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Optimal crop plans by using linear programming technique in Jayashankar Bhupalpally district of Telangana: A case study

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Abstract
The study was undertaken in Vilasagar village of Kataram Mandal, Jayashankar Bhupalpally district of Telangana, India. The aim of the study is to develop optimum crop plan to get more returns than the existing net average returns to farmer by using linear programming approach. Random sampling technique is used to select the farmers. The Data was collected from 30 farmers through a pre structured schedules which includes the details of land holdings, crops sown, man days, machine hours, operating costs, input costs and returns. LINGO17.0 tool is used to analyze the data. The result showed that in optimal model without consideration of land constraint has suggested to allocate maximum area of 100.32 acres of land to cotton crop out of total cropped area of 114 acres under sample farms which gave a net return of Rs. 46,33,730. There is an increase in net returns of 37% in optimal plan than existing farmer's plan. The alternate crop plans were developed with land allocation constraint showed an increase in net returns from 3.75% to 15%.

Keywords: Linear programming (LP), constraints, optimal crop plan, resource allocation, net returns

Introduction
In Indian agriculture, majority of the land holdings are small and medium farms and they are encountering difficulty in allocating their limited resources among different chosen crops as per the agro-climatic conditions. In order to increase the efficiency in the agriculture there is a need to explore the possibilities of optimal allocation of the scarce resources on various sizes of the farms. The increase in population leads to more demand for agriculture products which requires a proper planning (Kumar *et al.*, 2014) [8]. Crop planning is one of the important stages in crop production which has a considerable effect on farmer revenue. To get optimum farm outputs, decisions such as crop allocation, crop combination and operational activities performed for crop production are very crucial (Bhatia & Rana, 2020) [2]. Farm planning problems are much more complex. Farmers do not only produce different crops, but have to choose among a variety of ways of producing them (Hazel & Norton, 1986) [6]. Crop planning includes consideration of various factors viz., land availability, labour, tractor, capital, cropping pattern, cost of inputs like seeds, fertilizers, herbicides. The optimum crop plan on farm in Mutasa, Zimbabwe was developed by proper allocation of the resources which showed an increase in net revenue by 76 per cent (Buzuzi & Buzuzi, 2018) [4]. Traditionally, farmers have relied on experience, intuition and comparisons with their neighbours to make their decisions (Hazel & Norton, 1986) [6]. In addition to this the farmers used to rely on Agriculture Officers, extension personnel and input distributers for suggestions. A similar study by using linear programming technique to maximize income in farms of Thoothukudi district of Tamil Nadu through resource optimization was conducted where two optimal plans were developed for irrigated and rainfed condition which showed an increase in net income in both irrigated and rainfed condition in optimal plan over existing plan (Rathika *et al*., 2018) [11]. These problems of allocation of land for different crops, profit maximization, cost minimization is solved with the help of Operation research approach (Deka *et al*., 2019) [5]. One quantitative method which have found profound impact in solving farmers problem is linear programming (LP). The concept of linear programming is not new, the first application of linear programming is in field of 'Diet problems' by Stigler in 1945. In 1947, George B Dantzig, the father of LP used this technique to solve manufacturing and economic problems on planning strategies after the world war for the US air force (Alotaibi *et al*., 2021) [1]. The application of linear programming is seen in many fields viz., agriculture, military, hospital, production,

financial and marketing management. In general, there are a wide variety of application of LP in agriculture like crop rotation, feed mix problem, land allocation, irrigation and product transportation problems. The study used linear programming approach for decision making in agriculture with the objective of optimum land allocation to five food crops with respect to factors like land, capital, labour (Sofi *et al*., 2015) [12].

Material and Methods

Study Region

The study was undertaken in Vilasagar village of Kataram mandal in Jayashankar Bhupalpally district of Telangana. The major crops grown in the district are paddy, cotton, chilli and maize. In the study region, crop production is the main occupation to the farmers and the purpose of it is consumption as well as marketing.

Methodology

Random sampling technique was used to select 30 farmers for the study. The data regarding land allocation, labour days, machine hours, cost of seeds, fertilizers, and pesticides are collected from 30 farmers for four crops viz., paddy, cotton, chilli and maize which are grown. The linear programming model was developed by using averages of the sampled data with the objective to maximize the net returns. The resource constraints considered in the model are land, labour in man days, machine hours and operating cost.

Linear programming

Linear programming is a mathematical approach to determine the optimum plan for the selection and combination of farm enterprises, in order to maximize income and/or minimize costs within the available farm resources (Phillip *et al*., 2019) [10]. It is considered to be the most popular technique in operational research for models with objectives and constraints that are all linear functions (Alotaibi *et al*., 2021) [1]. It consists of three basic components: decision variables that will determine the objective (goal) function, maximization or minimization, and constraints that the solution must satisfy. The objective function is a mathematical expression that combines the decision variables and their coefficients to achieve the optimum solution. LINGO 17.0 tool is used to analyse the data. LINGO is a tool that is designed to solve linear, non-linear, quadratic, integer models fast and provides an accurate result (optimization modelling with Lingo- fifth edition).

The general form of linear programming model is

Maximize Z= $\sum_{j=1}^{n} Cj.Xj$

j= 1,2,3……n activites

Subjected to the constraints

$\sum_{j=1}^{n} aij.Xj \geq bi$ *(i = 1,…….K)*

$\sum_{j=1}^{n} aij.Xj \leq bi$ *(i = K+1,…….m)*

$\sum_{j=1}^{n} aij.Xj = bi$ *(i = m+1,…….v)*

$Xj, bi \geq 0$ *(non negativity constraint)*

Where,

Z= is the objective function to be maximized in the year

Cj= is the value or price of j[th] activity during *kharif* and *rabi* seasons of the year

Xj= is the unit of j[th] production activity during *kharif* and *rabi* seasons of the year

aij= amount of ith resource required by j[th] activity

bi= quantity of the ith resource

Resource constraints

Land

Land is the most important limiting factor and is the basic resource of production and all the land related activities are expressed in acre basis. The total land available for the present study is 114 acres. Paddy is the major crop grown by the farmers in the study region.

Labour

Labour is the important resource for carrying out the activities. The labour is taken in man days for the study.

Machine hours

Farmers are hiring the tractor services for land preparation and combine harvester for harvesting the paddy crop. Therefore, machine hours are considered as constraint in the study.

Operating capital

The operating capital refers to the funds required to meet the cost of seeds, fertilizers, farm yard manure, plant protection chemicals, insurance charges, marketing expenses and wages of the human and bullock labour and tractor power.

Alternate crop plans

The alternate crop plans are developed by taking the minimum and maximum land allocation constraint for the crops because in practical situation it is not applicable to allocate whole land to one crop due to the fluctuations in the demand and risk associated with specialization of one crop. In the existing crop plan, majority of farmers are cultivating paddy. As per the protocol of government of Telangana, there is a need to create awareness regarding crop diversification to the farmers. Faced with the bleak future of Food Corporation of India (FCI) not procuring the paddy from the Telangana's state farmers, the government has embarked upon the mission to wean sway farmers from paddy crop and shift towards alternative crop. Therefore, the alternative crop plans were developed in the present study by 20%, 50% and 80% reduction in land allocation for paddy crop. Tonk *et al*., (2019) [13] in their study developed four alternate crop plans by considering the land restriction constraint which showed an increase in net returns from 9.66% to 26.15%.

The decision variables of LP model were

X_1= acres allocated for paddy crop

X_2= acres allocated for cotton crop

X_3= acres allocated for chilli crop

X_4= acres allocated for maize crop

The LP model is given by

Max Z= $15434x_1+46186x_2+160607x_3+14088x_4$

Subject to

$x_1+x_2+x_3+x_4 \leq 114$ (Land constraint)

$29x_1+58x_2+308x_3+24x_4 \leq 5819$ (Labour man days)

$5x_1+4x_2+2x_3+4x_4 \leq 525$ (Machine hours)

$32474x_1+38897x_2+111962x_3+21713x_4 \leq 4343868$ (Operating capital)

$x_1, x_2, x_3, x_4 \geq 0$

Results and Discussion

The existing farmers plan is presented in Table 1. In the existing plan the farmers allocated maximum area of 83 acres to paddy, 20 acres to cotton, 7 acres to chilli and 4 acres to maize which gave returns of Rs.33,84,343. The optimal crop plan obtained from the LP model (Table 2) without consideration of land constraint has suggested to allocate maximum area of 100.32 acres to cotton which gave a net return of Rs.46,33,730.

Table 1: Existing farm plan before optimization

Particulars	Paddy (X1)	Cotton (X2)	Chilli (X3)	Maize (X4)	RHS
Land (acres)	1	1	1	1	≤ 114
Labour (Man days)	29	58	308	24	≤ 5819
Machine hours	5	4	2	4	≤ 525
Operating capital (Rs)	32474	38897	111962	21713	≤ 4343868
Net returns (Rs)	15434	46186	160607	14088	≤ 33,84,343

Table 2: Optimum crop plan suggested by LP model

Particulars	X1	X2	X3	X4	LHS	RHS
Land (acres)	0	100.32	0	0	100.32	114
Net returns (Rs)	46,33,730					

The cropping pattern suggested by the LP model increased the net returns by 37% by allocating the maximum land to cotton. The minimum land restriction of 7 acres and 4 acres is kept constant for chilli and maize. The remaining land is allocated by keeping minimum land restriction for paddy which is majorly grown by farmers and maximum land restriction for cotton which gave maximum net returns (Table 3).

Table 3: LP model with land allocation constraint

Crop plans	Paddy (min)	Cotton (max)	Chilli (min)	Maize (min)	Net returns
Farmers plan	83	20	7	4	33,84,343
LP model (without land constraint)	0	100.32	0	0	46,33,730
Plan-1	66	28.5	7	4	35,11,546
Plan-2	41.5	40.75	7	4	37,03,192
Plan-3	16.6	53.2	7	4	38,93,901

Alternate crop plan 1 suggested that by combination of 66 acres to paddy, 28.5 acres to cotton, 7 acres to chilli and 4 acres to maize can increase the net income by 3.75%. Crop plan 2 showed an increase in income by 9.42% by allocating 41.5 acres to paddy, 40.75 acres to cotton, 7 acres to chilli and 4 acres to maize. Crop plan 3 suggested that by combination of 16.6 acres to paddy, 53.2 acres to cotton, 7 acres to chilli and 4 acres to maize can increase the net income by 15%. By considering the plan 1, plan 2 and plan 3 we can see the increase in net returns from 3.75% to 15% respectively (Table 4).

Table 4: Percentage of net returns obtained in different crop plans

Crop plans	Land allocation (%)				Net returns (%)
	Paddy	Cotton	Chilli	Maize	
Farmers plan (control)	72.82	17.54	6.14	3.50	0
LP Model (without land constraint)	0	88	0	0	37
Plan-1	57.89	25	6.14	3.50	3.75
Plan-2	36.4	35.74	6.14	3.50	9.42
Plan-3	14.56	46.66	6.14	3.50	15

The comparison of the resource utilization (Table 5) of the farmers plan and suggested LP plan showed that of the total available land of 114 acres, 100.32 acres of land is suggested in the LP model to cotton crop whereas 13.68 acres of land is left unused. The difference of Rs.12,49,387 is seen in farmers income when compared between existing farmers plan and optimum plan (Table 6) which is about 37%.

Table 5: Comparison of resource utilizations

	Farmers plan	LP solution
Resources	Land	Land
Available	114	114
Usage	114	100.32
% Usage	100	88
Left over	0	13.68
% Left over	0	12

Table 6: Comparison of net returns

Farmers plan (Rs)	Optimal solution (Rs)
33,84,343	46,33,730

Conclusion

In this study linear programming model was used to determine the optimal crop plan for the farmers of Jayashankar Bhupalpally district of Telangana, India. The objective was to maximize the net returns of the farmers by optimum resource alloction. Crops considered for the study were paddy, cotton, chilli and maize. The model produces an optimal crop plan which suggested to allocate maximum area of 100.32 acres to cotton. The comparative analysis of the result of LP model and existing plan showed that the LP model increased the net returns by Rs.46,33,730. The net

returns received by farmers after incorporating maximum and minimum constraints were Rs.35,11,546; Rs.37,03,192; Rs.38,93,901 under plan 1, plan 2 and plan 3 respectively.

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