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NOTES

LINEAR PROGRAMMING APPLIED TO PROBLEMS IN INDIAN AGRICULTURE

In the United States, attempts are being made to use the technique of linear programming in farm planning. Particularly, in the field of farm management, it is used for determining: (1) the best combination of (*a*) crops alone, (*b*) livestock alone, (*c*) crop and livestock enterprises together ; (2) the best or least cost technique; and (3) the optimum combination of different enterprises.

There are three basic requirements for the application of linear programming method to any problem. It should have: (1) an objective, (2) alternative methods or processes for attaining the objective, and (3) resource restrictions. For typical farm management problems, the objective can be maximum income or minimum cost. There is, however, no reason why the objective should be so restricted. Linear programming can be applied to problems where the objective may be other than maximization of income or minimization of cost. The objective, however, must be clearly specified before computation takes place.

Once the objective is specified, the next step is to think of different processes by which the objective can be attained. The concept of a process is very important in linear programming. A process is a method of converting resources or other restrictions on planning into a product. It is more or less synonymous with activity. The linear programming technique enables us to choose from among the different processes, the processes which are most efficient in converting resources into the objective.

A linear programming problem does not exist unless resources are restricted or limited. The limiting resources are the fixed factors in the process of production. A farm may have a fixed amount of land, labour and capital. Linear programming technique helps in finding out the optimum plan for the farm in attaining a specific objective such as maximization of profits or minimization of costs.

Assumptions

The basic assumptions of linear programming are: (1) additivity and linearity, (2) divisibility, (3) finiteness, and (4) single-value expectations. By additivity it is meant that the total amount of resources used by several enterprises must be equal to the sum of resources used by each individual enterprise. Linearity is the most important assumption in linear programming. The linear relationship assumes constant proportionality between input and output within a process. This assumption is common for the budgeting technique also. The principal task in both methods is assembling of input-output coefficients. By divisibility it is assumed that factors and products are continuous and infinitely divisible. Thus a linear programming model would specify a programme which uses 18.55 acres of land and produces 26.33 maunds of Jowar as in Example 2 given below. This does not, however, create a serious difficulty in decision-making because the nearest rounded figures can be taken without making serious errors. Finiteness assumes that there is a limited number of processes and resource restrictions which need be considered. For the practical farmer this assumption is actually an aid to his decision-making. In single-value expectations the linear programming method assumes that the resource restrictions, input-output coefficients and prices are known with certainty.

Application of Linear Programming Technique to Problems in Indian Farming

Although farming in India is not commercialised to a large extent, it remains that the farmer has to make decisions regarding his business of farming with a view to attain certain objective. His objective may not be maximization of net profit in the usual sense; but it can be assumed that he would like to maximize farm income by which he can maintain himself and his family. One of the income measures adopted in Indian Agricultural Economics approximating to this concept is denoted by the term "Farm Business Income." This means the income which a farmer would get after deducting all the cash expenditure from the value of the gross output of his farm. Thus for application of linear programming technique, maximization of farm business income may be considered as an objective.

In Indian agriculture, the restrictions of resources are perhaps more dominant than anywhere else. The farmer in India has limited land. He has limited capital, and though he has ample labour of his own and his family to employ in farm work, he may face labour constraint when certain operations are to be carried out in a given time limit because he is not in a position to employ hired labour on account of the limited working capital. Thus the farmer in India operates under the conditions of input constraints of land, capital and labour.

The technique of linear programming can be explained by simple practical examples. These examples have been picked out from the data of farm management scheme in Bombay State. The examples may be considered as hypothetical cases.

Example 1

A farmer in Ahmednagar district of Bombay State had the following fixed amounts of resources to use in the production of two crops which he could grow on his farm in Rabi season :

Land	15·4 acres.
Labour	360 days.
Working Capital	Rs. 200.

The requirements of land, labour, and working capital per maund for the two crops (Jowar and Wheat) are given in Table 1. They are calculated from input and output per acre obtained from the data mentioned above. The table also shows the maximum quantities of Jowar and Wheat which can be produced with each resource if (1) all of this resource is used for one crop and (2) all other resources except the one under consideration are available in unlimited quantities.

TABLE I—REQUIREMENT OF INPUT RESOURCES PER MAUND

	Jowar	Wheat
Land (Acres)	0.59	0.22
Labour (Days)	5.11	3.64
Working Capital	4.59	5.63
Maximum Production (in maunds) from		
Land (15.4 Acres)	26.10	70.00
Labour (360 Days)	70.45	98.90
Working Capital (200 Rs.) ..	43.57	36.16

The data of Table 1 are graphically represented in Figure 1. There are three lines in the figure which indicate all possible combinations of Jowar and Wheat which can be produced within the "fixed" amount of resource if other resources are considered to be unlimited. These are iso-resource lines for labour, land and working capital. The lines for capital and land intersect whereas the line for labour is above the lines for capital and land and does not restrict the production possibilities of the two resources. The production of Jowar alone, Jowar and Wheat, and Wheat alone is shown by the figure bound by the segments AB of the working capital and BC of the land line. The problem now is to find the optimum production. This can be easily done by drawing "price line" for the two crops. The price line will show the ratio of farm business incomes of the two crops. It will be seen from Figure 1 that the corner point B where the price line is tangent to the "curve" ABC is the optimum point which shows the quantities of Jowar and Wheat to be produced to attain maximum farm business income. This is the point which shows the crop combination of 21 maunds of Wheat and 18 maunds of Jowar. This combination would give maximum farm business income of Rs. 585.

Computational Technique

For mathematical solution of a linear programming problem a special computational technique is evolved. This technique is explained in detail in literature on linear programming. No attempt is made here to explain this technique. The computational technique employed for the solution of the examples here is known as the simplex method. Under this method an optimum plan is always denoted by *Z-C* row filled with non-negative figures in a simplex tableau when the objective is profit maximization.

The details of the simplex tableau for the Example 1 are given in Appendix I. The solution of the simplex tableau shows that the farmer should produce 18.35 maunds of Jowar and 20.94 maunds of Wheat to attain maximum farm business income of Rs. 585. The *Z-C* row of the final section in the simplex tableau shows the marginal value products of the resource constraints. These are sometimes called shadow prices. This means that one acre of land, if kept idle, would reduce farm business income by 11 rupees whereas one rupee reduction in working capital would reduce farm business income by 2 rupees. Conversely, one acre of land would add 11 rupees to farm business income and one rupee of working capital would add 2 rupees to farm business income.

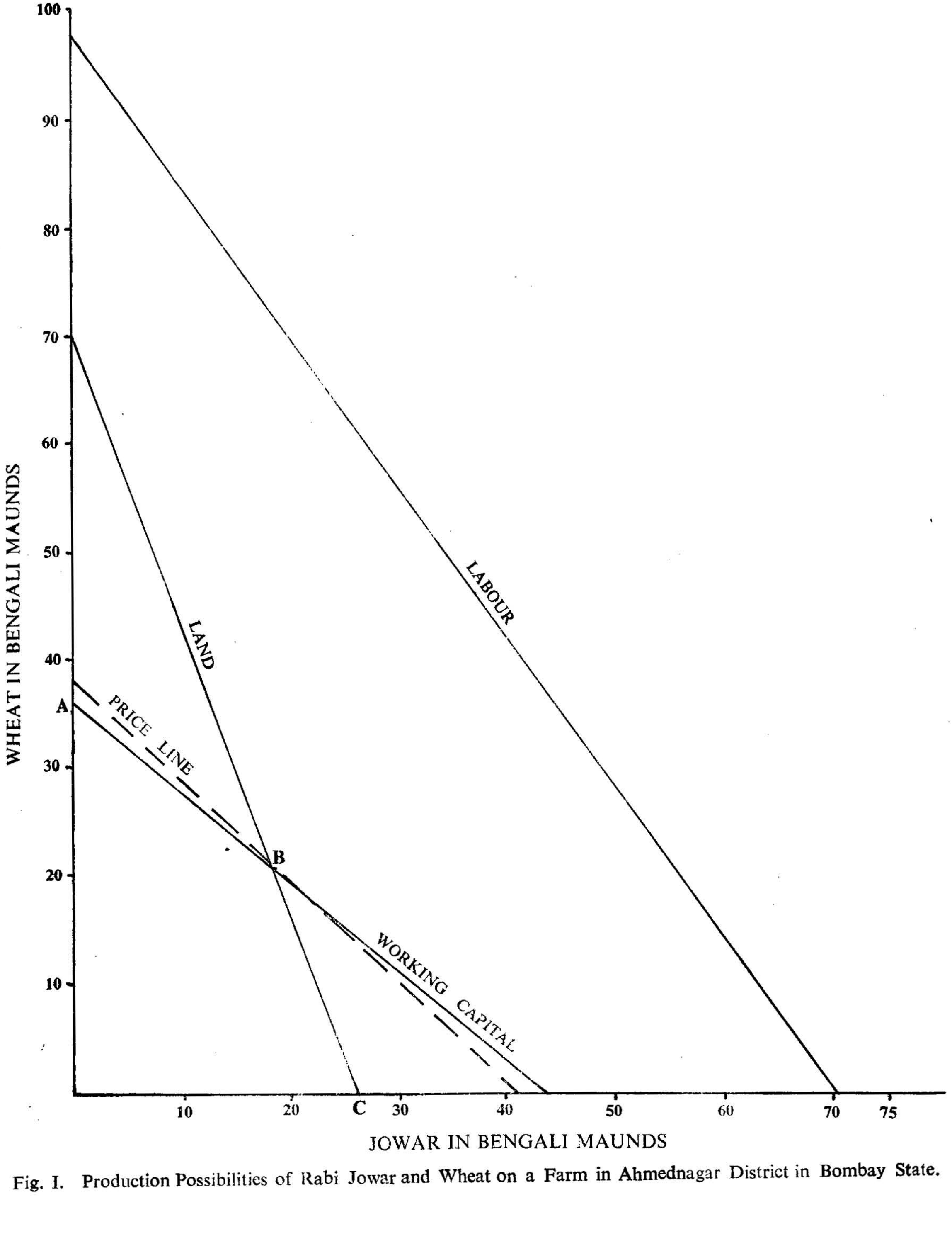

Fig. I. Production Possibilities of Rabi Jowar and Wheat on a Farm in Ahmednagar District in Bombay State.

Example 2

A second example involving larger number of processes and resource constraints was taken for programming. The problem involved choice of crop or a combination of crops from among the six crops which were selected for alternative processes. The crops were: (1) Dry Wheat (2) Irrigated Wheat (3) Dry Rabi Jowar (4) Irrigated Rabi Jowar (5) Dry Gram (6) Irrigated Gram.

A farmer had 18.55 acres of dry land and 4.46 acres of irrigated land which was irrigated by well water. The farmer had at his disposal 360 days of labour of his own and his family. He had also a working capital of Rs. 400.

An optimum plan was worked out for this farmer using the input-output coefficients and farm business income figures obtained from the source mentioned earlier. The details of the simplex tableau are given in Appendix II.

The final solution of the simplex tableau shows that the maximum farm business income under the given resource constraints would be Rs. 1199. To achieve this the farmer would be required to produce 16.14 maunds of dry Rabi Jowar, 26.33 maunds of irrigated Rabi Jowar, and 41.36 maunds of dry Wheat. It also shows that all the available resources were almost fully utilised except 1.30 acres of irrigated land. This was because of the restrictions of labour and working capital. Here lies the beauty of the linear programming method. It brings forth in a very rigorous manner the most limiting factors which are not always apparent to us. The solution of the problem shows that it was not land which was the most limiting factor but the most limiting factors were labour and working capital. The marginal value products of these factors were Rs. 1.90 and Rs. 1.26 respectively. This means that one additional labour day would add Rs. 1.90. and one additional rupee of working capital would add Rs. 1.26 to the farm business income. It is interesting to find that both the examples have shown the capital is the most restricting factor. This seems to confirm the general notion that Indian agriculture suffers from capital shortage. However, no conclusion is intended to be drawn from these examples. The purpose of this article is to show the utility of application of linear programming method to the problems in Indian farming. From the two examples cited above, it is suggested that linear programming should be explored as a technique for the purpose of farm planning in Indian agriculture.

It may be noted that the basic requirement for the application of either budgeting or linear programming technique is obtaining reliable figures of input-output coefficients and prices. Unfortunately, we lack in basic empirical data of this nature for various regions in India. It is encouraging to find that the Government of India is aware of this problem. The Research Programmes Committee of Planning Commission of India have undertaken a programme of farm management investigation in various regions of India. The first series of farm management investigation was undertaken in six different States from 1954 to 1958. The second series is now in operation in three States. Several such efforts on wider scale will generate the requisite input-output coefficients.

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APPENDIX—I

SIMPLEX TABLEAU FOR THE SOLUTION OF OPTIMUM CROP COMBINATION IN CASE STUDY 1 IN AHMEDNAGAR DISTRICT IN BOMBAY STATE

				Real Activities		Disposal Activities		
			C	16.00	13.91	O	O	R
	C			Jowar	Wheat	Land	Working Capital	
		P_0	B	P_1	P_2	P_3	P_4	
I ←	0	P_3 Land	15.4 acres	0.59	0.22	1.00	0.00	15.4÷59=26.10
	0	P_4 Working Capital	200.0 Rs.	4.59	5.53	0.00	1.00	200÷4.59=43.57
		Z	0	0	0	0	0	
		Z-C	0	—16.00	—13.91	0	0	
	16.0	→P_1	26.10	1.00	0.37	1.69	0.00	26.10÷37=70.54
II		←P_4	80.21	0.00	3.83	—7.75	1.00	80.21÷3.83=20.94
		Z	417.60	16.00	5.92	27.04	0.00	
		Z-C	417.60	0·00	—7.99	27.04	0.00	
	16.00	P_1	18.35	1.00	0.00	2.43	—.096	
III	13.91	→P_2	20.94	0.00	1.00	—2.02	0.26	
		Z	584.87	16.00	13.91	10.78	2.08	
		Z-C	584.87	0.00	0.00	10.78	2.08	

APPENDIX—II

SIMPLEX TABLEAU FOR THE SOLUTION OF OPTIMUM CROP COMBINATION IN CASE STUDY 2 IN AHMEDNAGAR DISTRICT IN BOMBAY STATE

	C		C	Real Activities						Disposal Activities				
				16.00 Dry Jowar	13.87 Irri. Jowar	13.91 Dry Wheat	9.45 Irri. Wheat	9.55 Dry Gram	9.27 Irri. Gram	0 Dry Land	0 Irri. Land	0 Labour	0 Working Capital	
		P_0	B	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	R
I	0 ←	P_7 Dry land	18.55 acres	0.59	0.00	0.22	0.00	0.37	0.00	1.00	0.00	0.00	0.00	18.55÷·59=31.4
	0	P_8 Irri. land	4.46 acres	0.00	0.12	0.00	0.18	0.00	0.14	0.00	1.00	0.00	0.00	4.46÷0=unlimited
	0	P_9 Labour	360.00 days	5.11	4.82	3.64	8.65	3.85	3.12	0.00	0.00	1.00	0.00	360÷5.51=70.4
	0	P_{10} Working Capital	400.00 Rs.	4.59	3.88	5.53	10.16	4.07	4.72	0.00	0.00	0.00	1.00	400÷4.50=87.1
		Z	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		Z-C	0	—16.00	—13.87	—13.91	—9.45	—9.55	—9.27	0.00	0.00	0.00	0.00	
II	16.00 →	P_1	31.44	1.00	0.00	0.37	0.00	0.62	0.00	1.69	0.00	0.00	0.00	31.44÷0=unlimited
	0 ←	P_8	4.46	0.00	0.12	0.00	0.18	0.00	0.14	0.00	1.00	0.00	0.00	4.46÷0.12=37.1
	0	P_9	199.35	0.00	4.82	1.75	8.65	0.68	3.12	—8.63	0.00	1.00	0.00	199.35÷4.82=41.3
	0	P_{10}	258.84	0.00	3.82	3.83	10.16	1.13	4.72	—7.75	0.00	0.00	1.00	258.84÷3.82=67.7
		Z	503.04	16.00	0.00	5.92	0.00	9.92	0.00	27.04	0.00	0.00	0.00	
		Z-C	503.04	0.00	—13.87	—8.01	—9.45	0.37	—9.27	27.04	0.00	0.00	0.00	
III	16.00	P_1	31.44	1.00	0.00	0.37	0.00	0.62	0.00	1.69	0 00	0.00	0.00	31.44÷·37=84.9
	13.87 →	P_2	37.16	0.00	1.00	0.00	1.50	0.00	1.16	0.00	8.33	0.00	0.00	37.16÷0=unlimited
	0 ←	P_9	20.24	0.00	0.00	1.75	1.42	0.68	—2.47	—8.63	—40.15	1.00	0.00	20.24÷1.75=11.5
	0	P_{10}	116.89	0.00	0.00	3.83	4.43	1.13	0.29	—7.75	—31.82	0.00	1.00	116.89÷3.83=30.5
		Z	1018.44	16.00	13.87	5.92	20.80	9.92	16.08	27.04	115.53	0.00	0.00	
		Z-C	1018.44	0.00	0.00	—8.01	10.35	0.37	6.81	27.04	115.53	0.00	0.00	
IV	16.00	P_1	27.16	1.00	0.00	0.00	—0.30	0.48	0.52	3.51	8.48	—0.21	0.00	27.16+8.48=3.2
	13.87	P_2	37.16	0.00	1.00	0.00	1.50	0.00	1.16	0.00	8.33	0.00	0.00	37.16÷8.32=4.4
	13.91 →	P_3	11.56	0.00	0.00	1.00	0.81	0.39	—1.41	—4.92	—22.92	0.57	0.00	11.56÷0=unlimited
	0 ←	P_{10}	72.62	0.00	0.00	0.00	1.33	—0.37	5.69	10.09	55.96	—2.18	1.00	72.62÷55.96=1.3
		Z	1111.03	16.00	13.87	13.91	27.26	13.10	—4.79	—11.27	—67.60	3.56	0.00	
		Z-C	1111.03	0.00	0.00	0.00	17.81	3.55	—14.06	—11.27	—67.60	3.56	0.00	
V		P_1	16.14	1.00	0.00	0.00	—0.47	0.53	0.33	1.99	0.00	0.12	—0.15	
		P_2	26.33	0.00	1.00	0.00	1.33	0.50	0.33	1.50	0.00	0.32	—0.15	
		P_3	41.36	0.00	0.00	1.00	1.27	0.25	0.88	0.79	0.00	—0.32	0.41	
		P_8	1.30	0.C0	0.00	0.00	0.02	—0.006	0.10	0.18	1.00	—0.039	0.018	
		Z	1198.91	16.00	13.87	13.91	28.09	18.89	10.54	0.05	0.00	1.90	1.26	
		Z-C	1198.91	0.00	0.00	0.00	18.64	9.34	1.27	0.05	0.00	1.90	1.26	

OPTIMUM LEVEL OF FERTILIZATION[1]

Various methods for obtaining an economic optimum dose of fertilizer have been suggested from time to time. Application of marginal analysis had been developed to achieve this end but the effect of extreme values of yield from plot to plot, due to random variations rather than due to fertilizer effects, is a disturbing factor which may more than nullify the advantage of easy computability. In one of the issues of *The Indian Journal of Agricultural Economics* a combination of conventional methods, used with the help of Murty's formula, is given which can indicate the optimum dose of fertilizer.[2] This procedure yields precise results and, at the same time, cuts down computational labour.

Now the question arises — are we really interested in an economic optimum dose of fertilizer for each plot or farm, when the supply of fertilizer is less than the total requirements for it ? Actually, the concept of *aggregative-optimum* may be more useful to follow in this context. Agricultural production will register an appreciable increase if a combination of fertilizer and all other resources put together is attempted which gives a maximum return per unit of fertilizer, fertilizer being a scarce resource.

An example could be worked out showing that net returns to 3 farmers, using 2 units each of fertilizer, will be greater as compared to the net returns obtained by a farmer who is applying all the six units on his land. In other words, not only the net contribution towards increased production per unit of fertilizer but also the net returns accruing to farmers (collectively) can be increased by using fertilizer in quantities less than those indicated by the economic optimum.

The above statement is graphically illustrated on the opposite page. The concept of aggregative-optimum will indicate a level of fertilizer-use between the points where marginal value product from the use of fertilizer is highest (point *a* in the graph), and a point indicated by the economic optimum (point *c* in the graph). Since we are so much short of fertilizer we may actually profit by operating nearer to *Region 1 of production* (extensive margin for the input—point *b* in the graph) rather than nearer the economic optimum.

It is quite possible that in some cases farmers are using fertilizer in quantities smaller than those indicated by point *a*, that is, in the region of increasing marginal productivity. This would suggest that, in such cases, an increase in fertilizer dose is called for in order to increase the net revenue accruing to an individual farmer as well as for maximising the returns per unit of fertilizer.

These observations have important implications for fertilizer distribution policy and extension education work ; fertilizer distribution programmes and the recommendations of extention workers should aim at securing a level of fertilizer use in the neighbourhood of the extensive use margin (point *b* in the graph).

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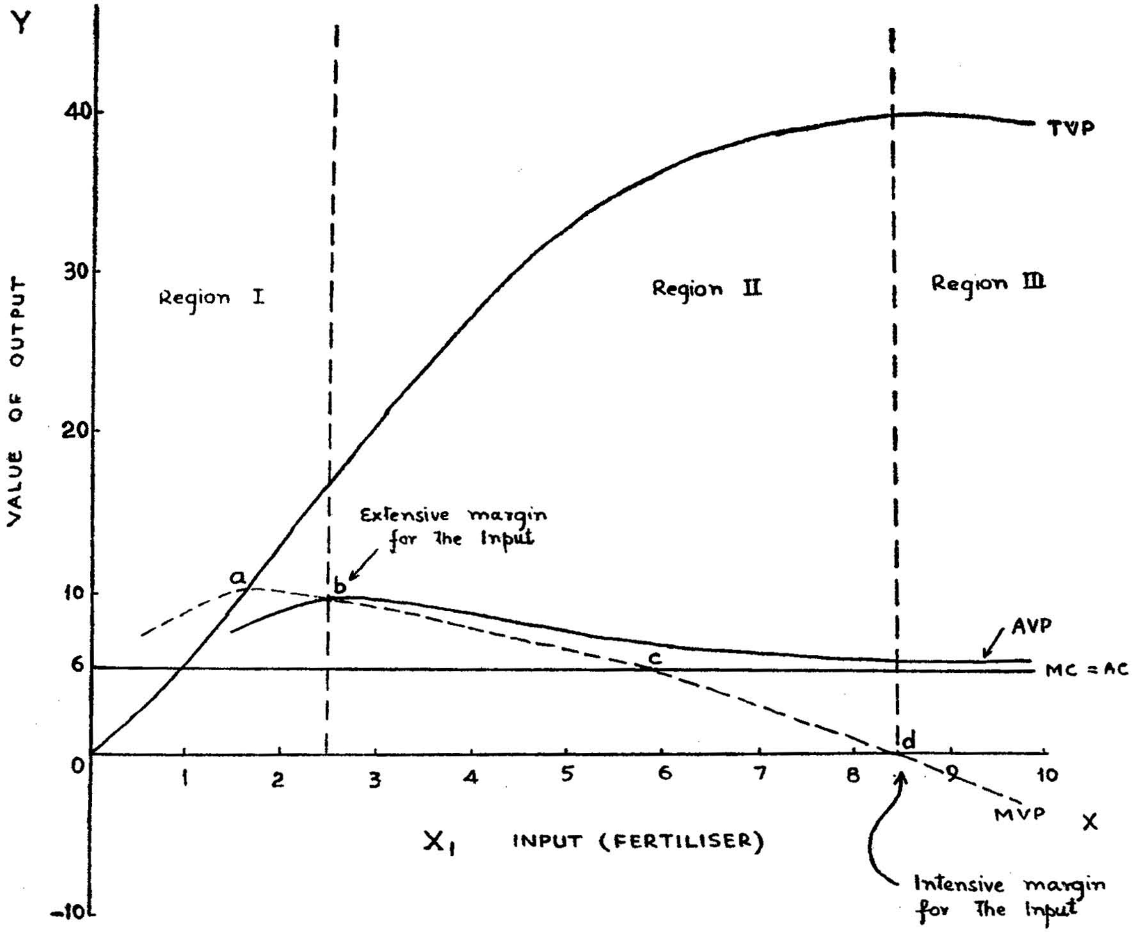
1. The author is indebted to Prof. A. K. Das Gupta and Dr. B. Natarajan of the National Council of Applied Economic Research, New Delhi, and Dr. P. K. Mukherjee and Dr. G. D. Agrawal of the Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India, for valuable comments.

2. Vasanth Kumar, B: "Economic Aspects of Fertilization": *The Indian Journal of Agricultural Economics*, Vol. XIV, No. 1, January-March 1959.



Graph showing the Total, Average and Marginal Value Product from the Use of an Input.

It may be difficult to restrain the farmer to the application of fertilizer doses thus indicated because he can still increase his net returns by applying more units ; normally he would be interested in increasing his own returns rather than increasing the total welfare of the community through increased agricultural production in the aggregate. The limitation on the quantity to be used by each farmer can be made effective through rationing. Government retail depots and Service Co-operatives could incorporate this principle into their distribution programmes. Need for credit on the part of small farmers will have to be met if extensive use is to be achieved.

The use of price-machanism may be made to achieve the desired pattern of fertilizer use. Moving in the direction of extensive use would involve raising the price of fertilizer for well-to-do farmers.[3] But for small farmers what may really be needed is not a rise in price but a reduction in the present price level ; this is especially important for farmers who are making a beginning in the use of fertilizers, or are to be drawn into the fold of fertilizer-users. The use of price differential,[4] or lowering of prices for everybody accompanied by rationing of the quantity to be distributed, is beset with problems — administrative and otherwise — which need careful examination; such an enquiry falls beyond the scope of this note.

The present fertilizer distribution system suffers from the defect that quota allotments[5] aimed at achieving the desired consumption pattern and made effective through administrative orders (non-market criteria) are generally used along with normal market-criteria beyond the state level (wholesale and retail—upto the point of actual sale to the consumer). The result of this simultaneous application of non-financial and financial criteria to fertilizer distribution has been that the desired consumption pattern has not been achieved.[6] Distribution by administrative order can make supplies *available* in the desired places but it does not ensure consumption by the desired class in the desired quantities.

As stated already, extension education work is needed for creating extensive demand; and the level of fertilizer yielding maximum physical return per unit is to be emphasised in place of the economic optimum. The whole question of the distributive mechanism needs to be considered in great detail keeping in view the policy objectives and the working of the existing distribution system.

Agricultural experiments conducted in the country so far generally relate to one level of fertilizer application or to a few levels. Experiments, in order to furnish useful results, should give returns from various levels of fertilizer application, *i.e.*, a range of returns. Ideally the range should include a spread of points denoting the region of the highest marginal return and that of no return (*i.e.*, where marginal productivity ceases to be positive). But the immediate needs, in conformity with the recommendation for extensive use of fertilizers, would be met if results of experiments showing responses around the extensive use margin

3. The rise in price will move the economic optimum (point *c* in the graph) back, indicating a smaller fertilizer dose.
4. Different prices for different categories of users; also different prices for the same category of users beyond a certain quantity (*i.e.*, a graduated price structure).
5. The quota is determined on the basis of normative considerations.
6. Walters Jr., J. Hart, "Distributing Fertilizers by Administrative Order in India: An Example of Applied Economic Policy," *The Indian Economic Journal*, Vol. VI, No. 4, April, 1959.

are made available. Since a great number of fertilizer experiments are presently being conducted (by the I.C.A.R. and the State Governments), it may be worthwhile to introduce necessary changes in the design of experiments.[7]

The above observations would apply equally to other inputs which are in short supply.

H. S. SINGH*

DEMAND FOR FOODGRAINS DURING THE THIRD FIVE-YEAR PLAN[1]

Food self-sufficiency is the most urgent need today. A considerable amount of foreign exchange is being spent towards imports of foodgrains. It is true that in the agricultural sector, more than in any other sector, target-setting is a hazardous game. Yet estimates of production potential, actual production, and likely demand have to be made from time to time at least to have an idea of the magnitude of the problem and the steps to be taken to solve it.

The demand for foodgrains by the end of the Third Five-Year Plan has been estimated in this note by taking into consideration three factors :

(i) Increase in population,
(ii) Increase in the level of per-capita disposable income, and
(iii) Income-elasticity of demand.

With the urban population rising twice as fast as the rural population, the urban demand will increase faster than the rural demand. This could mean an increase in the demand for finer cereals in preference to the coarser ones. There could also be a shift towards animal foods, which means an increase in demand for coarser cereals for animal feed. Increased agricultural output implies (in the absence of increased mechanization) greater demand for coarser cereals for animal feed. In view of these factors, a breakdown of the total demand by finer and coarser foodgrains has not been attempted.

The Nutrition Advisory Committee recommended the following diet for an adult per day.

Cereals	:	14 oz.
Pulses	:	3 oz.
Vegetables & Fruits	:	13 oz.
Milk	:	10 oz.
Sugar	:	2 oz.
Oil	:	2 oz.
Eggs	:	1 egg.
Fish & Meat	:	2 oz.

7. Most of the agronomic experiments conducted in India are generally designed to yield data on factor-product relationship. In the context of supplying data to decision-makers on the farms, one of the most important relationships which appears to be in the need of exploring pertains to the possibility of substitution among growth-factors including nutrient substitution. Only when empirical data on such basic relationships as *factor-factor* and *product-product*, and not just on factor-product relationship alone, are available, can a farmer evaluate alternative choices for maximising returns.

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1. Based on the paper read at the Agricultural Economics Seminar of the Department of Economics, University of Bombay, 1959-60

At present the consumption of milk, eggs, etc., is quite low. However, an increased availability of animal foods implies not an increase in the number of livestock but an increase in their standards of maintenance. It was estimated by the I.C.A.R. ("Human Nutrition *vs.* Animal Nutrition in India, 1954") that if proper nutritional standards are maintained for animals, the requirements of animals would be at 25 million tons of maize, gram and barley (per annum). At present the allowance made for seed, animal feed and waste is 12.5 per cent of total production which comes to 10 million tons if total production is at 80 million tons.

The following are the main limitations of the analysis given in this paper :

(1) It is assumed that the demand for non-human consumption increases exactly in the same proportion as that for human consumption. This, of course, may not be true in the light of the comments given above.

(2) Regional differences have been ignored. There is no doubt that wide disparities exist between the patterns of consumption in the different provinces.

(3) Changes in the age-and sex-composition of the population are ignored.

(4) Expenditure elasticity is assumed constant for all income groups, (*i.e.*, a linear function). It would be more realistic to assume a variable elasticity, the elasticity being lower for high income groups, higher for low-income groups and decreasing monotonically with increase in expenditure.

(5) Estimation is done in terms of quantity — not value. An increase in income results in an increased expenditure on food but a part of the increase in expenditure would be due to the substitution of superior foods for inferior ones. If we estimate the demand in value terms first and then convert it into quantity terms, we have to make the additional assumption of constant relative price between the different foodgrains. This will not be true if the production of the different varieties of foodgrains does not keep pace with the changing demand.

The method of estimation is as follows :

Let y be the rate of increase in income
p the rate of increase in population

Then rate of increase in per-capita income will be

$$\left\{ \frac{1 + y}{1 + p} - 1 \right\} = \frac{y - p}{1 + p}$$

If p is small this could be taken as y — p approximately.

e.g., if national income increases at 6%
and population increases at 2%
per-capita income increases at 4% approximately.
The exact formula gives 3.92%.

If e is the income-elasticity of demand (per-capita), the rate of increase in per-capita consumption is :

$$e.\frac{y - p}{1 + p}$$

Hence rate of increase in total consumption

$$= \left\{ 1 + e.\frac{y - p}{1 + p} \right\} (1 + p) - 1$$

$$= e(y - p) + p$$

or $$ey + (1 - e)p$$

The rate of increase in demand is thus the sum of two components :-

ey due to increase in income

and (1 — e)p due to increase in population.

These we may call the "income-effect" and the "population effect."

Assuming that :

(1) the total population increases at the rate of 2% per annum, *i.e.*, by 10.4% during the Third Five-Year Plan period,

(2) that the total disposable income increases by 28% during the same period, and

(3) that the expenditure elasticity (per-capita) of demand for foodgrains (quantity) is 0.6.

We get the rate of increase in demand for foodgrains

$= (0.6 \times 28) + (0.4 \times 10.4)$

$= 16.8 + 4.16$

$= 20.96$ or 21%

Assuming the base figure of 80 million tons in 1960-61, the demand for foodgrains will be roundabout 97 million tons by 1965-66.

The Foodgrains Enquiry Committee assumed the income-elasticity of demand for foodgrains (quantity) to be 0.50 and 0.25 for the rural and urban areas respectively. The income-elasticities (in terms of value—not quantity) calculated from the several rounds of the N.S.S. range between

0.5 and 0.7 for cereals in rural areas,

0.3 and 0.4 for cereals in urban areas,

0.8 and 0.9 for all food in rural areas,

0.7 and 0.8 for all food in urban areas.

Since our estimation is in terms of quantity, the elasticities will be less inasmuch as some increase in expenditure is due to the substitution of superior foodgrains for inferior ones. Hence, we have assumed e=0.6.

However, assuming p=10.4% and y=28%, the following Table gives the rates of increase in demand for different values of e.

Assuming the base figure in 1960-61 to be 80 million tons, the demand in 1965-66 has been calculated.

e	Income-effect	Population effect	Total increase	Demand in 1965-66
0·5	14	5·2	19·2 %	95·4 mill. tons.
0·6	16·8	4·16	20·96%	96·8 ,,
0·7	19·6	3·12	22·7 %	98·2 ,,
0·8	22·4	2·1	24·5 %	99·6 ,,

Estimation of Urban and Rural Demand

What is true of the general is also true of the particular. Hence, if

p_r = rate of increase in population in the rural sector

y_r = rate of increase in income in the rural sector

e_r = income-elasticity of demand in the rural sector

and if p_u, y_u, e_u represent the corresponding values for the urban sector, then

rate of increase in rural demand is :

$$d_r = e_r\, y_r + (1 - e_r)\, p_r$$

rate of increase in urban demand is

$$d_u = e_u + (1 - e_u)\, p_u$$

If k_r, and k_u be the proportions of rural and urban consumptions (total) in the initial period, then total rate of increase in demand is :

$$d = k_r d_r + k_u d_u$$

The estimation of the different constants presents a number of difficulties—particularly the constants y and y_u. Several arbitrary assumptions have to be made in order to estimate them.

Note : In our calculations we have taken the compounded values of y and p for the 5-year period and substituted in the formula.

If yearly figures are taken

$$p = 2\%$$

$$y = 5\%$$

$$e = 0.6$$

$$\therefore d = ey + (1 - e)\, p$$

$$= 3.8\%$$

Therefore, demand for foodgrains increases at 3.8% per annum. Over the 5-year period, this comes to 20.44%.

The figures obtained by this method of yearly compounding will be consistently lower than the figures obtained by the earlier method which has been used only for convenience.

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