AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Asian Journal of Agricultural Extension, Economics & Sociology

40(9): 112-120, 2022; Article no.AJAEES.87352
ISSN: 2320-7027

Optimization of Profit and Land Resources for Marginal/Small Farmers - A Linear Programming Approach

Hemant Poonia [a*], Manju S. Tonk [a], Jitender Kumar Bhatia [b] and Rekha [c]

[a] Department of Mathematics and Statistics, COBS&H, CCS HAU, Hisar, India.
[b] Department of Agricultural Economics, COA, CCS HAU, Hisar, India.
[c] Centre of Food Science & Technology, CCS HAU, Hisar, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2022/v40i930983

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/87352

Original Research Article

Received 05 April 2022
Accepted 02 June 2022
Published 06 June 2022

ABSTRACT

The study was aimed 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 a linear programming approach. The crops sown by the farmers in the Kharif season were rice and Jowar, whereas, in the 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 the Kharif season, marginal farmers took the same net returns through both farmer's plans and LP model, i.e LP suggested that the farmer's plan was optimum, but net returns can be increased slightly (up to 3.25%) by using remaining resources. In Rabi season, marginal farmers can raise net returns to 2.61%, but they can get more profit up to 8.08% by using left over resources. Net returns of small farmers can be increased to 8.88% and 5.11% in both Kharif and Rabi seasons, respectively, without imposing any restriction on 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.

**Corresponding author: E-mail: pooniahemant80@gmail.com;*

Keywords: Optimization; profit; land resources; marginal/small farmers; and linear programming approach.

1. INTRODUCTION

Agriculture plays a vital role in the Indian economy. India's geographical condition is unique for agriculture because it provides many favorable conditions. Recently, agricultural planning has been essential due to the increased demand for agricultural commodities because of the population increase. Agricultural economics deals with scientific planning for agricultural development, which has become an essential area of specialization in agriculture. The optimal cropping pattern with maximum production and profit is essential for agricultural planning using an optimization model. Optimization techniques such as linear programming, dynamic programming, and goal programming can be used to solve this type of problem. The 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 is used in agriculture almost since its inception for planning the best possible allocation of scarce resources. Hazel and Norton [1] 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 [2] developed an LP crop mix model for a finite-time planning horizon. Majeke et al. [3] modeled a small farm livelihood using Linear Programming Model in Zimbabwe. Results obtained from the model were compared to the traditional farming method, and a difference of 44.65% was achieved with the model. Nedunchezhian and Thirunavukkarasu [4] 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. [5] analyzed the income and employment in the crop, dairy, and poultry enterprises. Radhakrishnan D [6] and Raj Krishna [7] proposed the LP technique to optimize farm planning. Hassan et al. [8] reported that farmers' profit could not be maximized without optimum cropping patterns, ensuring efficient utilization of available resources. So the use of LP makes it possible to devise equilibrium solutions, including the specification of product levels, factors, and product prices. Developing a prototype enterprise cropping plan in arable crop production would be helpful 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 combinations for rural farmers in Hisar district, Haryana. Palash and Bauer [10] suggested that smallholders can improve their gross margins by improving the allocation of the available physical and non-physical resources. Patel et al. [11] determined the optimum land allocation to fourteen major crops using agriculture data for various factors like land utilization, labour in man-days, seeds, fertilizers, and yields for crops for the period 2010-2011. Upadhyaya [12] studied the application of optimization techniques for crop planning to improve farm productivity and indicated that existing practice, which is being followed at the farm, is the least profitable. Certainly, if other practices are followed, there could be scope for improvement in the profit from the farm. Tonk et al. [13] applied a mathematical programming approach to determine the optimum cropping pattern for the medium farmers in Bherian village, district Hisar. Poonia et al. [14] studied the cropping patterns and optimum use of land resources by marginal and small farmers of Shamsukh village in Hisar district during the Kharif and Rabi seasons. They developed a linear programming model to optimize the farmers' profit and maximum use of land resources. Alotaibi and Nadeem [15] reviewed the applications of linear programming to optimize agricultural solutions and highlighted the various tools that are central to analyzing LP model results. They discussed the different approaches to optimize agricultural

solutions. Kumar and Phougat [16] examined the status of e-Kharid portal and discussed the linkage of Meri Fasal Mera Byora (MFMB) portal with e-Kharid portal. Kumar and Phougat [17] assessed the performance of the crop insurance schemes implemented in Haryana. Economic survey of Haryana and the annual reports of the Agriculture Insurance Company (AIC) for several periods were examined. Kumar and Phougat [18] analyzed the PM-Kisan Samman Nidhi scheme implemented in India: With special reference to Haryana state.

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

2. MATERIALS AND METHODS

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 whereas 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.

The linear programming (LP) model was developed using the averages of the sampled data to maximize the net return at the end of the Kharif and Rabi seasons. The decision variables of the 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

$$\text{Max } Z = c_1x_1+c_2x_2 + c_3x_3$$

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 the Kharif season. As depicted in Table 1, the average resources available were land of 2.50 acres, man-days 104, and operating capital rupees 59042 in Kharif season. The study aimed to plan a suitable cropping pattern to get more returns than the existing net average returns of farmers, which was rupees 37314.

The linear programming (LP) model was developed using the averages of the sampled data to maximize the net return at the end of the Kharif and Rabi seasons. The resource constraints considered in the study were land, man-days, and operating capital and were kept the same as obtained from the 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 1. Marginal farmer's cropping pattern, resource use, and net returns* in the 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 cropping pattern suggested by the LP model (Table 2) shows that farmer's plan is optimum with optimal use of all available resources by allocating 2.00 acres of land to rice and 0.50 acres 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 manpower, the returns can be increased up to 3.25 %.

3.1.2 Rabi season

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

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

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

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

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

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*

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

3.2 LP Models for Small Farmers

3.2.1 Kharif season

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

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

The cropping pattern suggested by the 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, they can increase their income. But it is not practically acceptable. Since the LP model has allocated all land to Jowar which is a fodder crop. The farmer uses the fodder crop for Livestock, not for sale. So, the LP model suggests an alternate plan to fulfill farmers' minimum requirements using constraints on land allocation.

An alternate plan was considered, and an 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 the LP model for the alternate plan shows that returns can be raised to only 12.20 % by allocating 4 acres to rice and 1.00 acre to Jowar crop by optimal use of available resources. But, 3.84 man-days and Rs 9482.25 operating capital are leftover.

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*

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*

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*

3.2.2 Rabi season

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

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

The cropping pattern suggested by LP model (Table 9) shows that returns can be raised to 1.42 % by allocating 4.32 acres of land to wheat and 0.58 acres berseem crop. 0.10 acre land is left over due to less man days and operating capital availability. If farmers have more operating capital and manpower, the return can be increased up to 5.11%. There was no land allocation to mustard crops in the above LP model, 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 the mustard crop.

Using the LP model (Table 10), the cropping pattern suggested by the LP model for alternate plan shows that the farmer's plan is optimum with optimal use of all available resources by allocating 4.00 acres of land to wheat, 0.50 acres to mustard, and 0.50 acres 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 up to 1.45%.

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*

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*

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*

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 plan	2.00	0.50	-	-	2.00	0.25	0.25	-	-
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 the LP model for the marginal farmers was 3.25% and 8.08 % in Kharif and Rabi seasons, respectively. The % increase in net returns suggested by LP models for small farmers, allocating land without or with minimum constraints was 8.88%, 12.20 and 5.11%, 1.45% in Kharif and Rabi seasons, respectively (Table 11).

4. CONCLUSIONS

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

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

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hazell PBR, Norton RD. Mathematical programming for economic analysis in agriculture. New York: Macmillan Publishing Company; 1986.
2. Mohamad NHJ, Said F. A mathematical programming approach to crop mix problem. African Journal of Agricultural Research. 2011;6(1):191-197.
3. Majeke F, Majeke J, Mufandaedza J, 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.
4. Nedunchezhian P, Thirunavukkarasu M. Optimizing farm plans in different farming systems. Agricultural Economics Research Review. 2007;20:147-156.
5. Shukla AN, Gupta SN, Nantyal BL, Tiwari SK, Biswas PG. An analysis of income and employment in crop, dairy and poultry enterprises. Indian Journal of Dairy Science. 1994;47(7):549-555.
6. 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.
7. Raj Krishna. The optimality of land allocation: A case study of the Panjab. Indian Journal of Agricultural Economics. 1963;18(1):63-73.
8. Hassan I, Ahmad P, Akhter M, 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.
9. Poonia H, Tonk MS, Bhatia JK. 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. Palash Md, Salauddin, Bauer S. Diversification of farmland use in Bangladesh: Land allocation impacts on farm profitability. Open Agriculture. 2017; 2:175–188.
11. Patel N, Thaker M, 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.
12. 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.
13. Tonk MS, Poonia H, Bhatia JK, 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.
14. Poonia H, Tonk MS, Bhatia JK, Rekha, Rani N. Linear programming based crop land allocation to maximize profit of marginal/small farmers. Agric Res J. 2020;57(2):245-252.
15. Alotaibi A, 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.

16. Kumar D, Phougat S. e-Kharid portal: An initiative of Haryana Government for Agricultural Digitalization. Asian Journal of Research and Review in Agriculture. 2021;3(3):28-34.

17. Kumar D, Phougat S. Performance evaluation of crop insurance schemes in Haryana. Journal of Economics and Trade. 2021;6(1):34-39.

18. Kumar D, Phougat S. Analysis of Pradhan Mantri Kisan Samman Nidhi(PM-Kisan) Scheme: With special reference to Haryana State. Journal of Global Agriculture and Ecology. 2021;12(2):1-8.

© 2022 Poonia et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/87352