity at poorer farmers' fields.

All parameter estimates relating to water use from the tubewell sources (rented and/or owned) are statistically significant at the one percent level. The magnitudes of coefficients show that elasticity of production at the farms of very poor farmers is slightly lower than that at the farms of other groups. The water markets do not work efficiently because tubewells are immobile capital and water use depends on the availability of a water channel and downstream location of the plots. The data show that only 14 percent of the very poor farmers use their own tubewells for irrigation, while 32 percent of the rich group use their own tubewell water. Consequently, increasing access to tubewell water either through better functioning of water markets and or through improved access to institutional credit for installation of tubewells would help improve farm productivity of poor farmers and thus help in reducing poverty. Table 1 indicates that the non-user percentage of tubewell water on the poorer farms group is significantly higher than the percentage of non-users in the richer farms group. Moreover, the magnitude of water use per plot or per unit of land at the poorer farmers' fields is almost half the use at the richer farmers' fields.

The results show statistically significantly negative impact of pesticide use on poor farms' output, while the coefficient of rich farms is not statistically different from zero. As a matter of fact, the major chunk of pesticides used goes to cotton and rice crops, while the performance of both these crops was poor in the survey year because of availability of canal irrigation water below the normal level and attack of insects and pests. However, the richer farmers have spent about three times more on the purchase of pesticides than the expenditures incurred by the poor farmers. As a consequence, the reduction in rich farms' productivity due to attack of insects and pests was negligible.

The coefficients of farmyard-manure (FYM) variables are not significantly different from zero at 10 percent probability level. It could be due to the reason that most of the times our farmers apply FYM in an un-composed form and, therefore, it may not benefit the crops it is being used for.

To account for the impact of canal water, a dummy variable is included in the model. The parameter estimate is significant at the one percent probability level. The result shows that the plots receiving canal water are significantly more productive than those not receiving any canal water. The other canal irrigation-related variable used in the model is a dummy variables of plots located at the tails of watercourses. The

parameter estimate of this variable is significant at the one percent probability level and carries a negative sign. The magnitude of the coefficient shows that the farmers located at the tail of the watercourses produce about 22 percent less than the production of their fellow farmers located at the middle and/or head of the watercourses.

The data shows that the tail-enders use almost all inputs per unit of land less than the farmers having land at the head and/or middle of the watercourses mainly because of low availability of water (See Annexure 2).¹⁶ The use of tubewell water is, however, slightly higher on the plots located at the tails of the watercourses in order to supplement the shortage of canal water. The data further shows that tail-enders have greater soil-related problems (waterlogging and salinity/sodicity). The other pertinent characteristics of farmers located at the tail are the following:

- their farms are of smaller size than those of their counterparts located elsewhere;
- they keep fewer animals—since fodder crops require greater amount of water;
- they own less farm machinery;
- they have relatively small family size and are less educated;
- they received fewer production loans from institutional sources;
- they have proportionately less area under rice but greater area under cotton; and
- more importantly, a relatively greater proportion of these farmers belongs to the very poor and poor farmer household categories than that of their fellows located elsewhere.

The above facts clearly demonstrate that the lack of a policy to compensate the tail-enders is perpetuating poverty and intensifying it further through land degradation and lower productivity.

The coefficient of salinity variables is negative and statistically significant. The incidence of soil salinity/sodicity on poor farms is higher than on the non-poor farms, implying lower productivity on the plots of the poor than on the plots belonging to the rich farmers. The coefficient of waterlogging variable is also negative, and is however statistically non-significant. This weak inverse relationship between output and the waterlogging problem could be due to the fact that the cropping year 2000-01 was a bad year for agriculture because of an unprecedented drought situation in the country, and therefore the plots affected by the waterlogging problem proved to be a blessing in disguise, resulting in better crop harvests.

Nonetheless, the situation of waterlogging and salinity/sodicity has continued to be a very serious problem in Pakistan. About 2.5 million hectares of land has a water depth of 0-5 feet [Pakistan (2004)]. Such a level of water depth is

¹⁶Punjab farmers located at the head of the distributaries receive 1.6 times higher water discharge from their watercourses than the farmers located at the tail-ends [Shahid, *et al.* (1992)].

considered to be disastrous for agricultural production [Pakistan (1988) and Ahmad, Ahmad, and Gill (1998)], and crop yields on such lands are one-fourth of those being realised on the farms with a water depth of more than 10 feet [Javed (1991); Nadeem (1989); Mustafa (1991)]. However, the problem of waterlogging has decreased to some extent with the government efforts in the lining of canals and watercourses and with the construction for water drainage. The government seems committed to the lining of 100 percent watercourses in the country within the next few years. In contrast, the status of salinity/sodicity is deteriorating in the country. The total affected area with salinity is about 6.2 million hectares. Out of this, about 4.3 million hectares is severely affected by salinity/sodicity and about 80 percent of these lands are not even being cultivated. The remaining 1.9 million hectares is from slightly to moderately saline, producing significantly lower than the potential, resulting in a loss of more than 21 billion rupees of GDP annually [PIDE and PCST (2004)]. The poor farmers having a relatively greater area affected by waterlogging and salinity are adversely affected and thus are falling deeper into poverty. The data used in this study also shows that the applications of almost all inputs per unit of land are significantly lower on plots affected by the salinity and waterlogging problems (Annexure 3). Moreover, both of these problems have a greater incidence in rice-growing areas—since a higher proportion of affected plots has been under the rice crop. Consequently, agricultural productivity is low and the incidence of poverty is high among families cultivating such lands in these areas. The above facts imply that the land reclamation policy needs to be initiated with full intensity in order to stop perpetuation of poverty and to reduce its severity in the country.

The cropping year 2000-2001 was a bad year particularly for the cotton and rice crops due to the shortage of water and attack of diseases and insects. Consequently, the productivity of these crops was lower and faced negative growth trends. It is a well-known phenomenon that in both the cropping systems in Pakistan, the productivity of the subsequent crops sown after rice or cotton is reduced significantly, especially of the wheat crop, due mainly to its delayed sowing. Empirical work shows that the system's productivity has tended to decline in rice-growing areas of the Subcontinent [see Cassman and Pingali (1993); Pingali, Hussain and Gerpacio (1997); Ahmad, Ahmad and Gill (1998); Ahmad, Chaudhry and Iqbal (2002)]. To see the impact of rice area on farm crop production, a variable defined as the ratio of area under rice to the total cropped area at a particular plot is used. The parameter estimate of the rice-cropped area ratio is negative and statistically significant at the one percent level of probability, indicating considerably lower productivity on plots where the proportionate area under rice crop has been greater. Ahmad, Chaudhry, and Iqbal (2002) reached similar conclusion using a completely different data set. The proportionate area under rice in the first group of

farmers at the poverty scale is much more than the area under rice on richer farms. It is about 26 percent, 22 percent, and 14 percent, respectively, on very poor, poor, and rich farmers' farms. In addition to this result, sufficient evidence exists to show that the cropping system where the rice is being grown extensively is resulting in degradation and depletion of land resources [Cassman and Pingali (1993); Pingali, Husain and Gerpacio (1997); Ahmad, Ahmad and Gill (1998)]. This is turning out to be a serious threat in ensuring sustainability of the rice-wheat cropping system in Pakistan.

The parameter estimate of the ratio of cotton area to the total cropped area is also negative and statistically significant at the one percent level; the greater the proportionate area under cotton, the less the overall farm incomes. It is a well-known fact that the harvesting season of cotton crop and the sowing timings of wheat overlap. Consequently, wheat-sowing in cotton fields is delayed and results in reduced wheat productivity.

The tenancy variable turned out to be positive and significant at the one percent probability level. This implies that the farmers realise more of the potential output from the rented in plots.¹⁷ For the tenants, insecurity and financial difficulties are the key factors discouraging investment in more productive enterprising activities like improvements in land and managerial capabilities. Moreover, the tenants generally cultivate small landholdings and are often under financial stress, like paying rent/share, facing high variable costs, and saving something for the family's survival. As a result, the tenants tend to struggle more in achieving a higher production potential. Another main reason of higher productivity at the tenants' plots is that the rented in plots are of better soil quality, and are less affected by waterlogging and salinity (See Annexure 2).

3.3. Technical Efficiencies of Farmers

The technical efficiencies (TE) of the sampled farmers were obtained using Equation 3. As mentioned earlier, the technical inefficiency effects are significant; thus the technical efficiencies of sampled farmers are less than one. The cost accrued to the farmers due to the existence of technical inefficiencies is huge, ranging from 17 percent to 62 percent in terms of loss in output. The un-shaded area in Figure 1 indicates the technical inefficiency, while the shaded area represents the technical efficiency. The un-shaded area amounts to 43 percent loss in output on the average due to technical inefficiency.

¹⁷This result supports some of the work previously published on the issue in Pakistan, e.g., Ahmad, Chaudhry, and Iqbal (2002) and Ahmad and Qureshi (1999).

Fig. 1. Cost of Farm Level Inefficiency.

Table 4 shows that the least efficient group has TE equal to 0.49, implying that the least efficient group realises only 49 percent of the actual potential in agriculture, while the upper 20 percent on the efficiency scale realises 67 percent of the potential output. One major conclusion that can be drawn from the indicators given in Table 4 is that the least efficient group is not only operating significantly below the frontier but also operates at the lower portion of the production frontier. Table 4 further reveals that the least efficient group includes a greater proportion of poor farmers with a greater problem of waterlogging and salinity, less farm machinery, and low access to credit. Moreover, the least efficient group owns a lower number of livestock units, and a relatively greater number of farmers is located at the tail-ends of the watercourses. Enhanced access to the inputs, soil conservation technologies, agricultural credit, etc., would likely raise agricultural output, both along the production function and improvement in total factor productivity,¹⁸ particularly at the fields of the poor farmers.

¹⁸Improvement in TFP can be achieved by shifting the frontier upwards through introduction of new technologies and by helping the inefficient farmers to move closer to the frontier.

Table 4

Average of Variables by Technical Efficiency Groups of Farmers

	Least Efficient (Lowest 20%)	Most Efficient (Highest 20%)
Average Technical Efficiency	0.49	0.67
Farm Size (kanals)	83.77	88.43
Land (kanals)	41.92	39.08
HL (Rs/kanal)	46.05	62.96
Pest (Rs/kanal)	41.15	72.47
FYM (40 kg. maunds/kanal)	1.11	2.74
NPK (kg./kanal)	7.55	8.94
Twater (hours/kanal)	1.19	1.99
%Waterlogged	3.88	3.20
%Salinity	5.90	4.62
Tractor (#)	0.08	0.16
Twell (#)	0.18	0.28
Family Size	11.86	11.96
IFloans (Rs/kanal)	36.62	47.36
FLoan (Rs/kanal)	70.42	102.12
Education (years)	2.89	2.63
Livestock Units	4.00	5.84
Dtail	0.33	0.30
Tenant	0.44	0.43
Rice/Cropped Area	0.18	0.20
Cotton/Cropped Area	0.10	0.10
P ₁	0.33	0.34
P ₂	0.37	0.29
P ₃	0.30	0.37

4. CONCLUSION AND POLICY IMPLICATIONS

The results of the production frontier analysis show that the input elasticities of production are different at different levels of poverty. Production elasticity of land is about 28 percent higher at the rich farms than that at farms of the poorest group. However, elasticities of production with respect to fertiliser, hired labour, and water are greater at the poor farms. The data show that the use of these inputs per unit of land at the poor farmers' farms is considerably lower than the use at the rich farms. The salinity/sodicity problem is adversely affecting the farm productivity and efficiency, particularly at the poor farmers' farms. This, in turn, affects their ownership of other assets like farm machinery and livestock.

Farm productivity is negatively associated with the increase in proportionate area under rice crop. Moreover, sufficient evidence exists that in the cropping system where the rice is being grown extensively, the lands are being degraded and depleted. The data used in this study show that a considerably high percentage of total cropped area was allocated to rice crop on poor farms in cropping year 2000-01. The results also show that farm output is negatively associated with the greater proportionate area sown under cotton during the survey year mainly because of drought in the country and insect and pest attack.

Further, the results suggest that the rented in plots yield higher output. It may be due to the fact that these plots are of better soil quality, relatively less affected by waterlogging and salinity. The results reveal that the plots located at the tail-ends are significantly less productive as compared to the plots situated at the middle and/or head of the watercourses. The tail-enders use almost all inputs per unit of land, except tubewell water, but less than their counterparts, and have greater problems of waterlogging and salinity/sodicity.

The average cost accrued to the farmers due to the existence of technical inefficiencies is about 43 percent in terms of loss in output, with wide variations ranging from 17 percent to 62 percent. The input use is higher at the more efficient farms as compared to that on the inefficient farms. The least efficient group includes a greater proportion of poor farmers, who have a greater problem of waterlogging and salinity, have low access to credit, own less farm machinery, own a lower number of livestock units, and are more frequently located at the tail-end of the watercourses.

An important conclusion of the efficiency analysis is that the least efficient group is not only operating significantly below the frontier but also operates at the lower portion of the production frontier. The land is more productive at the rich farms. This implies that following a simple land distribution mechanism—using the notion of land reforms in favour of poor/small farmers—in the presence of prevailing farm structure, rural infrastructure, and weak farm-supporting institutions may not increase farm productivity and thus would not help alleviate poverty in rural areas. The results call for a strong and active role of the government in close partnership with the private sector in the rural areas in initiating income-generating activities both for the farm and non-farm poor households to break the vicious circle of poverty, land degradation, and low agricultural productivity. It is strongly felt that there is a need to establish agri-malls, possibly in joint private-public partnership, or encouraging the private sector by providing incentives like loans on attractive terms and conditions, better infrastructure, and other facilities to establish such type of businesses to put a stop to linearly rising poverty (which has an almost one-to-one relationship with low agricultural productivity). Such activities would improve access to inputs that would be an effective way to improve agricultural productivity and to reduce poverty. There is also a need to support and strengthen the non-farm sector to generate employment.

The interlocking of land degradation and poverty necessitates a land reclamation policy. Moreover, the area allocated to rice crop, particularly for coarse varieties, needs to be rationalised where the country has no comparative advantage. It is also required that cultivation of legumes and use of green manuring be promoted to restore soil fertility in affected areas. It is also imperative to have a gypsum use policy in the country, besides the use of fertiliser.

The results demonstrate that there is a lack of policy to compensate the tail-enders. Current practices are perpetuating poverty and intensifying it further through land degradation and lower productivity. Therefore, investment by the Irrigation Department as well as by the farmers or their organisations in desilting and lining of canals/watercourses may play an important role in increasing agricultural productivity and thus reducing poverty.

Annexure 1

Parameter Estimates of Model A

	Coefficient	Standard-error	t-ratio
Constant	-0.3466	0.8838	-0.3922
Ln (land)*P ₁	0.5318	0.3759	1.4148
Ln (land)*P ₂	0.5703	0.4580	1.2453
Ln (land)*P ₃	0.6663*	0.3609	1.8459
Ln (NPK)* P ₁	0.2846	0.1703	1.6715
Ln (NPK)* P ₂	0.2464	0.1631	1.5107
Ln (NPK)* P ₃	0.1870	0.1622	1.1532
P/NPK	0.1031	0.9899	0.1042
DMPK	0.8540	0.9213	0.9269
Ln(HL)*P ₁	0.1698	0.1193	1.4227
Ln(HL)*P ₂	0.1535	0.1210	1.2679
Ln(HL)*P ₃	0.1509	0.1209	1.2480
DHL	0.8026	0.9032	0.8886
Ln (Twater)*P ₁	0.0736	0.2103	0.3502
Ln (Twater)*P ₂	0.0884	0.1957	0.4515
Ln (Twater)*P ₃	0.0861	0.1997	0.4313
DTWH	0.5107	0.8852	0.5769
Ln (FL)*P ₁	0.1346	0.8678	0.1551
Ln (FL)*P ₂	0.2126	0.7509	0.2832
Ln (FL)*P ₃	0.2153	0.7933	0.2714
Ln (Pest)*P ₁	-0.0715	0.1236	-0.5785
Ln (Pest)*P ₂	-0.0782	0.1234	-0.6339
Ln (Pest)*P ₃	-0.0588	0.1201	-0.4891
Dpest	-0.2459	0.8915	-0.2758
Ln (FYM)	0.0438	0.1664	0.2633
DFYM	0.1793	0.8690	0.2064
Dcan	0.3823	0.7629	0.5012
%Wlogged	-0.0006	0.0035	-0.1574
%Salinity	-0.0069*	0.0036	-1.9180
Rice/Cropped Area	-0.4616	0.9418	-0.4901
Cotton/Cropped Area	-1.4198	0.9791	-1.4502
Dtail	-0.2475	0.7307	-0.3387
Tenant	0.2891	0.4408	0.6558
δ ₀	0.1994	0.5802	0.3437
δ ₁	0.0203	0.0245	0.8271
δ ₂	0.0005	0.0063	0.0783
δ ₃	-0.1028	0.2419	-0.4248
δ ₄	0.1543	0.2468	0.6252
δ ₅	-0.0925	0.9159	-0.1010
δ ₆	0.0247	0.2799	0.0883
δ ₇	-0.1575	0.3173	-0.4965
σ ²	0.7939***	0.0595	13.3380
γ	0.0059	0.0572	0.1029

Note: *Significant at the 10 percent level. ***Significant at the 1 percent level.

Annexure 2

*Use of Inputs and Output Produced at Rented in Plots and Plots
Located at the Tail of the Watercourse*

Variables	Farm Location		Tenancy Status	
	H&M	Tail-enders	Owner	Tenant
Farm Size (kanals)	84.41	71.45	79.16	73.78
Land (kanals)	41.88	36.70	37.75	37.39
NPK (kgs.)	406.95	338.48	353.08	325.94
P/NPK	0.23	0.2106	0.22	0.22
DNPK	0.06	0.075	0.11	0.08
HL (Rs)	2524.20	1988.45	2198.51	1834.58
Pest (Rs)	3514.92	2540.04	3365.84	1854.61
Twater	44.55	39.93	83.92	50.90
FYM (40 kgs.)	146.49	56.48	163.00	24.38
DLAB	0.60	0.54	0.57	0.65
DPEST	0.47	0.43	0.45	0.49
DFYM	0.27	0.27	0.36	0.16
DWAT	0.62	0.58	0.40	0.66
DCAN	0.98	0.99	0.66	0.82
%Waterlogged	3.64	4.46	4.55	2.18
%Salinity	5.85	7.93	6.60	4.82
Rice/Cropped Area	0.25	0.24	0.18	0.25
Cotton/Cropped Area	0.14	0.16	0.14	0.12
Output Index (Q _{ij})	291.81	154.06	167.92	230.63
Value of Output				
(Rs/farm)	54376.85	37311.21	43235.27	44521.01
Tenant	0.48	0.45		
Dtail			0.30	0.35
Tractor	0.15	0.10	0.16	0.07
Twell	0.17	0.13	0.36	0.11
IFLoan	1880.67	1917.75	1424.86	2236.30
FLoan	6958.42	4026.27	6927.10	1976.12
Education	3.00	2.63	3.06	2.21
Family Size	11.81	10.86	10.43	11.59
Livestock Units	4.69	4.10	4.92	3.81
P ₁	0.35	0.36	0.27	0.42
P ₂	0.32	0.36	0.32	0.35
P ₃	0.34	0.29	0.40	0.23

Note: H&M denote head and middle.

Annexure 3

Average Use of Inputs and the Output Produced at Non-problem and Problem Soils

	Saline		Waterlog	
	Non-saline	Saline	No Waterlog	Waterlogged
Farm Size (kanals)	74.75	86.62	77.46	70.58
Plot Area (kanals)	35.75	45.76	37.43	39.75
NPK (kgs/kanal)	9.35	8.21	9.30	6.70
HL (Rs/kanal)	56.78	46.57	57.47	19.96
Pest (Rs/kanal)	77.14	58.58	77.45	20.99
Twater	1.99	1.45	1.98	0.65
DCAN	0.70	0.85	0.72	0.86
P/NPK	0.23	0.19	0.22	0.19
DNPK	0.11	0.06	0.10	0.04
FYM (40 kgs./kanal)	2.46	4.04	3.01	0.53
DHL	0.61	0.59	0.60	0.73
DPEST	0.47	0.45	0.46	0.58
DFYM	0.29	0.24	0.29	0.16
Dwater	0.50	0.56	0.49	0.69
%Waterlogged	2.11	10.04		47.43
%Salinity		31.79	4.85	18.28
Rice/Cropped Area	0.19	0.27	0.19	0.40
Cotton/Cropped Area	0.13	0.16	0.14	0.07
Output Index	5.65	3.43	5.28	3.68
Value of Output	1248.76	871.57	1192.53	831.94
Dtail	0.30	0.44	0.31	0.43
Tenant	0.42	0.36	0.42	0.36
P ₁	0.32	0.37	0.32	0.47
P ₂	0.34	0.31	0.34	0.31
P ₃	0.34	0.31	0.34	0.22

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