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DECISION MAKING IN AGRICULTURE: A LINEAR PROGRAMMING APPROACH

DR. K. PUSHPAVALLI
Head & Associate Professor, Sri Sarada College for Women, Salem – 16, India.

DR. P. SUBASREE
Associate Professor, Sri Sarada College for Women, Salem – 16, India.

DR. S. UMADEVI
Assistant Professor, Sri Sarada College for Women, Salem – 16, India.

1. INTRODUCTION

The agricultural planning problems are important from both social and economic points of view. They involve complex interaction of vagaries of nature and economics. Agriculture contributes to nearly 25 % of GDP and about 70% of Indian population is dependent on agriculture for their livelihood. To meet out the food demand of increase population agricultural planning becomes inevitable. Filling up of demand-supply gap in food requirement is absolutely essential to avoid mal nutrition and under nourishment. One of the ways of achieving higher productivity is to increase the land area of the taken crop. Since the resources are scarce and limited in nature, the increased production of crops per unit area or the crop intensity must be achieved y proper utilisation of resources. Hence crop planning becomes very crucial. Optimum crop pattern with maximum profit at minimum cost is the need of the hour. With optimisation techniques available such as linear programming (LP) crop planning and efficiency of resources could be better achieved.

Linear programming (LP) technique is relevant in optimisation of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural production. The word linear is used to describe the relationship among two or more variables which are directly proportional. For example doubling or tripling the product of a product will exactly double or triple the profit and the required resources, then it is linear relationship programming implies planning of activities in a manner that achieve some optimal result with restricted resources.

Linear programming was developed y George B. Dantzing (1947) during 2nd world war. It has been widely used to find the optimum resource allocation and enterprise combination. Linear programming is defined as the optimisation (minimisation or maximisation) of a linear function subject to specific linear inequalities or equalities. The simplex algorithm developed by Dantzing, starts with a primal feasible basis and user pivot operations in order to preserve the feasibility of the basis and guarantee monotonicity of the objective value. For LP models with ≥ or = type of constrains the problem of obtaining initial basic feasible solution is difficult as this problems lack feasibility at origin. The usual approach to solve such problems is to use either two phase or big - m method each of which involves artificial variables and the introduction of artificial variable brings artificiality in other wise straight forward simplex method.

2. METHODOLOGY

A linear programming problem with "n" decision variables and "m" constraints can be mathematically modeled as (Taha [13], Zeleny [18], Winston [17] and Higle & Wallence, [7]).

$$\text{Maximum } Z = c_1 x_1 + c_2 x_2 + \ldots\ldots c_n x_n$$

Subject to (s.t.) (2.1)

$$a_{11} x_1 + a_{12} x_2 + \ldots\ldots + a_{1n} x_n \leq b_1$$
$$a_{2l} x_1 + a_{21} x_2 + \ldots\ldots + a_{2n} x_n \leq b_2$$
$$a_{m1} x_1 + a_{m2} x_2 + \ldots\ldots + a_{mn} x_n \leq b_m$$
$$x_j \geq 0,\ j = 1, 2 \ldots\ldots, n$$

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This can be written as,

$$\text{Max } Z = C^t X$$
$$\text{Subject to} \quad AX \le b, \quad X \ge 0 \tag{2.2}$$

From the model above, X represent the vector of variables (to be determined) while C and b are vectors of known matrix of coefficient. The expression to be maximized is called the objective function (C^t in this case). The equation $AX \le b$ is the constraint which specifies a convex polytope over which the objective function is to be optimized, The coefficients $c_1, c_2, \ldots c_n$ are the unit returns for the coming from each production process $x_1, x_2, x_3 \ldots x_n$.

3. PROBLEM FORMULATION

To formulate the problem mathematically, the following notations are used

Z = The objective function to be maximize,
X_j = Input Variables
C_i = Cost coefficients of the objective function Z
b_i = Maximum limit of the constraints.
a_{ij} = Coefficients of the functional constraint equations.

In general the planning models usually take the form

$$\text{Maximize } Z = \sum_{i=1}^{n} c_i x_j \tag{3.1}$$

Subject to

$$\sum_{j=1}^{n} A_{ij} x_j \le b_i \qquad i = 1, 2, \ldots, m \tag{3.2}$$

$$X_j \ge 0 \qquad j = 1, 2, \ldots, n \tag{3.3}$$

Where $A_{ij} = \lfloor a_{ij} \rfloor_{m \times n}$ $x_j = \lfloor x_{ij} \rfloor_{m \times 1}$ and $b_i = \lfloor b_{ij} \rfloor_{n \times 1}$ C_j, xij, $b_i \in R$

If we convert above G.L.P.P in standard form by using Slack Variables as x_{n+i}

$$\text{Maximize } Z = \sum_{i=1}^{n} c_i x_j$$

Subject to

$$\sum_{j=1}^{n} A_{ij} x_j + x_{n+i} = b_i \qquad i = 1, 2, \ldots, m$$

$$X_j \ge 0 \qquad j = 1, 2, \ldots, n$$

4. SOLUTION PROCEDURE FOR MAXIMIZING PROBLEM

In order to maximizing problem the following procedure is necessary,

1) Set up the inequalities describing the problem.
2) Convert the inequalities to equalities by adding slack variables.
3) Enter the equalities in a table for initial basic feasible solutions with all slack variables as basic variables.
4) Calculate $C_j–Z_j$ values for this solution where C_j is objective function coefficients for variable j and Z_j represents the decrease in the value of the objective function that will result if one unit of the variable corresponds to the column of a matrix is brought into the basis.
5) Determine the entering variable by choosing the one with the highest negative value.
6) Determine the row to be replaced by dividing the quality column b_i by their corresponding optimum column values and choosing the smallest positive quotient.
7) Compute the evolutes for the entering rows.
8) Compute values for the remaining rows.
9) Calculate $C_j–Z_j$ for this solution.
10) If there is positive $C_j–Z_j$ value, then optimal solution has been obtained otherwise go to next step's optimal solution is obtained when all the entries in $C_j–Z_j$ A = πr 2 positive or zero.

Numerical Illustration:

To determine the optimum allocation of 4 food crops viz, cholam, cumbu, Ragi and maize y using agriculture data with respect to various factors viz capital, daily wages and land for the period 1990-199l to 2014-2015. The data was collected from Season and Crop Reports of Tamil Nadu. The estimation of the coefficients a_{11}, a_{12} ....a_{mn} in (3.2) which are usually termed production coefficients, is probably the most difficult task in the formulation of the relevant mathematical model. To obtain the production coefficient it is necessary to determine the amount of a particular input required to produce an acre of cholam, cumbu, ragi and maize. A typical matrix of these coefficients including the expected output per acre and the requirement is shown in table 1.

Table – 1: Output per acre and the requirements

Name of the cereal crop	Average o/p in 25 Years	Average Land Utilised in 25 Years	Average Capital Requirement in 25 Years	Average Labour Working Hours
	× 1000 Tonns	× 1000 Acres	× 1000 in Rs. Acres	In Hrs. Per Acres
Cholam	356.122	356.109	16.320	34
Maize	581.732	150.730	18.400	40
Cumbu	161.189	125.759	11.000	38
Ragi	225.938	110.426	10.400	62
Requirements		743.024	594	192

In our case, the objective function is the output of various agriculture production of cereals, inequalities in the (i) Land (ii) Capital (iii) Labour and requirement in total.

Now, the objective is to find the optimum land for cereals production.

Table 1 represents in simplified manner, the basic information necessary in order to construct a linear programming model of land utilization.

This model, which is the interests of simplicity ignores live stock, is as follows:

$$\text{Maximize } Z = \frac{356.122X_1}{(Cholam)} + \frac{581.732X_2}{(Maize)} + \frac{161.189X_3}{(Cumbu)} + \frac{225.938X_4}{(Ragi)}$$

Subject to

Land $356.122\ X_1 + 581.732\ X_2 + 161.189\ X_3 + 225.938\ X_4 \le 743.024$

Capital $16.32\ X_1 + 18.400\ X_2 + 11.000\ X_3 + 10.400\ X_4 \le 594$

Labour $34\ X_1 + 40\ X_2 + 38\ X_3 + 62\ X_4 \le 193$

Where $X_1, X_2, X_3, X_4 \ge 0$

Applying the simple X procedure function obtaining the optimum land of cereals crops through LINGO computer based soft ware.

Model class: LP, Total variables: 4, Non-Linear variable: 0, integer variable: 0, Total constraints: 3, Non Linear constraints: 0, Total Non-Zero : 6, Non-Linear Non – Zero:0

The problem is converted to canonical form by adding slack, surplus and artificial variables as appropriate

- As the constraint 1 is of type '≤' we should add the slack variable X5,
- As the constraint 2 is of type '≤' we should add the slack variable X6.
- As the constraint 3 is of type '≤' we should add the slack variable X7.

MAXIMIZE

Z = 356.122 X1 + 581.732 X2 + 161.189 X3 + 225.938 X 4

subject to

356.109 Xl + 150.730 X2 + 125.759 X3 + 110.426 X4 ≤ 743.024

16.32 X1 + 18.4 X2 + 11 X3 + 10.4 X4 ≤ 594

34 Xl + 40 X2 + 38 X3 + 62 X4 193

X1, X2, X3, X4 ≥ 0

We'll build the first tableau of the Simplex method, Introducing slack variables $X_5 \geq 0$, $X_6 \geq 0$, $X_7 \geq 0$, the L.P.P in its standard form as

MAXIMIZE

Z = 356.122 Xl + 581.732 X2 + 161.189 X3 + 225.938 X4 + 0 X5 + 0 X6 + 0 X7

subject to

356.109 Xl + 150.73 X2 + 125.759 X3 + 110.426 X4 + 1 X5 = 743.024
16.32 Xl + 18.4 X2 + 11 X3 + 10.4 X4 + I X6 = 594
34 Xl + 40 X2 + 38 X3 + 62 X4 + 1 X7 = 193
Xl, X2, X3, X4, X5, X6, X7 ≥ 0

Table-2

Tableau 1			356.122	581.732	161.189	225.938	0	0	0
Base	**Cb**	**P0**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
P5	0	743.024	356.109	150.73	125.759	110.426	1	0	0
P6	0	594	16.32	18.4	11	10.4	0	1	0
P7	0	193	34	40	38	62	0	0	1
Z		0	-356.122	-581.732	-161.189	-225.938	0	0	0

The leaving variable is P7 and entering variable is P2.

Table-3

Tableau 2			356.122	581.732	161.189	225.938	0	0	0
Base	**Cb**	**P0**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
P5	0	15.75175	227.9885	0	-17.4345	-23.2055	1	0	3.76825
P6	0	505.22	0.68	0	-6.48	-18.12	0	1	-0.46
P2	581.732	4.825	0.85	1	0.95	1.55	0	0	0.025
Z		2806.8569	138.3502	0	391.4564	675.7466	0	0	14.5433

The optimal solution value is Z = 2806.8569

X1 = 0
X2 = 4.825
X3 = 0
X4 = 0

The solution be this model yields the following information. X2 = 4.83 acres of maize. The ultimate aim is to produce realistic agriculture planning model to the region in order to examine in detail the effect of variations in prices and quantities.

CONCLUSION

It has been observed that some LP problems, simplex algorithm takes less number of iterations as compared to other algorithms. In the present study, we framed LP model for land allocation to the four major cereal crops in agriculture. The solutios are obtained by Simplex Algorithm. The total land used is found to be 743.024 acres nor the maximum profit achieved is Rs. 2,807.00 per acre.

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