Original Research Article

Optimization of profit and land resources for marginal/small farmers - A linear programming approach

ABSTRACT

The aim of the study was to optimize the profit and land resources for marginal and small farmers of four different villages of Karnal zone, Haryana for both seasons *i.e.*, Kharif and Rabi using linear programming approach. The crops sown by the farmers in kharif season were rice and jowar where as in rabi season, wheat, mustard and barseem crops were taken. Data regarding total land holding, season wise land allocated to crops, man days, operating capital and net returns of the farmer enterprise was collected through a pre- structured schedule. Linear programming models were developed separately for marginal and small farmers. In kharif season, marginal farmers were taking same net returns through both plans farmer's and LP model i.e LP suggested that farmer's plan was optimum, but net returns can be increased slightly (up to 3.25%) by the use of more resources. In rabi season, marginal farmers can raise net returns up to 2.61%, but they can get more profit up to 8.08% by use of more resources. Net returns of small farmers can be raised up to 8.88% and 5.11% in both kharif and rabi seasons respectively without imposing any restriction of minimum land allocation to particular crops. If maximum/minimum requirement constraint on land allocation to crops is imposed, the cropping pattern suggests that the returns can be raised up to 12.20% and 1.45 % in both kharif and rabi seasons respectively.

Keywords: *Optimization, Profit, Land resources, Marginal/small farmers and Linear programming approach.*

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.

Marginal and small farmers are usually faced with the problem of how to allocate their limited resources among different crops so that they can maximize their profits. Farmers, often, follow their instinct and experience to handle this problem. Farm planning problems are much more complex. Farmers do not only produce different crops, but also have to choose among a variety of ways of producing them. Crop planning may involve choices about varieties, planting dates, and fertilizer and pesticide treatments. Linear Programming has been used in agriculture almost since its very inception for planning the best possible allocation of scarce resources. Hazel and Norton [3] say, "Traditionally, farmers have relied on experience, intuition and comparisons with their neighbors to make their decisions". Instinct and experience do not guarantee optimal results; however, farm planners can offer effective techniques, such as, linear programming (LP), to address such problems and produce optimal solutions. Mohamad and Said [5] developed an LP crop mix model for a finite-time planning horizon. Majeke et al. [4], modelled a small farm livelihood using Linear Programming Model in Zimbabwe. Results obtained from the model were compared to traditional farming method and a

difference of 44.65% was achieved with the model. Nedunchezhian and Thirunavukkarasu [6] developed an LP model to optimize farm plans in different farming systems in Orathanadu block of the Thanjavur district in Tamil Nadu. Shukla et al. [13], analysed the income and employment in crop, dairy and poultry enterprises. Radhakrishnan D [11] and Raj Krishna [12] proposed the LP technique for termining the optimal farm planning. Hassan et al. [2] reported that farmers profit cannot be maximized without optimum cropping patterns, which ensure efficient utilization of available resources; and so the use of LP makes it possible to devise equilibrium solution, which include the specification of products levels, factor and product prices. Developing a prototype enterprise cropping plan in arable crop production would be useful in the extension education package for use by extension workers. The prototype enterprise combination expected from this study shall thus assist in answering many resource allocation problems that would enhance farm productivity.

Poonia et al. [9] proposed a linear programming model to suggest optimal crop combination for rural farmers in Hisar district, Haryana. Palash and Bauer [7] suggested the smallholders that they can improve their gross margins by improving the allocation of the available physical and non-physical resources. Patel et al. [8] determined 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. Upadhyaya [15] studied the Application of optimization technique for crop planning to improve farm productivity and indicated that existing practice, which is being followed at the farm, is least profitable and certainly there is scope of improvement in profit from the farm, if other practices are followed. Tonk et al. [14] applied a mathematical programming approach to determine the optimum cropping pattern for the medium farmers in Bherian village, district Hisar. Poonia et al. [10] studied the cropping patterns and use land resources by marginal and small farmers of Shamsukh village in Hisar district during the Kharif and Rabi seasons and developed a linear programming model to optimize the profit and maximum use of land resources for the farmers. Alotaibi and Nadeem [1] reviewed the applications of linear programming to optimize agricultural solutions and also highlighted the various tools that are central to analyzing LP model results. They discussed the different approaches to optimize agricultural solutions.

No doubt, marginal and small farmers really need every type of support to increase their income. But the increase in income of all type of farmers is equally important for the progress of society as a whole. The present study was undertaken with the objective of finding the optimal crop plans for medium farmers.

In this paper, the study was undertaken in four different villages of Karnal zone, Haryana. The data were collected from marginal and small farmers for both seasons *i.e.,* Kharif and Rabi. The crops sown by the farmers in kharif season were rice and jowar where as in rabi season, wheat, mustard and barseem crops were taken. Data regarding total land holding, season wise land allocated to crops, man days, operating capital and net return of the farmer enterprise was collected through a pre- structured schedule. The LP problem was solved using MS Excel 2007, a computer application software package.

2. MATERIALS AND METHODS

The experiment was conducted for marginal and small farmers in the four different villages of Karnal zone, Haryana. In this context, the data were collected for the rice and jowar of kharif season and wheat, mustard and barseem of rabi season. The linear programming (LP) model was developed using the averages of the sampled data with the objective to maximize the net return at the end of the kharif and rabi season. The decision variables of LP model were as under:

x_1 = acres allocated for Rice /wheat crop
x_2 = acres allocated for jowar/mustard crop
x_3 = acres allocated for barseem fodder crop

The linear programming model is

Max $Z = c_1x_1+c_2x_2 + c_3x_3$

Subject to $x_1 + x_2 + x_3 \leq L$ (land constraint)

$d_{11}x_1+d_{12}x_2 + d_{13}x_3 \leq D$ (labour constraint)

$d_{21}x_1+d_{22}x_2 + d_{23}x_3 \leq R$ (Operating Capital constraint)

& $x_1, x_2, x_3 \geq 0$

Where, d_{11}, d_{12}, d_{13}, d_{21}, d_{22}, d_{23} are constants.

3. RESULTS AND DISCUSSION

3.1 LP models for Marginal farmers

3.1.1 Kharif season

The crops sown by marginal farmers were rice and jowar in kharif season. The average resources available as depicted in Table 1, were land 2.50 acre, man days 104 and operating capital rupees 59042 in kharif season. The aim of study was to plan a suitable cropping pattern to get the returns more than the existing net average returns of farmers which was rupees 37314.

Table 1: Marginal Farmer's cropping pattern, resource use and net returns* in kharif season

Resources	Rice	Jowar	Total used resources
	Per acre		
Land allocation (acre)	2.00	0.50	**2.50**
Man days	42.79	36	**104**
Operating capital (Rs)	26366.80	12616.67	**59042**
Net returns (Rs)	15411.20	12983.33	**37314**

*average of the sampled data

The linear programming (LP) model was developed using the averages of the sampled data with the objective to maximize the net return at the end of the kharif and rabi season. The resource constraints considered in the study were land, man days and operating capital and were kept same as obtained from farmer's sample

The decision variables of LP model were

x_1 = acres allocated for rice /wheat crop

x_2 = acres allocated for jowar fodder crop/mustard crop

x_3 = acres allocated for barseem fodder crop

Table 2: LP model's suggested cropping pattern, resource use and net returns in kharif season for marginal farmers

Resources	Available	Usage	Left over
Land allocation (acre)	2.5	2.50	-
Rice	-	2.00	-
Jowar	-	0.50	-
Man days	104	103.58	0.42
Operating capital (Rs)	59042	59042	0.00
Returns (Rs)	37314		
Net returns* (Rs)	37314		
Increase(%) in Net returns	Nil		

*Net returns = Returns + left over operating capital

The cropping pattern suggested by LP model (Table 2) shows that farmer's plan is optimum by optimal use of all available resources by allocating 2.00 acre land to rice and 0.50 acre to jowar. But 0.42 man days are left over due to less availability of operating capital. So if farmers have more operating capital and man power, the returns can be increased upto 3.25 %.

3.1.2 Rabi season

The farmer's cropping pattern, resource use and net returns in rabi season are as under:

The crops sown by marginal farmers were wheat, mustard and barseem. The average resources available as depicted in Table 3, were land 2.50 acre, man days 86 and operating capital rupees 52176 in Rabi season. The aim of the study was to plan a suitable cropping pattern to get the returns more than the existing net average returns of farmers which was rupees 37318.

Table 3: Marginal Farmer's cropping pattern, resource use and net returns* in Rabi season

Resources	Wheat	Mustard	Berseem	Total used resources
	Per acre			
Land allocation (acre)	2.00	0.25	0.25	**2.50**
Man days	34.34	28.83	40.4	**86**
Operating capital (Rs)	22444.20	17400.00	11750	**52176**
Net returns (Rs)	16133.80	8900	11300	**37318**

*average of the sampled data

The linear programming (LP) model was developed using the averages of the sampled data with the objective to maximize the net return at the end of rabi season.

Table 4: Linear programming model's suggested cropping pattern, resource use and net returns in Rabi season

Resources	Available	Usage	Left over
Land allocation (acre)	2.50	2.455	0.045
Wheat	-	2.180	-
Mustard	-	0.275	-
Berseem	-	0.00	-
Man days	86	86	0
Operating capital (Rs)	52176	52176	0
Returns (Rs)	38291.44		
Net returns (Rs)	38291.44		
Increase(%) in Net returns	2.61		

*Net returns = Returns + left over operating capital

The cropping pattern suggested by LP model (Table 4) shows that returns can be raised up to 2.61% by allocating 2.180 acre land to wheat and 0.275 acre to mustard crop. But 0.045 acre land is left over due to less availability of operating capital and man power. So if farmers have more operating capital and man power, the returns can be increased upto 8.08%.

3.2 LP models for Small farmers

3.2.1 Kharif season

The crops sown by small farmers were rice and jowar. The average resources available as depicted in Table 5, were land 5.00 acre, man days 211 and operating capital rupees 144812 in kharif season. The aim was to plan a suitable cropping pattern to get the returns more than the existing net average returns of farmers which was rupees 84581.

Table 5: Farmer's cropping pattern, resource use and net returns* in kharif season

Resources	Rice	Jowar	Total used resources
	Per acre		
Land allocation (acre)	4.50	0.50	**5.00**
Man days	42.79	36	**211**
Operating capital (Rs)	30859.00	11893.75	**144812**
Net returns (Rs)	16749.24	18418.75	**84581**

*average of the sampled data

The linear programming (LP) model was developed using the averages of the sampled data given in Table 5 with the objective to maximize the net return.

Table 6: LP model's suggested cropping pattern, resource use and net returns in kharif season for small farmers

Resources	Available	Usage	Left over
Land allocation (acre)	5.00	5.00	-
Rice	-	0.00	-
Jowar	-	5.00	-
Man days	211	180	31
Operating capital (Rs)	144812	144812	0.00
Returns (Rs)	92093.75		
Net returns* (Rs)	92093.75		
Increase(%) in Net returns	8.88		

*Net returns = Returns + left over operating capital

The cropping pattern suggested by LP model (Table 6) shows that returns can be raised up to 8.88% by allocating total land to jowar crop. But 31 man days are left over due to less availability of operating capital. If farmers have more operating capital, he can increase his income. But it is not practically acceptable. Since, LP model have allocated all land to jowar which is fodder crop. The farmer uses the fodder crop for Livestock not for sale. So, LP model suggests an alternate plan to fulfill farmer's minimum requirements using constraints on land allocation.

Table 7: LP model's suggested cropping pattern with constraints on land allocation, resource use and net returns in kharif season for small farmers

Resources	Available	Usage	Left over
Land allocation (acre)	5.00	5.00	-
Rice	-	4	-
Jowar	-	1	-
Man days	211	207.16	3.84
Operating capital (Rs)	144812	135329.75	9482.25
Returns (Rs)	85415.69		
Net returns* (Rs)	94897.94		
Increase(%) in Net returns	12.20		

*Net returns = Returns + left over operating capital

An alternate plan was considered and LP model was developed, by putting the constraint of maximum/minimum requirements of land allocation under jowar crop. A maximum land of 1.00 acre is allocated for jowar (fodder crop) in Table 7.The cropping pattern suggested by LP model for alternate plan shows that returns can be raised up to only 12.20 % by allocating 4 acres to rice and 1.00 acre to jower crop by optimal use of available resources. But, 3.84 man days and Rs 9482.25 operating capital are left over.

3.2.2 Rabi season

The crops sown by small farmers were same as of marginal farmers for rabi season. The average resources available as depicted in Table 8, were land 5.00 acre, man days 172 and operating capital rupees 102986. The aim of the study was to plan a suitable cropping pattern to get the returns more than the existing net average returns of farmers which was rupees 63282.

Table 8: Farmer's cropping pattern, resource use and net returns* in Rabi season

Resources	Wheat	Mustard	Berseem	Total used resources
	Per acre			
Land allocation (acre)	4.00	0.50	0.50	**5.00**
Man days	34.34	28.83	40.40	**172**
Operating capital (Rs)	21842.69	16483.33	14747.36	**102986**
Net returns (Rs)	13303.25	8666.67	11470.82	**63282**

*average of the sampled data

The LP model was developed using the averages of the sampled data with the objective to maximize the net returns at the end of rabi season.

Table 9: LP model's suggested cropping pattern, resource use and net returns in Rabi season for small farmers

Resources	Available	Usage	Left over
Land allocation (acre)	5.00	4.90	0.10
Wheat	-	4.32	-
Mustard	-	-	-
Berseem	-	0.58	-
Man days	172	172	0
Operating capital (Rs)	102986	102986	0
Returns (Rs)	64182.34		
Net returns* (Rs)	64182.34		
Increase(%) in Net returns	1.42		

*Net returns = Returns + left over operating capital

The cropping pattern suggested by LP model (Table 9) shows that returns can be raised up to 1.42 % by allocating 4.32 acre land to wheat and 0.58 acre berseem crop. 0.10 acre land is left over due to less availability of man days and operating capital. If farmers have more operating capital and man power, return can be increased upto 5.11%. In above LP model, there was no land allocation to mustard crop which is not practically acceptable. To fulfill the basic requirements of farmers, an alternate plan was considered by putting the constraint of minimum requirements of land allocation under mustard crop.

Table 10: LP model's suggested cropping pattern with constraints on land allocation, resource use and net returns in Rabi season for small farmers

Resources	Available	Usage	Left over
Land allocation (acre)	5.00	5.00	-
Wheat	-	4.00	-
Mustard	-	0.50	-
Berseem	-	0.50	-
Man days	172	171.97	0.03
Operating capital (Rs)	102986	102986	0
Returns (Rs)	63282		
Net returns* (Rs)	63282		
Increase(%) in Net returns	Nil		

*Net returns = Returns + left over operating capital

Using the LP model (Table 10), the cropping pattern suggested by LP model for alternate plan shows that farmer's plan is optimum by optimal use of all available resources by allocating 4.00 acre land to wheat, 0.50 acre to mustard and 0.50 acre to berseem. But, 0.03 man days are left over due to less availability of operating capital. So if farmers have more operating capital, the returns can be increased upto 1.45%.

Table 11: Land allocation (in acres) and Net returns (%) from farmer's plans and alternate plans of cropping pattern for Kharif and Rabi season

Plan	Land allocation (in acres)								
	Kharif Season				Rabi season				
	Rice	Jowar	Increase in Net returns	Increase % in Net returns after using more resources	Wheat	Mustard	Berseem	Increase % in Net returns	Increase % in Net returns after using more resources
Marginal Farmer's	**2.00**	**0.50**	**-**	**-**	**2.00**	**0.25**	**0.25**	**-**	**-**

plan									
LP plan (without constraints)	2.00	0.50	**-**	**3.25**	2.180	0.275	0.00	**2.61**	**8.08**
Small Farmer's plan	**4.50**	**0.50**	**-**	**-**	**4.00**	**0.50**	**0.50**	**-**	**-**
LP plan (without constraints)	0.00	5.00	**8.88**	**-**	4.32	-	0.58	**1.42**	**5.11**
LP plan (with constraints)	4.00	1.00	**12.20**	**-**	4.00	0.50	0.5	**-**	**1.45**

The % increase in net returns obtained by LP model for the marginal farmers were 3.25% and 8.08 % in kharif and rabi season respectively. The % increase in net returns suggested by LP models for small farmers, allocating land without or with minimum constraints were 8.88%, 12.20 and 5.11%, 1.45% in kharif and rabi season respectively (Table 11).

4. CONCLUSIONS

In kharif season, marginal farmers were taking same net returns through both plans farmer's and LP model i.e LP suggested that farmer's plan was optimum, but net returns can be increased slightly (up to 3.25%) by the use of more resources. In rabi season, marginal farmers can raise net returns up to 2.61%, but they can get more profit up to 8.08% by use of more resources.

Net returns of small farmers can be raised up to 8.88% and 5.11% in both kharif and rabi seasons respectively without imposing any restriction of minimum land allocation to particular crops. If maximum/minimum requirement constraint on land allocation to crops is imposed, the cropping pattern suggests that the returns can be raised up to 12.20% and 1.45 % in both seasons respectively.

LP model suggested that pattern of land allocation used by farmers was optimum, but they can get more profit, if they have more resources.

REFERENCES

1. Alotaibi A and Nadeem F. A Review of Applications of Linear Programming to Optimize Agricultural Solutions. International Journal of Information Engineering and Electronic Business (IJIEEB). 2021; 13 (2): 11-21.
2. Hassan I, Ahmad P, Akhter M and Aslam M. Use of Linear Programming Model to Determine the Optimum Cropping Pattern: A case Study of Punjab. Electronic. J. Environ. Agric. and Food Chem. (EJEAFChe). 2005; 4(1): 841-850.
3. Hazell PBR and Norton RD. Mathematical Programming for Economic Analysis in Agriculture. New York: Macmillan Publishing Company 1986.
4. Majeke F, Majeke J, Mufandaedza J and Shoko M. Modeling a Small Farm Liveli-hood System using Linear Programming in Bindura, Zimbabwe. Research Journal of Management Sciences. 2013; 2(5): 20–23.
5. Mohamad NHJ and Said F. A Mathematical Programming Approach to Crop Mix Problem. African journal of Agricultural Research. 2011; 6(1): 191-197.
6. Nedunchezhian P and Thirunavukkarasu M. Optimizing Farm Plans in Different Farming Systems. Agricultural Economics Research Review. 2007; 20: 147-156.
7. Palash Md, Salauddin and Bauer S. Diversification of Farmland use in Bangladesh: Land Allocation Impacts on Farm Profitability. Open Agriculture. 2017; 2: 175–188.
8. Patel N., Thaker M. and Chaudhari C. Agricultural land allocation to the major crops through linear programming model. International Journal of Science and Research (IJSR). 2017; 6 (4): 519-522.
9. Poonia H, Tonk M S and Bhatia J K. A linear programming model to find optimum combination of crop farm activities for the rural farmers. Annals of Agri-Bio Research. 2016; 21(2): 160-163.

10. Poonia H, Tonk MS, Bhatia JK, Rekha and Rani N. Linear programming based crop land allocation to maximize profit of marginal/small farmers. Agric Res J. 2020; 57 (2): 245-252.
11. Radhakrishnan D. An application of linear programming for farm planning A case study in West Godabari District of Andhra Pradesh. Indian journal of Agricultural economics. 1962; 17(2): 73-82.
12. Raj Krishna. The optimality of land allocation: A case study of the Panjab. Indian journal of Agricultural economics. 1963; 18(1): 63-73.
13. Shukla AN, Gupta SN, Nantyal BL, Tiwari SK and Biswas PG. An analysis of income and employment in crop, dairy and poultry enterprises. Indian Journal of Dairy Science. 1994; 47(7): 549-555.
14. Tonk M S, Poonia H, Bhatia J K and Rekha. A mathematical programming approach to determine the optimum cropping pattern: a case study. International Journal of Agricultural Science and Research. 2019; 9 (3): 107-112.
15. Upadhyaya A. Application of optimization technique for crop planning to improve farm productivity of ICAR-RCER, Patna, India. Journal of Agri. Search, 2018; 4 (1): 68-70.