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A Study of Effectiveness of LPP Model in Resources Based Decision Making in Agricultural Production: An Empirical Analysis

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Abbreviations
L.P. = Linear Programming
L.P.P. = Linear Programming Problem
LINDO = Linear, Interactive, and Discrete Optimizer
MOLP = Multiple objective linear programming

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ABSTRACT

Linear programming technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agriculture production of crops. In this paper a Linear programming technique is applied to determine the optimum requirement of various resources to get desired profit, allocation of outputs by using various data, with respect to various determining factors viz. Daily wages of labour water requirement for the period of last four years. The proposed LPP model is solved by standard simplex algorithm. It is observed that the proposed LP model is appropriate for finding the optimal land allocation to earn maximum profit for the crops.

1. Introduction

Linear Programming (L.P.) is a special class of optimization techniques, where the objectives and the constraints are all linear functions of decision variables. The first spark for the phenomenal growth of interest and the practical applications of linear programming problems came in 1947, when GB. Dantzing formulated the general linear programming problem and developed the Simplex Method for its solution. It was published for the first time in [Koopman(1951)]. Linear Programming has been used in agriculture almost since its very inception. Waush (1961) applied this technique to the problem of minimization of cost of dairy cows. Complete the farm planning by means of Linear Programming was initiated by Heady and Love (1952). Boles (1955) have applied Linear Programming in farm management analysis.

An extensive industrial use of L.P. in agricultural farm management analysis has been the field of mixing with the object of minimizing the cost of feed mix. Barker (1964) conducted a study in the use of L.P. in making farm management decisions and came to the conclusion that "L.P. can be value in farmer decision specified alternatives levels of resources use, and the larger the size of farm, the larger the number of alternatives and greater the likelihood of benefits from L.P." In addition to their uses at the micro level, that is cost minimizing the profit maximization of an individual farm, L.P. techniques have also been applied usefully at the macro level for solving the problems of agricultural marketing. A major part of the foreign exchange could have been used for augmenting industrial and other development programmes, until a few 42 years ago, was used up in the import of food grains to feed the ever increasing population of the country.

The agriculture scenario in India until a few years was marked by traditionalism which resulted low yield and low income. However there have been tremendous improvements in the areas of farming technology is associated with large investments on farms due to increase share of inputs like fertilizers, plant protection, chemicals and irrigation etc. Consequently the weaker sections of farmers have not been benefited from this technological development in agricultural sector in India.

In general food grains prices are not much volatile in nature and give almost guaranteed return, as in many countries (India) food grains have government support prices, whereas vegetable prices are mostly random variables and its cropping is also highly cost effective. In fact the vegetable cropping needs to manage the several costs viz., capital investment in insecticides, pesticides, fertilizers, frequent irrigation, labours and transportation cost. Sometimes unexpected production of same crops from local areas will also influence the market prices due lack of storage facility. Surprisingly vegetable prices also vary on day to day basis even in the same season. By keeping in view of volatility of vegetable prices, a proper land planning is initiated for optimal returns.

2. Literature Review

LPP is usedfor all sorts of decision making problems regarding production, distribution, marketing and policy decision making since it is perhaps the most important and best-studied optimization problem. Scarpari and Beaclair in the year 2010 argued that, "Optimized agricultural planning is a fundamental activity in business profitability because it can increase the returns from an operation with low additional costs". In management science several approaches have been developed to deal with multiobjective decision making problem. Among them, Vector maximum method, Goal programming and Interactive techniques are the three important and widely used methodologies to deal with MOLP problems.

Bellmann and Zadeh [1970] provided anorigin for decision making in fuzzy based environment whereas a new approach to the problem definition for finding a compromise solution to MOLP problem was initiated by Zimmermann [1978]. The proposition of this regard was to explore a compromise solution of MOLPP. The methodologies of obtaining compromise solution was further developed in various directions by Buckley [1983], Luhandjula [1982], Sakawa and Yano [1986], Chanas [1989] using various type of membership functions.

Radhakrishnan D [1962] and Raj Krishna [1963] proposed the LP technique for addressing the optimal farm planning. Andres Weintraub and Carlos Romero [2006] analyzed the use of operations research models to assess the past performance in the field of agricultural and forestry and highlighted the current problems and future score of research. (Tanko L. et.al. [2006]) concentrated on planning problems at the farm and regional-sector level, environmental implications, risk and uncertainty issues, multiple criteria, and the formulation of livestock rations and feeding stuffs.

Itohet. al. [2003] considered a problem of crop planning under uncertainty assuming profit coefficients are discrete random variables and proposed a model to obtain maximum and minimum value of gains for decision maker. In domain of agricultural production system, where uncertainty and vagueness play a major role in decision making, several researchers such as Slowinski [1986], Sinha et al. [1988], Sher and Amir [1994], Sumpsi et.al. [1996], Sarkeret. al. [1997], Pal and Moitra [2003], Vasant [2003], Biswas and Pal [2005] used fuzzy goal programming techniques for a farm planning problem. Kruse and Meyer [1987] attracted researchers to study agricultural crop planning with stochastic values as stochastic linear programming problem to address such problems. Hulsurkaret. al. [1997] studied the fuzzy programming approach to multiobjective stochastic linear programming problem. Lodwicket. al.[2000] made a comparison of fuzzy, stochastic and deterministic methods in a case of crop planning problem followed by a study of Itoh and Ishii [2001] based on possibility measure. Toyonagaet. al.[2005] studied a crop planning problem with fuzzy random profit coefficients. Dinesh K.Sharmaet. al.[2007] studied FGP for agricultural land allocation problem and proposed an annual agricultural plan for different crops.AnjeliGarg, Shiva Raj Singh [2011] provided a procedure to solve MOLP using MaxMin approach to build up the membership function and stated that it provides superior results than that of Itoh et. al. [2003] A combined application of General Information System and linear programming for strategic planning of agricultural uses was carried out by Campbell et al. [1992].

The land use planning techniques and methodologies with different objectives, applications, and land uses have been identified by Santé I and Crecente R [2005]. Keith Butterworth [1985] suggested that in the current economic climate, linear programming could well be worth reconsidering as a maximizing technique in farm planning. This particularly applies when it is used in conjunction with integer programming, which allows many of LP's problems to be overcome. Felix Majeke and Judith Majeke [2010] used an LP model for farm resource allocation.

A LP crop mix model for a finite-time planning horizon under limited available resources such as budget and land acreage, the crop-mix planning model was formulated and transformed into a multi-period LP problem by NordinHj. Mohamad and Fatimah Said [2011] to the maximize the total returns at the end of the planning horizon. Ion RalucaAndreea and TurekRahoveanu Adrian [2012] suggested LP method to determine the optimal structure of crops, different methods which take into account the income and expenditure of crops per hectare were used for optimizing profit.

3. Research Methodology

This section discuss how the entire paper is designed using various research tools and data collection methods.

3.1. Research Problem

When a farmer takes decision about various crops to be taken in the farm to optimize his profit from farming, he has to consider many constraint variables like labour availability, labour rates, and availability of land, Water availability etc. Present paper considers all the constraint variable to determine ideal allocation of land for different variety of vegetable crops to ensure optimum profitability.

3.2. Research Objectives

1. To understand role of Liner programming model in Agriculture problem solving and decisions.
2. To evaluate dynamics of each constraint variables in detail.
3. To understand profitability with respect to constraint variables.
4. To ensure ideal mix of crops and land allocation to optimize profit.

3.3. Hypothesis of study

H11: Liner programming effectively provides solution to optimize profit in agriculture

H12: Liner programming effectively manage constraint variables to make effective decisions

4. Variable Identification Modeling

Suppose if we consider the problem in which number of producible of crops are „n" and respective profits for these crops are ci1, ci2, ci3…….. ci n per unit area along with respective probabilities pi . The decision variable xj , element hj and wj denote cultivation area for crop j , the work time in labour hours and required water units for growing crop j at the unit area respectively.

As the land of a farm is limitedx1+ x2+ x3+ x4+……. xn has to be less than or equal to „L"acres and we call it as "land constraint". The total labour hours of working time is limited and thus h1x1+ h2x2+ h3x3+ h4x4+…….+hnxn has to be less than or equal to a certain „H" and we call it as "labour constraint". Similarly, water is also another constraint of having „W" units and the total requirement must be adjusted within the limit, then equation w1x1+ w2x2+ w3x3+ w4x4+…….+ wnxn can be treated as "water constraint".

Under these constraints and discrete crisp and fuzzy random profit coefficients, we want to find the decision variables xj so as to maximize the profit(R). equation known as **3.1.1**

Maximize R

Subject to $x1 + x2 + x3 + \cdots \ldots \leq L$ (Land constraint)
$h1x1{+}h2x2 + h3x3 + \cdots\ldots + hnxn \leq$ (Labour constraint)
$w1x1{+}w2x2 + w3x3 + \cdots\ldots + wnxn \leq$ (Water constraint)
c11x1+ c12x2+ c13x3+ c14x4+…….+ c1nxn ≥ R
c21x1+ c22x2+ c23x3+ c24x4+…….+ c2nxn ≥ R
C31x1+ c32x2+ c33x3+ c34x4+…….+ c3nxn ≥ R ……………..
cm1x1+ cm2x2+ cm3x3+ cm4x4+…….+ cmnxn≥ R
x1, x2, x3, x4,……. xn, R ≥ 0

5. Process of Solving LPP model by Using LINDO

Multi objective linear programming approach is given below

Step-1: Solve each objective function with the same set of constraints provided in (3.1.1) separately.

Step-2: Using the solution obtained in step1, find the corresponding value of all the objective functions for each of solution.

Step-3: From step 2, obtain the lower and upper bounds zk' and $zk*$ for each objective function and construct a table of Positive Ideal Solution (PIS).

Step-4: Consider a linear and non-decreasing membership function

Step-5: Transform multi objective linear programming into LPP as follows

Equation known as 3.3.2

$\boldsymbol{Max}$ R

Subject to $x1 + x2 + x3 + \cdots \ldots xn \leq L$ (Land constraint)
$h1x1{+}h2x2 + h3x3 + \cdots\ldots + hnxn \leq H$ (Labour constraint)
$w1x1{+}w2x2 + w3x3 + \cdots\ldots + wnxn \leq W$ (Water constraint)
$c11x1 + c12x2 + c13\,x3 + \cdots \ldots + c1nxn - \alpha z1 * - z1' \geq z1'$
$c21x1 + c22x2 + c23\,x3 + \cdots \ldots + c2nxn - \alpha z2 * - z2' \geq z2'$
$c31x1 + c32x2 + c33\,x3 + \cdots \ldots + c3nxn - \alpha z3 * - z3' \geq z3'$
$cm1x1 + cm2x2 + cm3x3 + \cdots \ldots + cmnxn - \alpha zm* - zm' \geq zm'$

Step-6: Equation (3.3.2) t can be solved easily using LINDO

Step-7: Finally, the guaranteed expected return can be calculated as $zi\ (x)\ piki{=}1$, wherezix is the value of the it objective function at the values of decision variables obtained from the solution of equation (3.3.2).

6. Numerical Illustration

A farmer has 12 acres of cultivable land and he wanted to grow multiple vegetable crops viz., Beans, Bottle gourd, potato and cabbage in a season. Out of his experience, he stated that labour work time available with him is 220 hours and availability of water is 25 acre-inches. The profit coefficients (lakh rupees), required work time and water for each crop for one acre of land are provided in the table as. How many acres he has to consider for each crop in order to get guaranteed net returns out of volatility among profit coefficients

	Beans	Bottle guard	Potato	Cabbage	Probability %
Profit coefficients (lakh rupees) (set 1)	0.35	0.32	0.69	0.95	40
Profit coefficients (lakh rupees)(set 2)	0.55	0.41	0.78	1.20	25
Profit coefficients (lakh rupees)(set 3)	0.65	0.53	1.02	0.68	15
Profit coefficients (lakh rupees)(set 4)	0.82	0.62	1.25	0.80	20
labour requirement per acre ('000 hours)	1.760	1.280	1.600	1.840	
Water requirement per acre (acre-inch)	27.2	17.5	18.2	18	

Here, we illustrate solution of the problem by the working procedure provided in the section-3.3. Let x1, x2, ,x3and x4 be the no.of acres to be considered for Beans, Bottle guard , Potato and cabbage respectively and the undertaken problem is to solve

Maximize Z1 = 0.35 x1 + 0.32 x2 + 0.69 x3 + 0.95 x4
Maximize Z2= 0.55 x1 + 0.41 x2+ 0.78 x3 + 1.20 x4
Maximize Z3 = 0.65 x1 + 0.53 x2 + 1.02 x3 + 0.68 x4 (4.1.1)
Maximize Z4 = 0.82 x1 + 0.62 x2 + 1.25 x3 + 0.80 x4
Subject to constraints x1+ x2 +x3 + x4 ≤ 12 (Land constraint)
1.76 x1 + 1.28 x2 + 1.60 x3 + 1.84 x4 ≤ 25(Labour constraint) (4.1.2)
27.2 x1 + 17.5 x2 + 18.5 x3 + 18.0x4 ≤ 220 (Water constraint)
x1 , x2 , x3 , x4 ≥ 0

7. Process of Analysis in LINDO

1. Open LINDO and type the decision variables (X1, X2, X3 and X4) and names of the constraints (Land, labour hours and water) in the cells A3 to A6 and E3 to E5
2. From B3 to B6 enter zeros and From F3 to F5 type the constraints given in (4.1.2) by using respective cell addresses for decision variables starting with (equal to) "=" symbol.
3. Similarly in the cells of LINDO type Max Z1 / (Z1)1, (Z2)1, (Z3)1, and (Z4)1respectively as shown in LINDO. Further, enter equations of four objective functions too.
4. Adjust and write equations as per constrains by using <,> or =.

5. After entering all constraints, select make unconstrained variables Non-Negative and Select Simplex LP and click on solve.
6. Copy the optimum solution and reset the decision variables values as zero in order to runthe same for the second objective function.

The Optimal solution to this crisp LP Problem for the first objective function with regard to constraints using (4.1.2) is x1 = 0 , x2 = 0 x3 = 0 x4 =12 (Z1)1 = 11.4. The four optimum solutions are summarized in Table.

Solutions at each objective function				
	Max Z_1	**Max Z_2**	**Max Z_3**	**Max Z_4**
X1	0	0	0	0
X2	0	0	0	0
X3	0	0	12	12
X4	12	12	0	0

Positive solutions can be obtained by arranging solutions at each objective function solved with regard to constraints using and are summarized in following table

	Max Z1	Max Z2	Max Z3	Max Z4	Max	Min	(Max - Min)
Z1	11.4*	11.4	8.28'	8.28	11.4	8.28	3.12
Z2	14.4*	14.4	9.36'	9.36	14.4	9.36	5.04
Z3	8.16'	8.16	12.24*	12.24	12.24	8.16	4.08
Z4	9.6'	9.6	15*	15	15	9.6	5.4
	X1	X2	X3	X4			

This step will help to reformulate the problem; it reduces to a LPP as known as 4.2.1

Maximize α Subject to X1 + X2 +X3 + X4 ≤ 12

1.76 x1 + 1.28x2 + 1.60 x3 + 1.84 x4≤ 25

27.2 x1 + 17.5 x2 + 18.5 x3 + 18.0x4 ≤ 220

0.35 x1 + 0.32 x2 + 0.69 x3 + 0.95 x4 – 3.12 α≥ 8.28

0.55 x1 + 0.41 x2 + 0.78 x3 + 1.20 x4 – 5.04 α≥ 9.36

0.65 x1 + 0.53 x2 + 1.02 x3 + 1.50 x4 – 4.08 α≥ 8.16

0.82 x1 + 0.62 x2 + 1.25 x3 + 2.50 x4 – 5.40 α ≥ 9.6

Output in software as follows

	A	B	C	D	E	F	G	H	1	J
1	**Salving MOLP provided in Equation (4.2.1)**									
2	**Decision variables**			**Constraints**						
3	xl=	0		Constraint! =	0					
4	x2=	0		Constraint2 =	0		**Return calculations**			
5	sc3=	0		Constraints -	0				Probability	
6	x4=	0		Constraint4 (Zl)=	0		zi=	0	40	
7	Alfa =	0		Constraints (Z2)=	0		12=	0	25	
8				Constraints (Z3)=	0		13=	D	15	
9				Constraint? [Z4)=	0		ZA=	D	20	
10							weighted returns		0	
11		Alfa (Objective Function) = 0								
12										
13		1								

Table: Required formulae to obtain the solution for provided in equation (4.2.1)			
Cell	Formulae to be entered	Cell	Formulae to be entered
E3	=B3+B4+B5+B6		
E4	=1.76*B3+1.28*B4+1.6*B5+1.84*B6		
E5	=27.2*B3+17.5*B4+18.2*B5+18*B6		
E6	=0.35*B3+0.32*B4+0.69*B5+0.95*B6 -3.12*B7	H6	=0.35*B3+0.32*B4+0.69*B5+0.95*B6

E7	=0.55*B3+0.41*B4+0.78*B5+1.20*B6 -5.04*B7	H7	=0.55*B3+0.41*B4+0.78*B5+1.20*B6
E8	=0.65*B3+0.53*B4+1.02*B5+0.68*B6 -4.08*B7	H8	=0.65*B3+0.53*B4+1.02*B5+0.68*B6
E9	=0.82*B3+0.62*B4+1.25*B5+0.80*B6 -5.40*B7	H9	=0.82*B3+0.62*B4+1.25*B5+0.80*B6
C11	=B7	I10	=SUM(H6*I6/100 + H7*I7/100+H8*I8/100+H9*I9/100)

Calculation of Optimum Solution as follows

	A	B	c	D	e	F		H	1	.
1	**Optimum solution by LINDO for Equation (4.2.1)**									
2	**Decision variables**			**Constraints**		1				
	xl=	0		Constraintl =	12					
4	x2 =	D		Constraint2 =	20.64		**Return calculations**			
5	x3 =	e		Constraints =	217.2				Probability	
	sc4=	6		Constraint4 (Zl)=	8.28		Zl=	9.84	40	
7	Alfa =	0.5		Constraints (Z2)-	9.36		Z2=	11.88	25	
8				ConstraintS (Z3)=	8.16		Z3=	10.2	15	
9				Constraint? (Z4)=	9.6		Z4=	12.3	20	
10							weighted returns		10.896	
11		Alfa (Objective Function) = 0.5								
12										
13										

From The optimum solution provided ,which satisfies four objective functions simultaneously is x1 =0, x2=0, x3=6 and x4 =6 which means that the farmer has to cultivate Potato and cabbage each at 6 acres of land in order to get guaranteed average net returns of Rs.10.896 lakhs in spite of fluctuating prices. The maximum profit is identified at the fourth set of profit coefficients which may happen only at 20% of the time.

8. Conclusion

Form the present study it can be said that linear programming is a wonderful managerial tool that provides solutions to almost all the decision making situations. Based on the present paper it can be said that farmer can make used of liner programming model to maximize its profit with while considering its many constraint variables. Pragmatic implications of the present study at ground root level can ease out many problems of marginal farmers in country like India.

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