Vol XVII
No. 2

ISSN 0019-5014

CONFERENCE
NUMBER

JANUARY-
MARCH
1962

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

fied: (1) The prices of onion and chillies are very much affected by foreign markets. When stocks pile up and export quota is not fulfilled, the cultivators get the rock bottom price for their entire harvest. They are not in a position to hoard and speculate. The uncertainty of the market is the major hurdle towards the adoption of the optimal plan. The farmer cannot afford to take great risk. The wholesale price range for chillies was between Rs. 45.96 to 77.42 per standard *maund* during the period 1952-57. (2) The uncontrollable seasonal factor and rainfall to which some of the cash crops are subject. Memory of the failure of chillies crop due to untimely rain and that of onions due to excessive rain during the previous years makes the cultivator a little cautious in risking too much land and capital on these two cash crops.

Except for these two factors, other considerations such as food and fodder requirements did not weigh heavily with the cultivator.

IV

CONCLUSION

In applying any technique to farm planning a host of extraneous factors need to be considered. Besides the appraisal of available resources, technical limitations such as suitability of soil, availability of adequate irrigational facilities, etc., are to be taken into account.

The all important fact of varying prices and the non-availability of an accessible market may detract significantly from the estimated net returns and lastly the uncontrollable physical phenomena of climate and rainfall may affect the crops, which may result in considerable loss.

Subject to these limitations, linear programming offers great scope for its usage with advantage and even alternate plans for varying prices could be worked out.

The pressing need for reorganizing the limited resources (land and capital in particular) makes the application of linear programming technique, a necessary step towards a better crop-planning and efficient farm business management.

FARM PLANNING BY BUDGETING AND LINEAR PROGRAMMING*

SUKESH K. GHOSH
Research Officer (Farm Management)
Agro-Economic Research Centre
Visva-Bharati University
Santiniketan

INTRODUCTION

The developmental plans in India have made much headway in the fulfilment of the essential targets of the agricultural sector and the amelioration of

* The author acknowledges with thanks the many helpful suggestions received from Dr. G. C. Mandal, Director, Agro-Economic Research Centre, Visva-Bharati University.

the rural economy of the country but much more remains to be done. Of the things that remain, the most vital is the re-thinking that planning should be geared to embrace agriculture at the farm or micro-level without which no radical improvement in the economy of this sector is possible.

Farm Planning

To attain this objective the Government should attach top priority to the maintenance of the proper scientific machinery whose function will be to assess the resource position of the farms and tailor suggestions for improvement benefitting the individual holdings. Each farm has its own individual characteristics and therefore certain physical, economic and personal or social factors should rightly be considered at the time of making production decision. Such physical factors are: (1) soil type and slope, (2) fertility level, (3) topography, (4) rainfall, (5) length of growing season of the crop, and (6) temperature; each one of these places restrictions on the range of crops which may be produced. The economic factors of importance however, are: (1) relative prices and cost, (2) size of the farm, (3) capital available, (4) buildings, (5) labour available, (6) indebtedness of the farmers, (7) farm tenure, and (8) marketing and storage facilities. The personal or social factors are the farmers' likes and dislikes.

The objective of this paper is to show the relative advantages and disadvantages of the two useful tools of planning—budgeting and linear programming and to apply it on a farm of Bihar (district Monghyr) selected for investigation under the Farm Management Studies (1957-60) by the Agro-Economic Research Centre of the Visva-Bharati University.

Budgeting

A farm budget[1] may be defined as a specific plan for the operation of the farm during some future period of time. The period planned may be the year ahead, 'the long-run or operational life' of the farm operator or any time-span between these extremes. In this sense, a budget is a forward looking plan. The purpose of the budget is to estimate the return which can be expected under alternative systems of organizing or managing the farm. It is by comparing the income expectations for these alternatives that one can arrive at the most profitable plan. Procedures involved in the process of budgeting are several. They are: (1) recording an inventory of resources, (2) forming price expectations, (3) preparing crop plan taking into account the complementary or competitive aspect of the crop enterprises, their supplementarity with the livestock activity that is in view, the fertility and productivity of land and availability of labour throughout the year, (4) estimating the yields, and (5) making the livestock plan taking into account the returns and the availability of feeds, maintenance labour and buildings. Depending on the process followed, budgeting may be complete or partial. In complete budgeting a plan is made for the whole farm and includes all decisions for one enterprise; in the other, attempt is limited to, for example, the estimation of the income and expenditure for the small part of the farm such as, wheat, paddy, livestock or some other part of the total business.

---

1. J. A. Hodges, "Development of Farm Budget in the United States," in "Resource Productivity, Returns to Scale and Farm Size" edited by E. O. Heady, G. L. Johnson & L. S. Hardin, Iowa State College Press.

Linear Programming

Linear programming, a development of the late thirtees is used by agricultural economists as a device to specify the optimum[2] organization of resources and enterprises on farms and to suggest desirable farm adjustments. The method as its name implies is based on linear relationships and inequalities. Linearity arises because of the fact that the input-output coefficients which are used are assumed to be constant or to be represented by a linear relationship between the factor inputs and the product output, and that the prices paid for a resources or received for products are assumed to be constant, *i.e.*, prices remain invariant with the volume of output. Inequality arises from the fact that our emerging plan (1) avoides using the supply of all available resources, and (2) ensures that the quantity of any activity or commodity produced will be equal to or greater than zero.

There is a good deal of similarity excepting for some differences in the computational procedures between the two techniques. Both use the assumption of linearity, constant input-output ratios, etc. Hence both have some common limitations. But the utility differences between the two are great: budgeting is seldom used to determine the one unique production programme out of many, which gives maximum profit. Ordinarily, it is used to find out which of the two producing methods or farm organizations is the better one. The other alternative organizations that may exist are not examined. Or even if they are, the process involves so much time that the determination of the optimum does not serve any practical purpose. Linear programming, on the contrary, has the advantage for large-scale problems and the time it takes in arriving at the optimum programme is only a fraction of that taken by the budgeting technique. Restriction is felt only if there is an opportunity cost problem, when the method should not be used at all.

Accuracy of computations is a pre-requisite for both the methods. But it is needless to state that the assembling of the right input-output coefficients and prices is important even more for both use the same technical coefficients and price quantities and the solution that each renders professes to be feasible.

FARM BUDGETING: APPLICATION

Method of Selection of the Farm

Before proceeding to the application of the budgeting method to the farm under study the method of selection may be discussed in brief. It may be recalled that the farms under the Farm Management Investigations in the district of Monghyr (Bihar) were selected by a method of stratified random sampling in which the strata were the five quintiles of the cultivating areas. These farms came at the second stage of sampling, the first stage units being the villages selected according to the size of the cultivating population from each of the three distinct natural divisions of Monghyr, the north, the central and the south. From North Monghyr the number of villages selected was 4 and from each of the selected villages a sample of 10 farms was taken. Rashidpur under Bachhwara

2. E. O. Heady & W. Candler: Linear Programming Methods, Iowa State College Press.

P. S. in Begusarai sub-division is one of these four villages and farm No. 5 under study is one of these 10 farms. The selection of this particular farm and not others was made because it represented a near average farm of the north at least in the sense of the size of the operational holding.

It may be mentioned that the collection of data in the farm management survey was made by the cost accounting method and the present study relates to the 2nd year, *i.e.*, 1958-59, of investigation utilizing wherever necessary the informations of the year following as well as preceding it.

Village Features

Rashidpur is an easily accessible village situated at a distance of 52 miles from Monghyr district headquarters and 26 miles from sub-divisional town connected by a motorable road with the nearest market place and the post and telegraph office 6 miles away. Ganga is the main river which flows at a distance south of Rashidpur from the west to the east. This apart, a number of other rivers flow from north to the south and discharges themselves into the Ganga. The effect of these rivers on the soil of Rashidpur cannot be clearly ascertained except that it keeps the soil alluvial.

The climate of the village can broadly be divided into three major seasons: (1) the hot weather season from March to mid-June, (2) the rainy season from mid-June to mid-October, and (3) cold weather season from November to February. May is the hottest month when the temperature goes upto 90 degrees F. The normal annual rainfall is 41.1″ based on an average of the years 1952-1956 of which a precipitate of 42.8″ falls in June-September quarter and the rest is distributed more or less evenly between the succeeding quarters.

No large-scale irrigation facilities are available in the village and the little irrigation that is done is perpetrated from wells and ponds. The educational level of the farmers is poor and they can mostly be classed as illiterates with attitude not always favourable to accepting the challenge of the time and the need of the day.

Resources of the Farm

Land: The farm under study as investigated in the year 1958-59 had an operated area of 6.19 acres of which 3.71 acres were fully owned and the rest, *i.e.*, 2.48 acres, was leased-in on share cropping basis. The lease assured a 50 per cent share of the produces raised over the year to the farmer in lieu of his labour and capital. The quality of the land constituting the farm represented an average for the village and varied from loamy to clayey with level mostly medium. Other requirements satisfying, it could not be unreasonably assumed that all lands under the possession of the farmer could be planted to any crop of his choice depending on the season.

Labour: The farm family consisted of the operator's wife, two sons and a daughter-in-law. Taking a man-equivalent year to consist of 300 days of 8 hours a day there was only three man-equivalent years' labour available from the farm family. The wife of the operator and the daughter-in-law, it may be mentioned, extended help not beyond light operations such as, sowing, inter-culture, weeding, winnowing or cattle maintenance.

The average acreage per man-equivalent or in other words the man-land ratio was 2.06 which implies that with an intensive system of farming which enabled the cultivators to productively use 100 man-work days per acre annually a little more than two-third of the labour available would be profitably employed on the farm. The lack of opportunity under the present system for more efficiently using labour available on the farm-holding pointed to a need for developing a plan for intensive agricultural production, the off-farm opportunity being virtually nil.

Capital investment in farming: Capital investment in farming for the farm under study amounted to Rs. 3,680 of which the major part (90 per cent) was blocked in cultivated land (Rs. 3,369) and the rest distributed between cattle-shed and storage (Rs. 50), livestock (Rs. 245) and dead stock (Rs. 16). On per-acre basis the value of investment came, however, to Rs. 604 only.

Livestock inventory consisted of a pair of bullocks in the depreciating age, of local breeds, a milch cattle and a home-bred calf. There were no goats or poultry. With the provision of adequate feeds, the pair of bullocks could be expected to undertake efficiently the intensive cropping programme in view in the alternative plan and the milch cattle to yield enough milk for home consumption in tune with the the nutritional standard set forth in the developmental plans. Since very little labour was needed for the upkeep and maintenance of poultry, a flock of poultry was assigned to the family with a view to increasing the return. Implements and machinery were few in number and were of the primitive type in the existing plans and as such they needed to be replaced by good varieties in the alternative plan.

Land Utilization, Cropping Pattern and Related Management Practices

Table I exhibits the land utilization and cropping pattern actually followed by the farm under study in the year 1958-59 and to be followed under the alternative plan and also indicates some of the management practices, *e.g.*, provision of irrigation facilities, fertilizers[3] and manure and improved seeds under the present (P) and alternative plans (A).

From Table I, paddy, maize, *jowar* and, wheat and gram appear as the main or principal crops and onion, chilli and *karaila* as minor ones. Irrigation was extended only to the two cash crops—onion and *karaila* and that too in the former case in part only. Fertilizers and manures were not used at all and improved seed was used from cash purchase only in case of the crops irrigated, others being left to the mercy of atmospheric moisture and rainfall.

The area single-cropped came to 4.30 acres while the area double-cropped was 2.12 acres, both together accounting for a gross cropped area of 8.31 acres yielding 134 per cent as the intensity of cropping (gross cropped area divided by the net area sown which was the area operated in the present instance). With the availability of greater irrigation facilities and family labour this intensity was increased considerably as is evident from the table relating to the alternative plan.

---

3. To arrive at the expected yield of the crops for the quantities of the fertilizers used, use was made of the following: (i) H. N. Mukerjee, "Soils of Bihar and a New Method of Determining Their Manurial Requirements," ***Proceedings of the Bihar Academy of Agricultural Sciences,*** Vol. I, No. 1 and (ii) Indian Council of Agricultural Research, The Report of the Results of Fertilizer Demonstration Trials in India, 1954-55.

TABLE I—LAND UTILIZATION, CROPPING PATTERN AND RELATED MANAGEMENT PRACTICES

		Crops								
		Season I				Season II			Season III	
		Paddy	Maize	*Jowar*	Kodo and *Jowar*	Wheat and Gram	Onion	Chilli	*Karaila*	
Area Sown (acres)	P	1.78	1.19	0.54	1.37	2.16	0.70	0.24	0.33	
	A	1.14	1.54	2.14	—	1.12	1.34	—	1.83	
Area Irrigated (acres)	P	—	—	—	—	—	0.29	—	0.33	
	A	0.57	1.54	2.14	—	1.12	1.34	—	1.83	
Fertilizers and Manures	P	—	—	—	—	—	—	—	—	
	A	FYM 10C	Mix 150 Rs. 38	A/S 200 Rs. 40	—	Mix 100 Rs. 25	—	—	Mix 150 Rs. 38	FYM 15C Rs. 75
Seed Used Home-grown (H) or Purchased (P)	P	H	H	H	H	H	P	H	P	
	A	H	H	H	H	H	P	H	P	

FYM — Farmyard Manure. A/S — Amonium Sulphate. Mix - Mixture of Amonium & Pot Sulphate. C - Cart-load.

Under the alternative plan the area single-cropped was 3.34, double-cropped 2.88 and the area irrigated 8.54; the intensity of cropping rose to 148 per cent.

A reorganization of the land available was effected in order to provide for larger area to the cash crops—onion (twice that of the previous plan) and *karaila* (6 times) for which the soil type was found to be moderately suitable—and to the fodder crop *jowar* to enable a richer feed production programme for the live-stock. Much greater use of irrigation from wells and ponds in order to more fully utilize the idle man-power (to be shown subsequently) and to raise productivity and appropriate use of fertilizers and manure was made at the time of preparation of the alternative plan. Consistent with the overall goal of improving the quality as well as the quantity of food a decrease in the acreage of the cereals like rice (not a popular diet with the farm family), cereal and pulse mixture, wheat and gram was, however, thought reasonable while increasing it in favour of maize. The increase or decrease was also planned with an eye on the cash sale and prefitability of the crops. Chilli although otherwise a highly profitable cash crop was found unsuitable to the prevalent soil type and hence it was dropped altogether in the alternative programme.

Labour Utilization

The relatively inefficient use of the labour resource under the present plan can be understood by studying Table II which shows the utilization of labour in man-work days in respect of the various crops by months. The relevant informations about the alternative plan can be had in the lower half of Table II.

TABLE II—LABOUR REQUIRED BY MONTHS AND ENTERPRISES UNDER PRESENT AND ALTERNATIVE PLANS

Enterprises	Labour (in Man-Work Days) required in each Month												
	June	July	August	September	October	November	December	January	February	March	April	May	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Present Plan													
Paddy (1.78)	14.75	5.25	—				34.00						
Maize (1.19)	17.00	14.50	0.75	2.25	1.50								
Jowar (0.54)	4.125	5.75				1.625							
Kodo and *Jowar* (1.37)	11.375	20.50				10.25							
Wheat and Gram (2.16)	1.50	5.50	4.50	8.125	5.75	9.00					20.75	4.75	
Onion (0.70)					3.00	6.00	8.50		3.00	16.00	7.00	5.00	
Chilli (0.24)		1.75	6.625	6.00			0.50						
Karaila (0.33)									1.25	14.50	2.00	3.25	
Total Crops	48.75	53.25	11.875	16.375	10.25	26.875	43.00		4.25	30.50	29.75	13.00	289*
Total Livestock	25.00	25.00	41.875	39.00	32.75	37.50	31.00	38.75	40.875	38.00	21.75	27.25	398
All Enterprises	73.75	78.25	53.75	55.375	43.00	64.375	74.00	38.75	45.125	68.50	51.50	40.25	687
Alternative Plan													
Paddy (1.14)	9.50	3.375	18.75	10.00			21.75						
Maize (1.54)	22.00	25.00	7.25	2.875	2.00								
Jowar (2.14)	25.00	32.50			6.50								
Wheat and Gram (1.12)	0.875	3.00	2.375	4.25	11.88	13.50	8.75				10.75	2.50	
Onion (1.34)					18.25	24.00	28.75		5.75	30.625	20.00	9.50	
Karaila (1.83)									19.375	92.875	23.50	18.00	
Total Crops	57.375	63.785	28.375	17.125	38.63	37.50	59.25		25.125	123.50	54.25	30.00	535†
Total Livestock	25.00	25.00	41.875	39.00	32.75	37.50	31.00	38.75	40.875	38.00	21.75	27.25	398
All Enterprises	82.375	88.875	70.25	56.125	71.38	75.00	90.25	38.75	66.00	161.50	76.00	57.25	933

* — of which labour was hired for 10 days, others being provided by family or exchange labour.

† — of which labour was hired for 57 days, others being provided by family or exchange labour.

TABLE III—FARM PRODUCTION AND USE UNDER PRESENT AND ALTERNATIVE PLANS

Present Plan					Alternative Plan				
Enterprise	Production and Use				Enterprise	Production and Use			
	Quantity (Maunds)	Value (Rs.)	Sales			Quantity (Maunds)	Value (Rs.)	Sales	
			Quantity (Maunds)	Value (Rs.)				Quantity (Maunds)	Value (Rs.)
Paddy (1.78)	37.68	339.12	—	—	Paddy (1.14)	25	369	—	—
					B.P.†		96	—	—
Maize (1.19)	19	304	5	90					
Jowar (0.54)	6	60	—	—	Maize (1.54)	36	390	16	240
					B.P.		72	—	—
Jowar and	8.13	81.3	—	—	*Jowar* (2.14)	24	360	—	—
Kodo (1.37)	3.5	17.5	—	—	B.P.		57	—	—
Wheat and Gram (2.16)	27.25	436	10	240	Wheat and Gram (1.12)	24	420	10	172
					B.P.		96	—	—
Onion (0.70)	87.5	700	51	408	Onion (1.34)	167	1,386	110	913
Chilli (0.24)	0.25	14	0.25	3	*Karaila* (1.83)	22	220	18	180
Karaila (0.33)	2.5	25	1.75	17.5	Milk (1)		49.72		
Milk (1)		33.15	—	—	Poultry (25)	200 dozen eggs		200 dozens	200

†B.P. means by-product.

Table II reveals that utilization of family labour in the crop enterprises increased by 199 man-work days or 71 per cent in the alternative over the present plan and most of this increase owed to the operations like irrigation and manuring specially envisaged in the alternative plan. The allocation of greater acreage to onion and the winter crop *karaila* tended to increase the level of utilization of labour in and about the third and fourth quarters of the year as was also the case in the first two quarters on account of the fact that the labour intensive operations like irrigation and the minor operation manuring were conducted upon in respect of the first and the remaining second season crops. Greater use of female than male labour was envisaged in the alternative plan for the upkeep and maintenance of the livestock and since no significant addition was made to the existing inventory, labour used on this account remained the same in both the plans.

It may be noted that the labour use index increased from 75 per cent in the present plan to 97 per cent in the alternative plan. Utilization of the labour available was, therefore, more fully complete in the alternative than in the existing plan. This was possible because the members of the farm family showed no aversion to working harder if the net return resulting would be greater. This point was, however, given due consideration to in the making of changes in present plan.

Farm Production and Use

Table III shows farm production and use under the two plans. It indicates that both the value of cash sale as well as the value of the production for home consumption increased—the former more significantly than the latter—in the alternative plan.

Feed Production Programme

The crop programme was designed in such a way that there was considerable increase in the quantum of feeds available as by-products for the livestock. Table IV shows the feed production in respect of green fodder and *Bhusa* (dry fodder) and also the percentage increase in the quantity of these feeds per animal unit in the alternative over the existing plan.

TABLE IV—QUANTITY OF FEEDS AVAILABLE UNDER PRESENT AND ALTERNATIVE PLANS

	Present Plan	Alternative Plan	Percentage Increase in the Alternative Plan
Green Fodder	147 Maunds	181 Maunds	
Bhusa and dry fodder	71 „	173 „	
Average green fodder per animal unit*	42 „	49 „	16
Average *bhusa* per animal unit	20 „	47 „	135

*The animal unit under present plan was 3.5 and that under alternative plan 3.7

Costs, Returns and Investment

The two plans may now be compared from the point of view of costs, returns and investment. The analysis[4] adopted places special emphasis on the

4. E. F. Daniel: Farm Planning and Management, Directorate of Economics & Statistics, Ministry of Food & Agriculture, New Delhi.

items of net cash income and net cash income plus value of home use products as both are important from the viewpoint of welfare of the farm family. Incorporated is also a comparison of net returns per man-work days used to show how far the plan evolved was successful in fully, profitably and efficiently using the family labour. The detailed analysis is shown in Table V.

TABLE V—COSTS, RETURNS AND INVESTMENT UNDER PRESENT AND ALTERNATIVE PLANS

(in Rupees)

Items	Present Plan	Alternative Plan	Items	Present Plan	Alternative Plan	Percentage increase
Investment						
Cultivated land	3,369	3,369	Net cash income (b) — (c)	699	1,239	90
Cattle shed and storage	50	100	Value of home used products less rent (kind), seeds (home-grown),			
Dead stock (implements and machinery)	16	50	payment for repairs (kind)	853	1,420	67
Livestock	245	295	Net Cash Income plus Value of Home-used			
Others	—	—	Products	1,552	2,659	73
(a) Sub-total	3,680	3,814	Depreciation	97	147	
Gross cash income from sale of:						
(i) Crops	758.5	1,508	Returns to Capital, Labour and Management	1,455	2,512	
(ii) Livestock Products (eggs)	—	200				
(b) Sub-total	758.5	1,708	Interest on Investment at 3 per cent	110	114	
Cash Expense						
Seed	22	105	Returns to Labour and Management	1,345	2,398	
Fertilizer and Manure	—	216				
Feeds	—	30	Total man-work days Used	676	875	29
Hired Labour	15.5	88				
Land Revenue and Cess	14	14				
Repairs	8	16	Net Return per man-work days	2.0	3.0	50
Others	—	—				
(c) Sub-total	59.5	469				

Table V brings to light many significant features of the alternative plan as distinct from those of the previous one. First, the total added annual cost obtained by lumping interest on additional investment, depreciation on added capital and added operating cash expense was 173 per cent, the major part of which (150 per cent) was accounted for by added operating expense (in cash). Fertilizers, seeds and, to some extent, hired labour used in the alternative plan were responsible for this added operating expense. Interest on added investment was a minor expense as only slight adjustments were made in cattle shed and storage; equipment and livestock. The added depreciation then, was significant and was caused by the addition of the poultry flocks and the pen.

As for incomes and labour utilization, there was 90 per cent increase in the annual net cash income, 67 per cent increase in net cash income plus value of home use products, 29 per cent increase in labour utilization and 50 per cent increase in the net returns per man-work day in the alternative plan as compared to the existing plan. All these, therefore, point to certain significant improvements of the existing plan being made in the alternative plan.

LINEAR PROGRAMMING: APPLICATION

The objective of this part of the paper is to apply the linear programming technique for determining the optimum crop plan for the farm studied so far and the objective is accomplished within the restriction of existing farming technique for the crops specified.

The farm, it may be recapitulated, utilized 8.31 acres of land under the various crops the labour for which had to be provided for from the family itself, through exchange and from hire. The amount of cash available was Rs. 300 only. In the optimum plan to be evolved all the other crops except chilli, *i.e.*, paddy, maize, *jowar*, wheat and gram, onion and *karaila* were retained. Chilli was dropped as it was found unsuitable to the particular soil type and had a huge demand on labour if it had to be made profitable. In respect of labour, June, July, December and March appeared to be limitational as in these months labour had to be sought in exchange or on hire basis. The optimum plan was, therefore, to be determined subject to the limitation that June, July, December and March labour[5] could not exceed 27, 48, 26 and 44 man-work days respectively (*i.e.*, those provided from the farm family), the labour available in the other months being, however, unlimited under the present system of farming. Cash expense could not exceed Rs. 300 and land could not be utilized for more than 8.31 acres. Without the risk of much error it could be assumed at least in the present instance that the land available could be planted to any crop of the farmer's choice defined above and that there would be perfect elasticity in the supply of family labour even after considering the fact that the indeterminancy of the leisure-preference curve for the particular farm household might introduce an element of uncertainty in the availability of the family labour.

To determine[6] the optimum plan we may proceed in the following way. Suppose R_j referring to the crop enterprise or activity is a column vector in which a_{ij} denotes the amount of the *ith* scare resource used in the *jth* activity. Then, $R_j = (a_{ji}, a_{2j} \ldots\ldots\ldots\ldots a_{6j})$, $j = 1,2 \ldots\ldots\ldots 6$ representing respectively the paddy, wheat and gram, maize, *Jowar*, onion and *karaila* enterprises and $i = 1, 2 \ldots\ldots\ldots 6$ representing respectively the resources land, cash expense, June labour, July labour, December labour and March labour. Let $R = (R_1, R_2 \ldots\ldots\ldots\ldots R_6)$ = a matrix with 6 rows and 6 columns. Suppose further that the column vector $X = (x_1, x_2 \ldots\ldots\ldots\ldots x_6)$ expresses the activity intensities (the amount of each crop produced) and S_i expresses the quantity of each resource available. Then the resource supply restrictions take the form:

$$a_{11}\,x_1 + a_{12}\,x_2 + \ldots\ldots\ldots + a_{16}\,x_6 \leq S_1$$
$$a_{21}\,x_1 + a_{22}\,x_2 + \ldots\ldots\ldots + a_{26}\,x_6 \leq S_2$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$a_{61}\,x_1 + a_{62}\,x_2 + \ldots\ldots\ldots + a_{66}\,x_6 \leq S_6$$

Or $\quad AX \leq S$

---

5. The March labour restriction is included at the suggestion of Dr. J. P. Bhattacharjee (Rapporteur) at the conference. Maximization of the net return and not gross return is attempted here. The author is indebted to him for the suggestion.

6. Bernard Bowlen & E. O. Heady: Optimum Combination of Competitive Crops at Particular Locations (Application of Linear Programming), Research Bulletin 426, Ames, Iowa, April, 1955.

TABLE VI—A LINEAR PROGRAMMING SOLUTION BY SIMLEX METHOD FOR 6 ACTIVITIES FORMING THE CROP PLAN) WITH SIX LIMITATIONAL RESOURCES IN RASHIDPUR, MONGHYR (BIHAR)

Resource Used or Crop Produced	Letter to Identify	Supply Remainder or Output	Resource for Disposal or Crop for Production: Land	Cash	June Labour	July Labour	Dec. Labour	March Labour	Paddy	Wheat & Gram	Maize	*Jowar*	Onion	*Karalia*	K
			Net Price (P) for resource disposal or crop production												
	O	O	O R_7	O R_8	O R_9	O R_{10}	O R_{11}	O R_{12}	13.72 R_1	17.20 R_2	14.85 R_3	14.57 R_4	8.17 R_5	4.67 R_6	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Land	R_7	8.31	1	0	0	0	0	0	.065	.143	.064	.179	.008	.132	58.11
Cash	R_8	300.00	0	1	0	0	0	0	.476	.301	.152	·429	.131	5.331	996.67
June Labour	R_9	27.00	0	0	1	0	0	0	.538	.099	.917	1·377	0	0	272.70
July Labour	R_{10}	48.00	0	0	0	1	0	0	.191	.386	.782	1.896	0	0	124.35
December Labour	R_{11}	26.00	0	0	0	0	1	0	1.238	0	0	0	.097	0	Unlimited.
March Labour	R_{12}	44.00	0	0	0	0	0	1	0	0	0	0	.182	5.800	Unlimited.
Opportunity Cost	C	0	0	0	0	0	0	0	0	0	0	0	0	0	
Net Marginal Profit[5]	C—P	0	0	0	0	0	0	0	—13.72	—17.20	—14.85	—14.57	—8.17	—4.67	
17.20 Wheat and Gram	R_2	58.11	6.99	0	0	0	0	0	0.454	1	0.448	1.250	.056	.920	1038
Cash	R_8	282.51	—2.10	1	0	0	0	0	0.339	0	0.017	.053	.114	5.054	2478
June Labour	R_9	21.25	—.69	0	1	0	0	0	.493	0	0.873	1.253	—.006	—.091	
July Labour	R_{10}	25.57	—2.70	0	0	1	0	0	.016	0	.608	1.414	—.022	—.355	
December Labour	R_{11}	26.00	0	0	0	0	1	0	1.238	0	0	0	.097	0	268
March Labour	R_{12}	44.00	0	0	0	0	0	1	0	0	0	0	.182	5.800	242
Opportunity Cost	C	999.49	118.68	0	0	0	0	0	7.809	17.200	7.706	21.500	.963	15.824	
Net Marginal Profit	C—P	999.49	118.68	0	0	0	0	0	—5.911	0	—7.144	6.930	—7.207	11.154	

(Contd.)

TABLE VI (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
17.20 Wheat and Gram	R_2	44.57	6.99	0	0	0	0	—.31	.454	1	.448	1.250	0	—.865	99
Cash	R_3	254.95	—2.10	1	0	0	0	—.63	.339	0	.017	.053	0	1.421	14997
June Labour	R_9	22.70	—.69	0	1	0	0	.03	.493	0	.873	1.253	0	.100	26
July Labour	R_{10}	30.89	—2.70	0	0	1	0	.12	.016	0	.608	1.414	0	.346	51
December Labour	R_{11}	2.55	0	0	0	0	1	—.53	1.238	0	0	0	0	—3.091	
8.17 Onion	R_5	241.76	0	0	0	0	0	5.49	0	0	0	0	1	31.868	
Opportunity Cost	C	2741.78	120.23	0	0	0	0	39.52	7.809	17.20	7.706	21.500	8.170	245.484	
Net Marginal Profit	C—P	2741.78	120.23	0	0	0	0	39.52	—5.911	0	—7.144	6.930	0	240.814	
17.20 Wheat and Gram	R_2	32.92	7.34	0	—.51	0	0	—.29	.200	1	0	.607	0	—.916	165
Cash	R_3	254.51	—2.09	1	—.02	0	0	—.63	.329	0	0	.028	0	1.419	773
14.85 Maize	R_8	26.00	—.79	0	1.14	0	0	.03	.565	0	1	1.435	0	.114	46
July Labour	R_{10}	15.08	—2.22	0	—.69	1	0	.10	—.327	0	0	.541	0	.277	
December Labour	R_{11}	2.55	0	0	0	0	1	—.53	1.238	0	0	0	0	—3.091	2
8.17 Onion	R_5	241.76	0	0	0	0	0	5.49	0	0	0	0	1	31.868	
Opportunity Cost	C	2927.50	114.52	0	8.16	0	0	40.31	11.830	17.20	14.850	31.750	8.170	246.299	
Net Marginal Profit	C—P	2927.50	114.52	0	8.16	0	0	—40.31	—1.890	0	0	17.180	0	241.629	
17.20 Wheat and Gram	R_2	32.51	7.34	0	—.51	0	—.16	—.20	0	1	0	.607	0	—.417	
Cash	R_3	253.84	—2.09	1	—.02	0	—.27	—.49	0	0	0	.028	0	2.241	
14.85 Maize	R_8	24.84	—.79	0	1.14	0	—.46	.27	0	0	1	1.435	0	1.525	
July Labour	R_{10}	15.75	—2.22	0	—.69	1	.26	.24	0	0	0	.541	0	—.540	
13.72 Paddy	R_1	2.05	0	0	0	0	.81	—.43	1	0	0	0	0	—2.497	
8.17 Onion	R_5	241.76	0	0	0	0	0	5.49	0	0	0	0	1	31.868	
Opportunity Cost	C	2931.35	114.52	0	8.16	0	1.53	39.52	13.72	17.20	14.850	31.750	8.170	241.576	
Net Marginal Profit	C—P	2931.35	114.52	0	8.16	0	1.53	39.52	0	0	0	17.180	0	236.906	

Denoting by x7, x8 .....x12 as the variable for disposal activities (*i.e.*, an enterprise standing for the non-use of the resource), the inequalities above can be written in the equality form as follows:

$$a_{11}\ x_1 + \ldots\ldots\ldots + a_{16}\ x_6 + 1 \cdot x_7 + 0 \cdot x_8 \ldots\ldots + 0 \cdot x_{12} = S_1$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$a_{61}\ x_1 + \ldots\ldots\ldots + a_{66}\ x_6 + 0 \cdot x_7 + 0 \cdot x_8 \ldots\ldots + 0 \cdot x_{10} + 0 \cdot x_{11} + 1 \cdot x_{12} = S_6$$

If $R' = (R_1\ R_2\ R_6 \ldots\ldots\ldots R_{12})$, then $R' = R.I.$), I being the identity matrix. The resource restrictions then become (i) $X \geq 0$ and (ii) $R'X = S$.

In the particular instance, on the basis of average yield per acre based on the years 1957-58, 1958-59 and 1959-60 and resource utilization as prevailing in 1958-59 under the existing plan, the following equation was obtained:

.065	.143	.064	.179	.008	.132	1	0	...	0	
.476	.301	.152	.429	.131	5.331	0	1	...	0	(X_1 X_2...
.538	.099	.917	1.377	0	0	0	0	...	0	X_{12})
.191	.386	.762	1.896	0	0	0	0	...	0	Solution
1.238	0	0	0	.097	0	0	0	...	1	vector
0	0	0	0	.182	5.800					

Input-Output coefficient Matrix (6 × 6) × Identity Matrix (6 × 6)

= (8.31, 300, 27, 48, 26, 44)
Supply Vector

To determine $x_1 \ldots\ldots\ldots\ldots x_{12}$ such that the net revenue function $13.72\ x_1 + 17.20\ x_2 + 14.85\ x_3 + 14.57\ x_4 + 8.17\ x_5 + 4.67\ x_6$ becomes maximum, where the coefficients of X'S are the net prices of the activities obtained by taking a difference of the average of the 1957-58, 1958-59, and 1959-60 prices from the variable cash costs.

The arithmetic process[7] is shown in Table VI from which the following solutions are obtained:

$$X_1 = 2.05x_2 = 32.51\ x_3 = 24.84, x_4 = 0, x_5 = 241.76$$
$$X_6 = 0 \qquad x_8 = 253.84, \quad x_{10} = 15.75$$

The optimum plan had then the net revenue of Rs. 2,931 above capital expense and the allocation of resources took place in the way as shown in Table VII.

TABLE VII—ALLOCATION OF RESOURCES AMONG THE SIX ACTIVITIES OF THE OPTIMUM CROP PLAN

	Paddy	Wheat and Gram	Maize	*Jowar*	Onion	*Karaila*	Total
Acres	.14	4.64	1.59	0	1.94	0	8.31
Capital Expenses (Rs.)	.98	9.79	3.78	0	31.67	0	46.22
June Labour (days)	1.10	3.22	22.78	0	—	0	27.1
July Labour (days)	.39	12.55	19.42	0	—	0	48.1
Dec. Labour (days)	2.54	—	—	0	23.41	0	25.95
March Labour (days)	—	—	—	0	—	0	44.00

7. Earl O. Heady, "Simplified Presentation and Logical Aspects of Linear Programming Technique," *Journal of Farm Economics*, Vol. XXXVI, December, 1954.

Wheat and gram, onion, maize and paddy emerged in the descending order of importance as the three most profitable crops in the optimum crop plan.

The cost and return of the optimum plan with those of the already existing one may now be compared. This is done in details in Table VIII.

TABLE VIII—COST AND RETURN OF PRESENT AND OPTIMUM CROP PLAN
(In Rupees)

Optimum Crop Plan		Present Crop Plan	
(a) By-product in excess of feed for draught cattle	73	(a) Value of output and by-product in excess of feeds	2,244
(b) Value of output above Cash expense	2,931	(b) Cash operating expense	60
(c) Rent (kind)	333	(c) Rent (kind)	333
(d) Seed (farm grown)	86	(d) Seed (farm grown)	145
(e) Repair (kind)	9	(e) Repair (kind)	9
(f) Depreciation	99	(f) Depreciation	99
(g) Interest on fixed capital for enterprises	108	(g) Interest on fixed capital for crop enterprises	108
(h) Total Cost excluding operating cost	635	(h) Total Cost including operating cost	754
Returns to labour and management [(a) + (b) — (h)]	2,369	Returns to labour and management [(a) — (h)]	1,490
Man work days used for crop operations and draught cattle maintenance	596	Man work days used for crop operations and draught cattle maintenance	44
Net Returns per Man work days used	3.97	Net Returns per Man work days used	2.74

The table shows that taking only the crop enterprises the optimum plan had been able to increase the net return per man-work day used by 45 per cent over the existing crop plan.

The method of programming as applied here refers to a static concept. An alternative area of application—optimum resource use through time and selection of alternative programmes for resource development—is less well explored. But in India, it needs no emphasis to demonstrate the utility of the dynamic models specially in view of the fact that the growth of the economy under the impact of the developmental plans is increasing and the optimum solution obtained for one time point or period may not apply well to a period which lies ahead. Much attention has, therefore, to be given to the consideration of the element of growth[8] while developing models on which the programming technique may be applied.

8. G. C. Mandal: Studies in the Problem of Growth of a Rural Economy, World Press, Calcutta.