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# LINEAR PROGRAMMING AND FARM PLANNING

Miss Meenakshi Malya
*Research Officer (Statistics)*
*Agricultural Economics Research Centre*
*University of Madras*
*Madras*

## INTRODUCTION

There are three methods of approach to farm planning: the classical theory of firm and profit maximization, the more recent and popular method of budgeting, and thirdly the technique of linear programming. This paper seeks to examine (1) the basic concepts of linear programming as compared with the other two methods, (2) the current studies in the field of application of Linear Programming to farm planning in India, and (3) the application and practicability of this technique in farm planning by undertaking a case study of a farm under well irrigation and with food and cash crop combination.

## I

## BASIC CONCEPTS

Recently there has been rapid progress in the development of this particular branch of Econometrics dealing with a set of techniques, *viz*., Linear Programming or more generally termed as "programming of inter-dependent activities." This branch of research and methodology deals with the problem of planning a complex pattern of economic action in the best possible (optimal) manner. When the problem is to achieve an objective and when alternative methods of achieving it exist, given resource restrictions, programming can be employed with advantage. Programming can be linear or non-linear. Research is being conducted in the field of quadratic programming but not much application is found as yet. Programming in linear economies denotes the fact that the basic restrictions in the problem can be expressed in terms of simple first degree equations or inequalities.

In farm planning, the objective of a cultivator may be to maximize his net returns or farm business income with the limited resources of land, labour and capital at his command. This will entail the determination of the best possible combination of crops and|or livestock enterprises, choice of alternate crops, etc. Linear programming as a technique gives the optimal solution provided certain basic assumptions[1] and conditions of internal consistency, accuracy of data, etc., are satisfied. It also helps in determining the best method or most efficient process of production. Thus farm mechanization problems and their economies can be worked out by using this modern tool.

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1. See D. K. Desai, "Linear Programming Applied to Problems in Indian Agriculture," *Indian Journal of Agricultural Economics*, April-June, 1960, p. 59.

## LINEAR PROGRAMMING AND MARGINAL ANALYSIS

The theory of firm and profit maximization as developed by marginal product analysis can be applied to farm also. When the farm produces only one product, assuming unlimited continuous availability of resources, the highest profit is got when the marginal cost equals marginal revenue. If inputs are used beyond this optimum level, profits will diminish. When there are many alternative crops, *i.e.*, when products are competitive, substitution between products with optimum resource allocation leads to maximum returns when the marginal rate of substitution is inversely equal to the product-price ratio.

Precise functional relationship or production functions are to be determined as a first step. The first derivatives give the marginal product curves from which the level of optimum resource allocation can be determined. Linear programming technique assumes linear relationships and hence no complex mathematical functions are involved.

The essential difference in the two approaches is the mathematics behind them. The matrix of technical co-efficients and resource restrictions together with the "net" prices arranged neatly, facilitates a neat and rigorous solution for a complex pattern of possibilities. When the alternate crops that can be grown in the particular soil and climate are numerous, working out marginal rate of substitution between crops and arriving at an optimum cropping pattern by successive steps is a cumbersome process. But the algebra of simultaneous equations on which is based the solution of linear programming provides a short-cut to the final solution.

## BUDGETING AND LINEAR PROGRAMMING

Budgeting is non-mathematical. Based on a first-hand knowledge of the farm 'to be planned,' its production possibilities, the capacity of the farmer to carry out the alternate plan suggested, etc., it takes into account a flexible production programme, suggesting improved agricultural practices to the farmer. Budgeting can be partial (for any particular crop) or total (taking the entire farm). The advantage of this method is apparent from the numerous studies undertaken by the various research bodies, specially in U. P. Budgeting can especially be used in extension work, since it does not involve tedious calculations and is within the comprehension of any intelligent farmer.

On the other hand, since it is essentially a trial and error method, no guarantee of optimal allocation of profit maximization is there. Only by successive steps can the farmer be guided to better his farming practices. It leaves room for uncertainties. But this "rough and ready" method is the most practicable and the popular one.

Given the data as regards the maximum resources at the farmer's disposal, the input data on different crops (average or irreducible minimum) along with output, etc., and the technicians, Linear Programming can be used with better advantage. It gives the best solution when the problem is complex. A host of limiting conditions such as labour requirements in peak seasons, availability of irrigational facilities, etc., can be brought into the matrix of coefficients. Thus Linear Programming can also "dip deeper" into the problem. But when the choice is between only two crops with a small farm, budgeting may be adopted rather than setting up an elaborate table. In a nutshell, when the problem is 'large scale' use linear programming as a time-saver. When the problem is 'small scale use budgeting.'[2]

II

REVIEW OF CURRENT LITERATURE

Having examined the various approaches to the problem of farm planning, a brief review of the application of these techniques, linear programming in particular, in the field of Indian agriculture may be relevant.

Marginal analysis does not find wide application mainly for the reasons outlined in Section I. In the first report (1954-55) of the Farm Management Studies (Madras) an attempt has been made to fit a Cobb-Douglas production function for each of the three important crops in the region. Based on this production function, marginal productivity of land and labour were also calculated. While the data throw some light on this interesting problem, no attempt has so far been made to examine the practical utility of these equations.

Budgeting however has been adopted in quite a number of studies.[3] This has been tried with success in Kanpur District by the Kanpur Agricultural College and by the U. P. Government Scientific Enquiry Committee, and in Allahabad by the Allahabad Agricultural Research Institute, etc. The case studies conducted by Dr. E. F. Daniel make use of Farm Management Survey data in different regions.[4] Alternate farm plans are discussed taking into consideration all the minute details of resource availability, etc. The partial and total farm plans evolved for farmers covered in the Package Plan area also can be cited as examples of 'budgeting'.

Fewer studies are available in the application of Linear Programming techniques. Dr. D. K. Desai in his note[5] on Linear Programming has outlined the basic concepts and explored the possibilities of its application by working out optimal plans for two selected farms in Bombay State.

In an article[6] on the "Methodological Approach to the use of input-output relations in an appraisal of the production potentialities", Dr. K. S. Rao and Mr. I. H. Naqvi discuss the possibilities of making use of data from Farm Management Studies for optimum allocation pattern either by using budgeting or linear programming. The matrix of technical coefficients is set up by the input-output data of the most efficient farmers in Zone I, Ahmednagar District, Bombay. The conclusion arrived at is that the "best plan is when 52 per cent of available land resources are put under *jowar* and 48 per cent under wheat." The implication that this cropping pattern is the best one on all suitable land available needs to be

2. Earl O. Heady, "Simplified Presentation and Logical Aspects of Linear Programming Technique", *Journal of Farm Economics*, Vol. 36, 1954, p. 1035.
3. Refer articles by G. D. Agrawal, N. S. Randhawa, S. M. Pathak, D. S. Mann and others in *Agricultural Situation in India*, mainly in the 1957-60 volumes; S. P. Dhondyal, A. Wycliffe in *The Indian Journal of Agricultural Economics*, Vol. XV.
4. E. F. Daniel, Farm Planning and Management, New Delhi, 1960.
5. D. K. Desai, *Op. cit.*
6. Government of India, Studies in Agricultural Economics, Vol. [illegible] p. 109.

examined. The authors have aggregated the individual items of inputs of the best farmer for each crop to arrive at the total "availability" of resources. Obviously no generalisation of cropping pattern can be made based on this serious limitation. The plan of 52 per cent of land for *jowar* and 48 per cent under wheat is the best one only for a farmer with the resources of 2.31 acres of land, 116 days of human and 101 days of bullock labour at his command. (The modal group in the region is 10-20 acres). For a 10-acre farm with 800 human labour days and 730 days of bullock labour, the optimal pattern works out to 93 per cent under wheat and 7 per cent under *jowar*. Farm management data are no doubt essential to set up the matrix of technical coefficients but the resource restrictions, varying from farm to farm will necessarily give different solutions for optimal crop pattern.

Not many published studies are found in the application of linear programming technique in farm management; this field is as yet unexplored. In the next section, an attempt has been made to study the possibility and practicability of the application of this method in planning a farm in South India.

## III

A farm in Vadamalapuram village in Sattur Taluk of Ramanathapuram district (Madras State) has been selected for study. In this village, agriculture mainly depends upon well irrigation and seasonal rainfall. Paddy, *cholam* and millets are the food crops and cotton, chillies and groundnut, the cash crops of the region. In garden land plantains are sometimes cultivated. The nearest market is Virudhunagar, 12 miles away from the village accessible by a good metalled road. The soil is not very fertile and requires heavy manuring.

The farm taken up for study is a holding of 16 acres scattered over 4 fragments. Out of these 16 acres, 11 are wet and 5 dry. There is a well with pumpsets on each of the fragments of wet land. In two of the three fragments, water is available for irrigation to raise two crops whereas in the third fragment, (of 5 acres) only one wet crop can be raised. In the dry land only one crop can be raised.

The cultivator owns a pair of bullocks but during peak seasons he has to hire additional bullock labour. However, no additional expenditure is involved in hired bullock labour, because he realises this amount by hiring out his pair of bullocks for transport and ploughing. The following matrix gives the total available resources during two seasons.

TABLE I

| | I Season | II Season |
|---|---|---|
| Wet Land | 11 acres | 6 acres |
| Dry Land | 5 acres | 5 acres |
| Human Labour | 2,250 Man-days | 900 Man-days |
| Bullock Labour | 375 Days | 300 Days |
| Working Capital | Rs. 4,000 | Rs. 1,000 |

The above table has been arrived at by a detailed discussion with the farmer. Besides the listing up of available resources, cost of cultivation of each crop (per acre) has also been arrived at, based on his cultivation practices. The following matrix gives the relevant details.

TABLE II — COST OF CULTIVATION AND NET INCOME PER ACRE

| Crop | Human Labour (Man-days) | Bullock Labour Days | Working Capital* (Rs.) | Net Income** (Rs.) |
|---|---|---|---|---|
| | | Season I | | |
| Irrigated Chillies | 248 | 28 | 464 | 766 |
| Irrigated Onions | 164 | 14 | 260 | 566 |
| Unirrigated Fodder | 10 | 4 | 2 | 50 |
| Unirrigated Cotton *Karunganni* | 60 | 16 | 40 | 80 |
| Irrigated Paddy | 108 | 14 | 287 | 285 |
| | | Season II | | |
| Irrigated Cotton *Uganda* | 47 | 14 | 70 | 225 |
| Unirrigated Groundnut | 65 | 12 | 95 | 200 |
| Unirrigated *Cumbu* | 40 | 18 | 40 | 100 |
| Unirrigated *Cholam* | 20 | 20 | 100 | 195 |

*Working Capital means expenditure on seed, manure, fertilizers, pesticide, irrigation costs and transport charges.
**Net Income is the return for family labour, land and livestock investment.

The present cropping pattern, followed by the cultivator gives him a net income of Rs. 5,451 in Season I and Rs. 2,140 in the Season II.

With the matrix above, simplex tableau was set up introducing four slack variables. Depending on the sign and magnitude of simplex C, one variable was introduced at a time till the optimal solution was reached as indicated by positive values for all the remaining variables. Thus optimal plan was worked out for each season separately, taking into account the general cropping pattern of the village and the ryot.

Table III shows the present and optimal plans corrected to the nearest half acre.

Table III — AREA UNDER CROPS (IN ACRES)

| Season I | | | Season II | | |
|---|---|---|---|---|---|
| Crop | Present | Optimal | Crop | Present | Optimal |
| *Paddy | 3 | 1 | Groundnut | 1 | 5 |
| **Chillies | 4 | 5.5 | *Cumbu* | 2 | — |
| Onions | 2 | 4.5 | *Cholam* | 2 | — |
| Cotton | 5 | — | Cotton | 6 | 6 |
| Fodder | — | 5 | | | |

The net income with the optimal plan works out to Rs. 7,295 in the first season and Rs. 2,350 in the second season.

## PRACTICAL IMPLICATIONS

With this farm plan which only involves reorganization of available resources, the feasibility and practicability of its execution was discussed with the farm cultivator. It is gratifying to note that the cultivator evinced keen interest and decided that the plan was feasible provided certain basic requirements were satisfied: (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.

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# 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

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