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while simulating expected returns in the command area under various area combinations of two crop rotations.

Findings and Conclusions

The main finding of the study is a set of optimal decision rules for applying irrigation water of Tomaria reservior in different crops and in different fortnightly periods under various combinations of inital soil moisture and initial water supply. Table II presents the optimal irrigation decision rules and corresponding quantities of water to be applied in different crops in four fortnights. In the first two fortnights only sugarcane crop was in the field to be irrigated whereas in the later two fortnights paddy and sugarcane competed for irrigation. The study also showed that the gross returns in the command area of Tomaria reservoir can be increased by shifting land from paddy + wheat rotation to sugarcane at the current prices of Rs. 105, Rs. 75 and Rs. 12 per quintal of wheat, paddy and sugarcane respectively, and at the existing level of fertilizer use. The study indicated that the gross return in the command area of Tomaria reservoir could have been increased by 20 per cent by adopting optimal decision rules and adjusting area under the three crops.

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AND A. S. SIROHI*

AN ANALYSIS OF THE IMPACT OF FACTOR-PRODUCT PRICES AND CREDIT AVAILABILITY ON THE DEMAND FOR FERTILISERS IN THE PUNJAB

Fertiliser is one of the most crucial inputs in farming. It can bring about a rapid increase in agricultural production even in the short-run, which is the dire need of a developing country like India. However, the continuous use and adoption of fertiliser depend mainly on its profitability and physical availability at the right time.

It would be important to analyse the impact of factors which are responsible for the consumption of fertiliser. Most of the work done on the demand of fertiliser use deals with the responsiveness of fertiliser to changes in its own prices.[1] The estimates of price elasticity of fertiliser demand do not show consistent pattern, because the demand for fertiliser as an input cannot be divorced from the prices of the resulting output. In optimizing the use of this important input, its price must be related to the price of the final product and the availability of working capital. This study is, therefore, an attempt in this direction where all these points have been taken into consideration and the impact of each of these factors on the demand for fertiliser has been analysed.

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1. Such studies are listed in the references.

The main objective of the study is to examine the impact of factor/product prices and availability of working capital on the demand for fertiliser[2] by estimating the elasticities of demand with respect to fertiliser prices, product prices and availability of working capital in one of the most agriculturally developed States of India, *i.e.*, Punjab, where the yields of major food crops are comparable to that of most developed regions of the world.

Design of the Study

Data for this study, relating to the year 1972-73, were obtained from the information generated under the scheme 'Cost of Cultivation of Principal Crops in the Punjab.[3] Three-stage random sampling design with tehsil[4] as the first stage unit, a cluster of three villages, the second stage unit, and the operational holding as the ultimate unit was adopted. The entire State of Punjab was divided into three crop homogeneous zones, *viz.*, (*i*) wheat, paddy and maize zone, (*ii*) wheat, maize and groundnut zone, and (*iii*) wheat, cotton and bajra[5] zone.

In all, 20 tehsils were selected from the above-mentioned three zones. The number of tehsils selected from each zone was proportional to the area under the principal crop. In each selected tehsil one nucleus village was selected with varying probability in a similar way which was used for the selection of tehsils in a zone. Then a cluster of three villages, as the second stage unit, was formed around the nucleus village. In this way, 20 clusters were selected in all, *i.e.*, one from each tehsil. In each cluster, all the operational holdings were arranged in ascending order of their size. The total number of holdings was then divided into five groups in such a way that the area in each group was approximately equal. Then two holdings from each size-group were selected at random for giving representation to all sizes of holdings. In this way, ten holdings from each cluster and 200 holdings in all were selected. On the basis of these holdings one representative farm situation was constructed in each zone by taking the arithmetic means of farm size, resources, input-output, net price coefficients, etc. This representative farm situation was considered as the basis for the programming analysis.

The Analytical Model

Parametric linear programming (LP) model was used to generate the requisite data for the estimation of fertiliser demand functions. Such an approach has to be preferred over the conventional method of estimating the fertiliser demand functions mainly because there were no quality time-series data available. It may, however, be pointed out here that the approach used is normative, accounting for the cultivators' potential response under the cele-

2. In this study, the term fertiliser is used to represent nitrogenous fertilisers which constitute the bulk of all fertilisers consumed in the State.
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4. Tehsil is a revenue unit in a district.
5. Pearl millet (*Pennisetum typhoides*).

brated assumption of profit maximization and perfect knowledge about the economic and biological environments around them. Realising that these circumstances might result generally in an over-estimation of demand response over the actual demand response, we have tried to minimize the same by structuring the model such that important socio-economic and behavioural factors influencing the farmer's response were directly or indirectly built into the LP model used.

The present study takes into account the sensitivity of fertilizer demand with respect to changes in the fertiliser and product prices and availability of capital mainly due to changes in the crop mix and varying rates of nutrient application on the important crops. Specifically, in zone I (paddy zone) three paddy growing activities using respectively 71.36, 58.89 and 86.04 kg. of nitrogen per hectare were incorporated in the model. Similarly, every effort was made to incorporate more than one production activity using different levels of fertilisers per hectare for the important crops in each zone. The sensitivity of fertiliser demand is, therefore, affected only to a limited extent by the rates of application on specific crops because for individual crops as many activities as the levels of application of nutrient could not be incorporated in the model.

The simplex linear programming model, incorporating various constraints about land, labour, working capital, minimum and maximum area for specific crops and fertiliser nutrient constraints, is given as below:

We wish to find the maximum Z of the objective function

$$Z^* = \max_{x} \; (cx)$$

Subject to the linear constraints

$$A X \; (\leq \; = \; \geq) b$$

and the non-negativity restrictions

$$X \geq 0,$$

where,

Z is the value of the objective function, *i.e.*, returns to fixed farm resources in rupees, under the optimal plan x*,

c is the n-dimensional vector of coefficients of the objective function c_j for j = 1, 2 ... n,

x is the n-dimensional vector of the level of activities x_j for j = 1, 2 ... n,

A is the m × n matrix of coefficients representing the technical and institutional structure of production, and b is the m-dimensional vector of fixed and quasi-fixed factors and numerical values of behavioural constraints b_i for $i = 1, 2...m$,

The optimal solution is indicated by starred variables.

Activities Used

Besides all the important crop activities in the three zones, capital borrowing, labour hiring and fertiliser purchase activities were also considered among the real activities. Input-output coefficients for all the crop activities were calculated separately at their respective existing levels for all the three zones from the data collected from the sample farmers as under:

(*i*) *Returns to fixed farm resources:* The objective function was to maximize the net returns. These were obtained by subtracting variable expenses of each crop enterprise from their respective gross returns on per hectare basis.

(*ii*) *Variable expenses:* The variable expenses were also calculated on per hectare basis and included cost of seeds (purchased as well as home produced), insecticides, pesticides, manures purchased and produced at the farm and fertilisers, irrigation charges, if any, casual labour charges, hired machinery charges, bullocks feed costs, fuel and lubricants, etc.

The input-output data and constraints used for the programming analysis were prepared for three crop homogeneous zones separately. Important economic constraints, such as, land, capital available for farming, human labour, etc., were developed by taking means in each of the three zones.

Variable price programming for fertiliser was carried out with two sets of activities for the average farm resource situations in each zone. In all, 24 observations were generated to fit the fertiliser demand functions, taking the different levels of fertiliser prices, product prices and capital level as given below:

(*i*) Three levels of fertiliser prices were specified. First level was the prices existing before the sharp increase in fertiliser prices in June, 1974. The second level was the prices, *i.e.*, after June, 1974 and the third level consisted of the latter set of prices increased by 50 per cent.

(*ii*) Four levels of product prices, measured as price indexes,[6] were also taken. These were the average post-harvest prices pertaining to the years 1971-72 to 1974-75.

6. The method followed in preparing price indexes is given in the Appendix and was adopted from O. Ogunfowora and D. W. Normann, "Farm-Firm Normative Demand Response in the North Central State of Nigeria," *Journal of Agricultural Economics,* Vol. XXIV, No. 2, May, 1973, pp. 301-309.

(*iii*) Two levels of working capital were also specified, one with existing level of capital with the farmer and the other unrestricted capital by introducing a capital hiring activity at the prevailing rate of interest.

The programming analysis of each possible combination of independent variables at their specified levels resulted in 24 observations which were used in estimating the demand functions.

The solution quantities of fertiliser (N), the prices of fertiliser, prices of output and capital levels were used to construct a smooth continuous regression function from which the elasticities were worked out. Since the data do not meet the assumption of normality and independence, statistical inference and probability statements cannot be made.

Fertiliser Demand Model

The fertiliser demand function can be theoretically stated as:

$$D_f = f(X_1, X_2, X_3, T),$$

where

D_f = demand for fertiliser per unit of time,
X_1 = price of fertiliser,
X_2 = price index of product prices,
X_3 = capital level, and
T = level of technology.

The level of technology was assumed constant in the short-run and hence the fertiliser demand functions got reduced to the following:

$$D_f = f(X_1, X_2, X_3).$$

Two types of functions, namely linear and log-linear were fitted and the criteria for assessing the best fit of a function were: (*a*) conformity of signs of regression coefficients with economic logic, and (*b*) the size of the coefficients of multiple determination, *i.e.*, R^2.

The elasticities with respect to fertiliser prices., product prices and capital level were got directly from the log function and from the linear function these were worked out at the arithmetic mean levels using the following formula:

$$e_{x_i} = \frac{\partial D_f}{\partial X_i} \frac{\bar{X}_i}{\bar{D}_f}$$

where,

e_{X_i} = estimate of elasticity of fertiliser demand with respect to the variable X_i,

D_f = quantity of fertiliser demand per annum,

X = ith independent variable,

$\bar{X}_i$ = mean of ith independent variable, and

$\bar{D}_f$ = mean quantity of the fertiliser demanded.

Assumptions

Besides the fundamental linear programming assumptions, following additional assumptions were required: (*i*) rational behaviour of the farmer; (*ii*) perfect knowledge about prices, technological changes, environmental factors, etc.; (*iii*) the supply of working capital for farming purposes was considered available according to the need of the farmers at existing rate of interest and farmers are supposed to borrow capital to the extent it is profitable, *i.e.*, upto the point where marginal value product of capital=rate of interest; (*iv*) labour is available at existing wage rate; and (*v*) the area under *kharif* and *rabi* fodders in the existing plan was considered as optimum.

Fertiliser Demand Functions

As already mentioned, two types of fertiliser demand functions, linear and log-linear, were fitted separately for each of the three zones. These functions along with their R^2 values are presented in Table I.

TABLE I—FERTILISER DEMAND FUNCTIONS FOR THE PUNJAB STATE: 1972-73

Zone	Type of function	Function	R^2
I	Linear	$94.3918-13.9475X_1-22.1035X_2+333.7464X_3$	0.9764
	Log-Linear	$2.677X_1^{-0.1401}X_2^{-0.0726}X_3^{0.9934}$	0.9733
II	Linear	$93.4967-31.8564X_1+116.3834X_2+288.4277X_3$	0.6481
	Log-Linear	$2.7136X_1^{-0.2612}X_2^{0.1624}X_3^{0.8182}$	0.7830
III	Linear	$15.3626-43.0527X_1+183.6779X_2+399.4815X_3$	0.8207
	Log-linear	$2.7572X_1^{-0.2964}X_2^{0.4309}X_3^{0.9289}$	0.8237

All the signs attached with the regression coefficients were rational and consistent with economic logic except in one case, *i.e.*., regression coefficient attached with product price which bore negative sign in zone I. This coefficient was too low, and hence it was ignored.

Estimates of Elasticities

The coefficients of elasticities with respect to fertiliser price, product price and capital level were obtained directly from the log-linear function and from the linear function these were worked out at their mean levels as already stated. The estimates obtained from these functions are given in Table II.

TABLE II—ESTIMATES OF DEMAND ELASTICITY FOR NITROGENOUS FERTILISER IN PUNJAB: 1972-73

Zone	Function	Estimates of elasticities with respect to		
		Fertiliser price (X_1)	Product price (X_2)	Capital (X_3)
I	Linear	—0.1210	—0.0504	0.9850
	Log-linear	—0.1401	—0.0726	0.9934
II	Linear	—0.2653	0.2720	0.8170
	Log-linear	—0.2612	0.1624	0.8182
III	Linear	—0.3067	0.3626	0.9698
	Log-linear	—0.2964	0.4309	0.9289

The elasticities with respect to fertiliser price obtained from log-linear functions were —0.1401, —0.2612 and —0.2964 in zones I, II, and III respectively. The demand elasticity with respect to capital was 0.9934 for zone I, 0.8182 for zone II and 0.9289 for zone III. The elasticity coefficients worked out from linear functions at the mean levels of the fertiliser price, product price and capital level were quite close to their corresponding estimates obtained from the log functions.

Conclusions

The results of this study showed that the estimates of elasticities of demand for fertiliser with respect to its price were very low and close to zero, indicating thereby that the demand for fertiliser was inelastic with respect to its price. It implied that a smaller cut in the price of fertiliser by the Government with the hope of boosting up fertiliser demand and agricultural production, may not achieve the desired objective. On the other hand, since the availability of working capital turned out to be an important variable affecting the demand for fertiliser, therefore, it appeared likely that a desired increase in the demand for fertiliser and agricultural production may be effected through liberal availability of working capital to the farmers on easy terms and at the right time.

Because the demand for fertiliser is mainly a derived demand, depending on product prices, hence the estimates of elasticity with respect to product price were observed to be positive in general, varying from 0.1624 to 0.4309. Since increasing product prices appear to be a doubtful option for any government interested in boosting up fertiliser demand, hence it may be suggested that fertiliser price cuts along with liberal credit supply to the farmers may be effected. This would hopefully lead to increased demand for fertiliser and agricultural production without adding to inflation.

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APPENDIX

NOTES ON THE CALCULATIONS OF PRICE INDEXES USED IN THE FERTILISER DEMAND FUNCTIONS

The prices of all the products in the parametric programming model change more or less together. The solution quantity of each product did not remain constant over all price changes, presumably because of enterprise substitution.

Thus, in order to give individual products weights that are commensurate with their importance, their prices were weighted by the quantities of individual products generated by the optimum solutions usiug Fisher's Ideal formula:

$$P = \left(\frac{\Sigma\, p_1 q_0}{\Sigma\, p_0 q_0} \cdot \frac{\Sigma\, p_1 q_1}{\Sigma\, p_0 q_1}\right)^{\frac{1}{2}}$$

where,

P = price index,

p_0 = base price of the product,

p_1 = changed price of product,

q_0 = base quantity of product derived from the first linear programming solution, and

q_1 = quantity of product when its price is changed.

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REFERENCES

1. Zvi Griliches, "The Demand for Fertilizer: An Economic Interpretation of a Technical Change," *Journal of Farm Economics*, Vol. 40, No. 3, August, 1958, pp. 591-606.

2. Zvi Griliches, "The Demand for Inputs in Agriculture and a Derived Supply Elasticity," *Journal of Farm Economics*, Vol. 41, No. 2, May, 1959, pp. 309-322.

3. Yujiro Hayami, "Demand for Fertilizer in the Course of Japanese Agricultural Development," *Journal of Farm Economics*, Vol. 46, No. 4, November, 1964, pp. 766-779.

4. Earl O. Heady and Martin H. Yeh, "National and Regional Demand Functions for Fertilizer," *Journal of Farm Economics*, Vol 41, No. 2, May, 1959, pp. 332-348.

5. Robert C. Hsu, "The Demand for Fertilizer in a Developing Country: The Case of Taiwan, 1950-66," *Economic Development and Cultural Change*, Vol. 20, No. 2, January, 1972, pp. 299-309.

6. Ashok K. Parikh, "Consumption of Nitrogenous Fertilizer: A Continuous Cross-Section Study and Co-Variance Analysis," *Indian Economic Journal*, Vol. XIV, No. 2, Econometric Annual, 1966 pp. 258-274.

7. Ashok K. Parikh, "Demand for Nitrogenous Fertilisers: An Econometric Study," *Indian Journal of Agricultural Economics*, Vol. XX, No. 3, July-September, 1965, pp. 13-19.

8. P. L. Sankhayan and A. S. Sirohi, "Step Demand Functions for Fertilizers in Mandi District of Himachal Pradesh," *Indian Journal of Agricultural Economics*, Vol. XXVII, No. 3, July-September 1972, pp. 69-77.

9. Y. Sung Bai, Dale C. Dahl, and Yong K. Shim, "Projection of the Demand for Fertiliser-Time-Series Data Analysis," *Journal of Agricultural Economics* (Korea), Vol. 15, 1973, pp. 21-32.

TRENDS IN FARM MECHANIZATION DURING THE POST-GREEN REVOLUTION PERIOD AND ASSOCIATED VARIABLES—AN INTER-STATE ANALYSIS*

The main objectives of this paper are to analyse (*i*) the trends in farm mechanization in India, (*ii*) to study the inter-State variations in and (*iii*) the variables associated with farm mechanization.

Trends in Farm Mechanization

Before the 'fifties there was no significant use of machines in Indian agriculture. Using the Quinquennial Livestock Census of India, the trends of the most important farm machines—tractors, oil engines and electric pumps—from 1951 to 1972 are given in Tables I and II. Information relating to wooden as well as iron ploughs is also shown. The percentage growth rate of machines and implements between the quinquennia is shown in Table I and their intensity is shown in Table II. Tractors, electric pumps and oil engines reach new heights in 1972. The rate of growth is the highest and more dramatic during the period 1966-1972. Throughout the period iron ploughs substituted wooden ploughs. Wooden ploughs even showed decreasing trend between 1966 and 1972. One would naturally attribute the dramatic rise in machines to the 'Green Revolution' which has started in the middle 'sixties and spread during this period.

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