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FERTILIZER DEMAND FOR WHEAT CROP IN PUNJAB

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Lately, a great deal of interest has been shown in projecting the country's requirements of fertilizers in the seventies. Most important among the estimates are those of the Committee on Fertilizers, Working Group of Manures and Fertilizers, USAID, Donahue and Brown.[1] The methodology adopted by them may differ, but the conclusions are more or less identical within limits of tolerance. The methodology adopted by these studies is the use of optimum doses of fertilizers (N, P and K), the levels which maximize the profit or the net returns of various crops.

Though fertilizer is one of the important inputs for increasing agricultural production, it is not a sufficient input by itself. Timely and adequate supply of water and other inputs is equally essential. With the increased demand for fertilizers, the levels of other inputs need to be changed in order to get maximum profit. The recommendations about the optimum fertilizer doses does not solve the problem. The recommendations of doses of fertilizer should be such that they are consistent with the prevailing levels of other inputs such as irrigation, improved farm machinery, improved seeds and the other farm practices. To estimate the future demand for fertilizer, it is, therefore, important to consider the future levels of other inputs as well because it is the interaction of all these inputs which increases the agricultural production. Keeping all this in view, the model adopted in this paper to estimate the fertilizer demand for wheat in Punjab is discussed below. No attempt has been made to estimate the demand for other inputs but the model takes care of these changes while estimating the fertilizer demand.

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1. S. M. H. Burney, "National Policy for Agricultural Inputs in Seventies," Seminar on Co-ordinated Marketing and Use of Fertilizers and Other Inputs, Proceedings, The Fertilizer Association of India, New Delhi, 1970.

MODEL

If D_t^i is the demand for the ith type of fertilizer (i = N, P, K) during the tth year, then $D_t^i = A_t \times F_t^i$ .... (1)

where A_t is the area under wheat (in hectares) and F_t^i is the amount (in kgs.) of the ith fertilizer to be used on one hectare of wheat crop.

To estimate the future demand for N, P and K, it is, therefore, necessary to project the area under the crop as well as the fertilizer dose.

Area under Wheat

For projecting the area (A_t) under wheat, if we assume that the rate of change of A_t is proportional to its size, *i.e.*, $\frac{DA}{dt} \propto A$, then we get the exponential growth curve of the type $A_t = \alpha B^t$ where $G = (B-1) \times 100$ is the compound rate of growth (in per cent) per annum.

This model though widely used for projecting the acreage has the drawback that A_t tends to be very very large ($A_t \rightarrow \infty$ for $t \rightarrow \infty$), which is unrealistic.[2] In fact the more realistic curve for the acreage plotted against time-axis is exponential in the initial stages and should reach a plateau—that is a Sigmoid Curve.

If the cultivated area C in Punjab may be taken as the ultimate target, for wheat acreage (it is not necessary to assume that the whole of the cultivated area will come under wheat), then the Probit transformation of $\frac{A_t}{C} \times 100$ transforms the Sigmoid Curve to a straightline relationship given by:[3]

$$\text{Probit}^4 \left(\frac{A_t}{C} \times 100\right) = A + Bt \qquad \ldots\ldots\ldots (2)$$

where t is the time variable for the period 1950-51 to 1971-72 (t = 0 for 1965-66 representing the pre-green revolution year), and C is the cultivated area and A_t is the area under wheat.

It has been assumed here that with the increase in irrigation and increase in the levels of other farm technology, the area under wheat is bound to increase. The gap between the cultivated area and the area under wheat will be narrowing with the passage of time.

2. H. K. Bal and D. Raghavarao : Long and Short Run Projections of Area under Wheat in the Punjab State (unpublished).
3. R.A. Fisher and F. Yates: Statistical Tables for Biological, Agriculture and Medical Research, Oliver and Boyd, Edinburgh, 1943, p. 69.
4. The probit corresponding to a given percentage is the normal deviate (increased by 5 to avoid negative values) for which the probability (single tail) equals this percentage.

Fertilizer Doses

Fertilizer doses which maximize the profit or the net returns to the farmer vary with the levels of other agricultural inputs such as irrigation, seed rate, and the technological advances as applied to agriculture and the input-output price ratios, etc. Therefore, the recommended fertilizer doses which are worked out by maximizing the profits followed by the recommended levels of other inputs must not be confused with the optimum doses which are obtained at the existing (or current year's) levels of other inputs. The recommended fertilizer doses are normally obtained from the experimental data where the other inputs are held at their best. These doses, however, may not fare well at the existing levels of other inputs when the recommendations are made at the farmer's level. But it can be assumed that the new farm technology will help in increasing the levels of all the inputs and the farmers will be motivated to achieve the target of recommended doses of all the inputs. This may take years to train the farmers to adopt the recommendations in a proper way and this also requires the timely supply of inputs. Therefore, these recommended doses can be taken as the target doses in the following models which are to be used for estimating the future doses of N, P and K.

$$\text{Probit}\left(\frac{F_t^{ia} \times 100}{F_T^i}\right) = a + bt \qquad \ldots\ldots\ldots (3)$$

and $$\text{Probit}\left(\frac{F_t^{io}}{F_T^i} \times 100\right) = a' + b' t \qquad \ldots\ldots\ (4)$$

where i = N, P and K,

F_T^i = target dose of ith type of fertilizer,

F_t^{ia} = average dose (kgs./hectare) used by the farmers during the tth year,

F_t^{io} = optimum dose (kgs./hectare) obtained from the sample farmer data with the existing levels of other inputs, and

t = time variable ($t = 0$ for 1965-66, *i.e.*, the pre-green revolution year).

Here, the target doses (F_T^i) and the optimum doses (F_t^{io}) were obtained by fitting the response surfaces to the experimental data relating to Kalyan wheat (1971-72) and the farmers' data through sample survey for the year 1971-72.[5] The response surface is given below :

$$Y = a + b_{1N}\,N + b_{2N}\,N^2 + b_{1P}\,P + b_{2P}\,P^2 + b_{NP}\,NP + b_k\,K$$

5. Annual Report of the All-India Co-ordinated Agronomic Experiments—Schemes, Data Volumes I and II, Kharif and Rabi, 1971-72, Department of Soils, Punjab Agricultural University, Ludhiana, 1972.

It was not possible to get the optimum dose of K from this response surface because the square term and its interaction with other nutrients were not present in the function. The reason for deleting these terms was that in the experimental data only two levels of K (0 and 60 kgs.) were considered and in the farmers' data, a large proportion of the farmers did not use this nutrient and even those who used it, did so in a small quantity.

The doses of N and P which maximized the profit ($Y.P_y - N.P_N - P.p_P$) were obtained from the equation :

$$\frac{\partial Y}{\partial N} = \frac{p^N}{p^Y} , \quad \frac{\partial Y}{\partial P} = \frac{p^P}{p^Y}$$

where p_Y, p_N and p_P are the product and factor prices.

Recognizing the importance of the variability of farmers' attitudes, responsiveness of crop, variation in rainfall and availability of irrigation water and differences in soil fertility among the districts of Punjab, it was not considered as valid to estimate F_t^i (t = 1971-72) for the pooled sample of the farmers at the State level.

For this purpose, the Punjab State was divided into three zones homogeneous with respect to the agro-climatic conditions. The details of the zones and the selection of the ultimate unit (cultivators) are shown in Appendix 1. In all, there were 72 cultivators from Zone I, 72 from Zone II and 72 from Zone III.

Response surfaces were fitted for each zone and the optimum doses were worked out for each zone. F_t^{io} was then obtained as :

$$F_t^{io} = p_1 F_{t,1}^{io} + p_2 F_{t,2}^{io} + p_3 F_{t,3}^{io} = \sum_{j=1}^{3} p_j F_{t,j}^{io}$$

for i = N, P and K

j = 1, 2, 3 (for zones)

and F_{tj}^{io} is the optimum dose of ith fertilizer for the jth zone (t = 1971-72). And p_1, p_2 and p_3 are the proportions of wheat area in the zones to the total wheat area of the State as shown in Appendix 1.

This method, however, requires the use of cross-sections of sample farmers for each year of the study period (1950-51 to 1971-72) and then the estimation of F_t^{io} for each year from the response surfaces in order to estimate the constants of model (4). This being difficult due to the non-availability of the data at the farmers' levels, the constants were calculated by taking the data at two points of time, *i.e.*, for 1965-66 and 1971-72. The year 1965-66 represents the pre-green revolution year. Before this, only *desi* wheat was sown and the Mexican varieties were not yet introduced. F_o^{io} for this year was taken to be the average dose[6] = F_o^{ia}

Substituting the following co-ordinates

For 1965-66 ... ($t=0$, $F_o^{io} = F_o^{ia}$)
1971-72 ... ($t=6$, F_6^{io} as obtained from the response surfaces)

in model (4), the values of the constants a′ and b′ can be found out.

Similarly, the constants of the model (3) were evaluated by substituting the co-ordinates :

For 1965-66 ... ($t=0$ F_o^{ia})
1971-72 ... ($t=6$, F_6^{ia})

where F_o^{ia} denotes the average amount of N, P and K.[7]

After arriving at the estimates of area [model(2)] and the N, P and K doses [models (3) and (4)], the total demand for these nutrients can be worked out [model (1)] as :

$$D^{ia} = \frac{C}{\phi\,(A+Bt-5)} \times \frac{F_T^{\,i}}{\phi\,(a+bt-5)} \quad \ldots. \quad (5)$$

(if the farmers use the average amounts of the nutrients)

and

$$D_t^{io} = \frac{C}{\phi\,(A+Bt-5)} \times \frac{F_T^{\,i}}{\phi(a'+b't-5)} \quad \ldots. \quad (6)$$

(if the farmers are motivated to use the optimum doses within the constraints of other inputs during that year)

$$\text{where } \phi(z) = \int_{-\infty}^{z} \frac{1}{\sqrt{z\pi}}\, e^{-\frac{1}{2}z^2}\, dz$$

RESULTS

Area Projections

The results of fitting model (2) to the time-series data for the period 1950-51 to 1971-72 taking $t = 0$ for 1965-66 are as follows :

$$\text{Probit}\left(\frac{A_t}{C} \times 100\right) = 4.8192 + 0.0276\ t,\ r^2 = .8523$$

6. A. S. Kahlon, S. Miglani and Mehta : Studies in the Economics of Farm Management in Ferozepur District (Punjab), Report for the Year 1969-70.
7. The average amount of N and P (in kgs./hectare) used for wheat *desi*, however, relates to the year 1966-67.

where A_t = area under wheat (thousand hectares),

C = 4102 thousand hectares, this is the cultivated area for 1971-72.

The projections of area under wheat were worked out for years 1971-72 (t=6), 1972-73 (t=7), 1975-76 (t=10), 1980-81 (t=15), 1984-85 (t=19) and 1985-86 (t=20). And these projections are presented in Table I.

TABLE I—PROJECTIONS OF AREA UNDER WHEAT IN PUNJAB

Year	Estimated percentage of wheat area to the cultivated area	Estimated wheat area (thousand hectares)	Actual area (thousand hectares)
1971-72	56.1	2,301	2,336
1972-73	57.2	2,346	—
1975-76	60.5	2,382	—
1980-81	65.7	2,695	—
1984-85	69.6	2,855	—
1985-86	70.6	2,896	—

Projections of F^{io} and F^{ia}

The analysis of the experimental data of 1971-72 gave the following response surface :

$$Y = 3605.0180 + 17.6732\,N - 0.0537\,N^2 + 11.7113\,P - 0.0797\,P^2 + 0.0327\,NP + 8.4294\,K$$

Number of observations = 100.

F_T^i—the optimum levels of N and P—were determined at the product price of Rs. 76 per quintal and the factor prices at p_N = Rs. 2.25 per kg. and p_P = Rs. 2.21 per kg. Therefore the factor-product price ratio worked out to be 2.9606 for N and 3.9474 for F This analysis does not take care of the variations in the factor-product price ratio in this paper, the ratio is assumed to be constant. The values of N and P which maximize the profit worked out to be 160 kgs. per hectare and 80 kgs. per hectare respectively. This resulted in the yield of 6,409 kgs./hectare at K = 60 kgs. per hectare.

Response surfaces fitted to the farmers' data for the three zones are given below :

Zone I

$$Y = 1835.7802 + 15.1182\ N - 0.0395\ N^2 + 12.6712\ P - 0.0611 P^2 - 0.0127\ NP + 2.2356\ K.$$

Number of observations = 72.

N_{opt} = 50 kgs., P_{opt} = 55 kgs., Y_{opt} = 3,677 kgs./hectare at K = 30 kgs.

Zone II

$$Y = 2520.5680 + 12.9931\ N - 0.0339\ N^2 + 13.4805\ P - 0.0759\ P^2 + 0.0025\ NP + 4.5136\ K.$$

Number of observations = 72.

N_{opt} = 150 kgs., P_{opt} = 55 kgs., Y_{opt} = 4,375 kgs./hectare at K = 30 kgs.

Zone III

$$Y = 1718.3902 + 13.2814\ N - 0.0346\ N^2 + 12.1306\ P - 0.0659\ P^2 - 0.0215\ NP + 3.1816\ K.$$

Number of observations = 72.

N_{opt} = 137 kgs., P_{opt} = 40 kgs., Y_{opt} = 3,246 kgs./hectare at K = 30 kgs.

The optimum doses of N and P at the State level were worked out by taking the weighted average of the zonal estimates.

$$F^{NO} = p_j\ F_j^{NO} = 149.77 \text{ kgs.}$$

$$F^{PO} = p_j\ F_j^{PO} = 63.17 \text{ kgs.}$$

From the same data the average amount of N, P and K used on per hectare basis was worked out. On an average, the farmers used 82 kgs. of nitrogen and 23 kgs. of superphosphate for one hectare of wheat crop. Out of the 216 sample holdings only 71 used potash and that too to the extent of about 6 kgs. per hectare. This is why the optimum level of K could not be worked out.

With the help of models (3) and (4), the fertilizer requirements were projected and the results are presented in Table II. The estimates of the constants of the models are :

Model (3)

$$\text{Probit}\left(\frac{F_t^{Na}}{160} \times 100\right) = 3.8783 + .1920\,t, \text{ for nitrogen}$$

$$\text{Probit}\left(\frac{F_t^{Pa}}{80} \times 100\right) = 3.1337 + .2172\,t, \text{ for superphosphate}$$

Model (4)

$$\text{Probit}\left(\frac{F_t^{No}}{160} \times 100\right) = 3.8783 + .4418\,t, \text{ for nitrogen}$$

$$\text{Probit}\left(\frac{F_t^{Po}}{80} \times 100\right) = 3.1337 + .4455\,t, \text{ for superphosphate}$$

TABLE II—PROJECTIONS OF FERTILIZER REQUIREMENTS

(kgs. per hectare of wheat crop)

Situation	I		II	
Year	Average doses [using model (3)]		Optimum doses [using model (4)]	
	N	P	N	P
1971-72	81.92	22.96	152.10	63.20
1972-73	94.08	29.20	159.92	71.60
1975-76	126.08	49.60	159.98	79.61
1980-81	153.60	73.44	159.98	80.00
1984-85	159.07	79.05	159.98	80.00
1985-86	159.47	79.47	159.98	80.00

Fertilizer requirements in Situation I are obtained just following the trend pattern (Sigmoid relationship) whereas the requirements in Situation II are worked out under the assumption that the farmers will be motivated to follow the optimum requirement at the prevailing levels of other inputs.

Demand Projections

With the help of the above two tables or the models (1), (5) and (6), the projections of the fertilizer requirements for the wheat crop were obtained and the results are shown in Table III. The results of this table show that if the farmers are motivated to use the optimum doses of fertilizer which are optimum in the tth year with respect to these levels of other inputs which exist during the tth year, the demand for N would be 3499.82 thousand quintals as against the estimated consumption of 1882.82 thousand quintals for the wheat crop during 1971-72.

The estimated consumption of P for this crop was 528.31 thousand quintals as against the requirement of 1454.23 thousand quintals during 1972-73.

TABLE III—TOTAL FERTILIZER REQUIREMENTS FOR WHEAT IN PUNJAB

Year	Fertilizer requirements for wheat (thousand quintals)			
	D_t^{Na}	D_t^{Po}	D_t^{No}	D^{Po}
1971-72	1882.68*	528.31*	3499.82	1454.23
1972-73	2207.12	685.03	3750.71	1679.74
1975-76	3129.31	1231.07	3970.70	1975.92
1980-81	4139.52	1979.21	4311.46	2156.00
1984-85	4541.45	2256.88	4567.43	2284.00
1985-86	4618.25	2301.45	4633.02	2316.00

* These figures denote the total consumption of N and P for the wheat crop during 1971-72 as estimated from the farmers' data.

A comparison of the two sets of demand projections indicate that the gap between the optimum use and the estimated average use is narrowing. For the year 1984-85, the differences in the estimates of demand obtained by using the two different approaches become negligible. This is the time when the farmers on an average will be using 160 kgs. per hectare of N and 80 kgs. per hectare of P for the wheat crop and these are the target recommendations (from experimental data). This suggests that the target yield of 6,409 kgs. per hectare for wheat will be achieved if the proper supply and distribution to the extent of 4567.43 thousand quintals for N and 2284.00 thousand quintals of P is assured. Wheat production in Punjab could then be estimated at 182.98 million quintals (in 1984-85) as against the production of 43.18 million quintals in 1969-70. However, these demand forecasts should not be regarded as exact because the demand depends upon a number of uncontrollable factors such as weather conditions, farmers' attitudes, price levels and availability of credit.

APPENDIX 1

DESCRIPTION OF THE ZONES AND SAMPLE

Zone	Percentage area (1971-72)	Percentage of wheat area (P_j) (1971-72)	No. of tehsils in the sample	No. of village clusters in the sample	No. of sample-cultivators
I. Wheat-paddy-maize areas	41.85	41.11	6	6	72
II. Wheat-maize-groundnut areas	27.60	31.13	6	6	72
III. Wheat-cotton-bajra areas ..	30.55	27.76	6	6	72
Total	100	100	18	18	216

Note on the sample : Six tehsils were selected at random from each zone and then one village cluster was selected randomly from each sample tehsil. This gave a sample of 18 village clusters in all. Twelve cultivators (4 from each of the small, medium and large categories) were selected from each sample village cluster, thus selecting 72 cultivators from each zone.