Agricultural Land Allocation to the Major Crops through Linear Programming Model

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Abstract: ***Linear Programming technique is applied to determine the optimum land allocation to fourteen major crops using agriculture data with respect to various factors like land utilization, labour in mandays, seeds, fertilizes, yields for crops for the period 2010 -2011. The problem is solved by LINDO software. The study is carried out in the Patan district of Gujarat, India. The aim of the study is to get more production there for more profit for the marginal and small farm holders. The proposed linear programming model is appropriate for finding the optimal land allocation to the major crops of the study area.***

Keywords: Land allocation, Linear programming, Patan District

1. Introduction

Agriculture plays vital role in the Indian economy. India's geographical condition is unique for agriculture because it provides many favorable conditions. Recently Agricultural planning is important due to the increased demand of Agricultural commodity because of population increase. Agricultural economics deals with scientific planning for Agricultural development which has become an important area of specialization in Agriculture. Optimal crop pattern with maximum production and profit is important information for Agricultural planning using optimization model. Optimization techniques such as linear programming, dynamic programming, goal programming can be used to solve this type of problem. Linear programming model is more popular because of the proportionate characteristic of the allocation problems.

2. Literature Review

These days LP is utilized by all sorts of firms in making decisions about establishment of new industries and in deciding upon different methods of production, distribution, marketing and policy decision making. Linear Programming (LP) is perhaps the most important and best-studied optimization problem. A lot of real world problems can be formulated as linear programming problems. The simplex algorithm developed by Dantzig [3], starts with a primal feasible basis and uses pivot operations in order to preserve the feasibility of the basis and guarantee monotonicity of the objective value. For LP models with ≥ or = type constraints, the problem of obtaining initial basic feasible solution is difficult as these 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 otherwise straightforward simplex method. H. Arsham [5] has proposed a new general solution algorithm, which avoids use of artificial variable in above stated situations and developed the comparison tool for Simplex and Push-Pull algorithms (SixPap [6]). H. Arsham *et.al.* [7] implemented the Push-Pull algorithm and standard simplex algorithm, for solution and comparison of computational techniques of general LPP, using. The push-pull algorithm, when used, brings no to a state of cycling in contrast to the simplex algorithm in presence of singular basis. V. I. Kustova [18] proved that each of the active constraints, which on some stage have become a strict inequality, can be neglected in subsequent computations. This statement is allowed, in one's turn, to establish fact that the number of arithmetic operations required for solving the general problem of linear programming is estimated by the value which is polynomially dependent on the dimension of the problem under scrutiny.

Radhakrishnan D [14] and Raj Krishna [15] proposed the LP technique for determining the optimal farm planning. The land use planning techniques and methodologies with different objectives, applications, and land uses have been identified by Santé I and Crecente R [16]. Another example is the combined application of General Information System and linear programming to strategic planning of agricultural uses was carried out by (Campbell et al. [2]). Keith Butterworth [10] 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 [4] used an LP model for farm resource allocation. They compared between the results obtained from the use of the LP model and the traditional method of planning and observed that the results obtained by using the LP model are more superior to that of obtained by traditional methods. 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 Nordin Hj. Mohamad and Fatimah Said [13] to the maximize the total returns at the end of the planning horizon. Ion Raluca Andreea and Turek Rahoveanu Adrian [9] 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. They observed that, after applying the econometric model the profit rose to 143% and costs reduced to 81%. Andres Weintraub and Carlos Romero [1] analyzed the use of operations research models to assess the past performance in the field of agricultural and forestry and to highlight current problems and future directions of research and applications. In the agriculture part, they 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. Studies in optimum resource allocation using LP approaches have largely been attempted in many countries (Tanko L. et.al. [17]).

Fuzzy mathematical programming has been investigated and developed in several research studies. One of the important early contributions in fuzzy programming was given by Zimmermann [19] and [20]. In fuzzy multi-objective programming, Sakawa et al. [21] have presented an interactive fuzzy approach for multi-objective linear programming problems. One of the main approaches in dealing with fuzzy models is the possibility theory. The basic work in possibility theory was introduced by Dubois and Prade [22].

3. Study Area

Patan district is located at $20^{\circ}41'$ to $23^{\circ}55'$ North Latitude and $71^{\circ}31'$ to $72^{\circ}20'$ East Latitude in western India. Patan district is surrounded by Banaskantha District, Desert of Kutch, some part of Surendranagar District and Mahesana District.

Total geographical area of the district is about 5.66 lakhs hectares. 70% of the geographical area is under cultivation in the district. Economy of the district mainly depends on agriculture, as 63.9 percent workers are engaged in primary sector.Net sown area of the district is about 3.93 lakh hectare and gross sown area is about 4.86 lakh hectares. The major crops cultivated in the district are castor, mustard and cotton. Also other crops grown are cumin, bajara, wheat, juwar and fennel. In some areas pulses like mung, tur, gram and vegetables are cultivated in the district. Depletion of water table, Deterioration of soil and water conditions due to salinity ingress, irregularity of rainfall, recurrent droughts/ scarcity is the major factors that have impeded agricultural productivity in the Patan district. The purpose of applying the techniques discussed in this paper is to achieve the best model for crop cultivation planning.

4. Methodology

A linear programming problem with "n" decision variables and "m" constraints can be mathematically modelled as (Taha[24];Zeleny[26]; Wiston[25]; Higleetal.[23]).

$$\begin{aligned}
&Maximize\ Z = c_1x_1 + c_2x_2 + \dots\dots + c_nx_n\\
&Subject\ to\ condition(s\ to\ c)\\
&\quad a_{11}x_1 + a_{12}x_2 + \dots\dots + a_{1n}x_n \le b_1\\
&\quad a_{21}x_1 + a_{22}x_2 + \dots\dots + a_{2n}x_n \le b_2\\
&\quad \vdots \qquad\qquad\qquad\qquad \vdots\\
&\quad a_{m1}x_1 + a_{m2}x_2 + \dots\dots + a_{mn}x_n \le b_m\\
&\qquad x_j \ge 0 . j = 1,2, \dots\dots, n
\end{aligned}$$

This can be written as ,

$$\begin{aligned}
&Max\ Z = C^tX\\
&Subject\ to\ condition(s\ to\ c)\\
&\qquad AX \le b,\\
&\qquad X \ge 0
\end{aligned}$$

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 an objective function (C^tin 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 $c_1, c_2, \dots\dots, c_n$ are the unit returns for the coming from each production process $x_1, x_2, x_3, \dots\dots, x_n$.

5. Mathematical formulation of crop production problem

The objectives of the problem are to maximize the production and there for profit. The computational algorithm developed above is implemented step by step to find a optimal solution of crop production for Patan district, Gujarat. In this district farmers grow Cotton, Mung , Udad, Sesamum, Bajra in kharif season, Bajara in summer season. Gram, Wheat, Mustard, Castor, Fennel, Cumin, Tur, Potato in rabi season. The land available is 392669 hectare with given labour hours constrains. The labour availability for each season is given to be 220 total mandays. A small farm holder needs at least 400 kg of wheat, 200kg of Bajara and 40 kg of Mung for his annual food grains requirement. The problem of the framer is to plan a suitable crop combination model for his land to get maximum profit and aspiration level of rupees 175000 is set to meet his other annual family requirement. The objectives of the problems are to maximize profit and production to provide minimum food grain requirement.

Out put per hectare and requirements

Crop variable	Cotton $(x_{1,1})$	Mung $(x_{1,2})$	Udad $(x_{1,3})$	Sesamum $(x_{1,4})$	Bajara $(x_{1,5})$	Gram $(x_{2,1})$	Wheat $(x_{2,2})$	Mustard $(x_{2,3})$	Castor $(x_{2,4})$	Fennel $(x_{2,5})$	Cumin $(x_{2,6})$	Tur $(x_{2,7})$	Potato $(x_{2,8})$	Bajara $(x_{3,1})$
Labour manday/ha	189	39	31	40	68	310	88	74	63	57	110	13	71	76
Production(Kg. /ha.)	992	481	745	421	497	698	3238	1562	1854	1358	441	985	23281	2563
Return (Rs. /ha.)	32119	5894	2964	6948	2985	1093	18418	7485	61067	116925	36633	4046	66853	5066

Where

$x_{i,j}$ =the land area for cultivation of crop j in Season i(=1, 2, 3) (heaters)

i=1=kharif season, i =2=Rabi season,

i =3=summer season

The **objective functions** are:

Production:

$$Maximize\ Z_1 = 992x_{1,1} + 481x_{1,2} + 745x_{1,3} + 421x_{1,4} + 497x_{1,5} + 698x_{2,1} + 3238x_{2,2} + 1562x_{2,3} + 1854x_{2,4} + 1358x_{2,5} + 441x_{2,6} + 985x_{2,7} + 23281x_{2,8} + 2563x_{3,1}$$

Subject to **constraints**:

Labour:

$$189x_{1,1} + 39x_{1,2} + 30x_{1,3} + 40x_{1,4} + 68x_{1,5} \leq 220$$

$$310x_{2,1} + 88x_{2,2} + 74x_{2,3} + 63x_{2,4} + 57x_{2,5} + 110x_{2,6} + 13x_{2,7} + 71x_{2,8} \leq 220$$

$$76x_{3,1} \leq 220$$

Land:

$$x_{1,1} + x_{1,2} + x_{1,3} + x_{1,4} + x_{1,5} \leq 392669$$

$$x_{2,1} + x_{2,2} + x_{2,3} + x_{2,4} + x_{2,5} + x_{2,6} + x_{2,7} + x_{2,8} \leq 392669$$

$$x_{3,1} \leq 392669$$

Food requirements:

$$3238x_{2,2} \geq 400$$

$$497x_{1,5} + 2563x_{3,1} \geq 200$$

$$481x_{1,2} \geq 40$$

Where all $x_{i,j} \geq 0, i = 1,2,3 \; \& j = 1 \; to \; 8$

Solve this linear programming problem by LINDO software for objective function Z.

LP OPTIMUM FOUND AT STEP 5

6. Objective Function Value

1) 81815.73

Variable	Reducecost	Value
$x_{1,1}$	0.000000	3701.500000
$x_{1,2}$	0.083160	0.000000
$x_{1,3}$	7.225225	0.000000
$x_{1,4}$	0.000000	572.333313
$x_{1,5}$	0.000000	1191.666626
$x_{2,1}$	0.000000	100951.437500
$x_{2,2}$	0.123533	0.000000
$x_{2,3}$	0.000000	22702.705078
$x_{2,4}$	0.000000	18803.789062
$x_{2,5}$	0.000000	17332.380859
$x_{2,6}$	0.000000	35628.156250
$x_{2,7}$	0.000000	3277.718262
$x_{2,8}$	2.945480	0.000000
$x_{3,1}$	2.894737	0.000000

Row	Slack Or Surplus	Dual Prices
2)	0.000000	24.833334
3)	0.000000	327.901398
4)	0.000000	33.723682
5)	392661.687500	0.000000
6)	392665.937500	0.000000
7)	392666.093750	0.000000
8)	0.000000	-7.911465
9)	7219.210449	0.000000
10)	0.000000	-1.013514

NO. ITERATIONS= 5

The solution to this model yields the following information. $x_{1,2}$ =0.083160 ha. land for Mung, $x_{1,3}$ =7.225225 ha. land for Udad, $x_{2,2}$ = 0.123533 ha. land for wheat , $x_{2,8}$ = 2.945480 ha. land for Potato, $x_{3,1}$ = 2.894737 ha. land for Bajra.Discussion :In this study linear programming model suggested the five major (Kharif Mung & Udad, Rabi Wheat & Potato and Summer Bajra) crops to the farmers of Patan district. Land constraint is very important to determinethe optimal land allocation.According to the results a farmer can get profit of 2,35,760 rs.and maximum production of 81816kgs.through out the year.

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