Application of optimization technique for crop planning to improve farm productivity of ICAR-RCER, Patna, India

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ABSTRACT

Use of Linear Programming employing Simplex method under application of optimization techniques in agriculture for maximization of profit or minimization of loss is being practiced since long. It gives an opportunity for planning and better allocation of resources in agriculture because one gets an opportunity to identify the interventions in agriculture, which are more profit, oriented either due to less input cost or more income from outputs. In the present paper, various scenarios have been generated by allocating various parcels of farm land under different crops and it was observed that existing practice is least profit oriented and there is fairly good scope of improvement in profit from farm.

Keywords: Land allocation, Optimization, Simplex method, Profit maximization

INTRODUCTION

Land and water are finite natural resources in our country. These resources are diminishing slowly and gradually due to indiscriminate and unscrupulous exploitation. In order to meet out the food and fodder requirement of ever increasing human and livestock population, the need of hour is to enhance land and water productivity from limited resources. Also, it is equally important for farmers to know the optimum option of allocating different parcels of agricultural lands under various interventions related to agriculture so that their profit is maximized from available land and water resources and other prevailing constraints (Manibhushan *et al.*, 2014). In the present paper, institute farms' actual input and output data has been analyzed and various scenarios have been generated along with optimum solution. Obtaining a solution to optimize profit for farmers with the available resources is really a passionate subject for researchers as well as farmers and since long research work is being carried out in order to improve problem formulation, methodology and solution. Radhakrishnan (1962) and Raj Krishna (1963) proposed the LP technique for determining the optimal farm planning. Keith (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.

Other 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.* (1992). The land use planning techniques and methodologies with different objectives, applications, and land uses have been identified by Sante and Crecente (2005). Andres and Carlos (2006) 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. Tanko *et al.* (2006) mentioned that studies in optimum resource allocation using LP approaches have largely been attempted in many countries. Felix and Judith (2010) 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 and Fatimah (2011) to the maximize the total returns at the end of the planning horizon. Ion and Turek (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. They observed that, after applying the econometric model the profit rose to 143% and costs reduced to 81%. Wankhade and Lunge (2012) reported that linear programming (LP) technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural productivity. They mentioned that Linear programming technique was applied to determine the optimum land allocation to 10 major crops of the saline track of rain fed zone using agriculture data, with respect to various factors viz. cost of seeds, cost of fertilizers/ pesticides, yield of crops, daily wages of labour and machine charges, selling base price of commodities, for the period 2009-2010. A case study was carried out in the saline track of rain fed zone of Murtizapur Tahsil of Akola District. Mugabe *et al.* (2014)

developed an optimal land use plan for Long Croft farm (LCF) by assessing the available land resources. It evaluates the potential of the land resources for recommending optimum, sustainable and appropriate land utilisation in agriculture development. Possible ways in improving farming systems and more efficient utilization of the scarce available agricultural resources especially arable land were determined. The study used quantitative analytical approach in optimal land use allocation analysis. The Linear programming model with an objective function that seeks to maximise net farm income subject to land, labour, capital and consumption constraints was run using Microsoft excel premium solver.

The results of the study showed resource surveying, land evaluation and land use planning should be employed in Zimbabwe's agriculture to boast production. Gadge *et al.* (2014) formulated a linear programming model to suggest the optimal cropping pattern for surface irrigation in a command area. The objective of the model was to achieve the maximum net benefits. The objective function of the model was subjected to the constraints viz., the total available water and land during different irrigation periods. The model was applied to the command area of direct minor no. 3 of the Mula Irrigation Project, Ahmednagar, Maharashtra for different proportions of the total command area of minor no. 3. The model gave the optimal cropping pattern for 431.7 ha of command area having water availability of 171280 m 3 during the "ON" period (7 days) of canal rotation for 60% proportion. The net return from the optimal cropping plan was 50.68 Million Rs.

The optimal cropping pattern includes allocation of 25.9 ha area for papaya, 25.90 ha for sugarcane, 96.4 ha for Rabi tomato, 6.17 ha for Rabi onion, 78.35 ha for Kharif brinjal, 2.98 ha for cabbage, 55.03 ha for summer brinjal and 12.88 ha for summer onion.

Sofi *et al.* (2015) reported that linear programming (LP) technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agriculture production of food crops (Rice, Maize, wheat, Pulses and other crops) . They applied linear programming technique to determine the optimum land allocation of 5 food crops by using agriculture data, with respect to various factors viz. Daily wages of labour and machine charges for the period 2004-2011. The LP model was solved by standard simplex algorithm. It was observed that the proposed LP model was appropriate for finding the optimal land allocation to the major food crops.

MATERIALS AND METHODS

Wheat is major staple food and chief source of energy, similarly mustard play a vital role in to supplement fatty acids component in human diet, likewise lentil is second most important pulses crop after chickpea primarily responsible for protein, being a majority of population are still vegetarian. Wheat, mustard and lentil are the important crop of winter season in the entire eastern region of India (Singh *et al.,* 2008).

Keeping in view above fact in mind and in order to assess the present net benefits and further scope of improvement in net benefits from 8.5 ha land available at Sabajpura farm of Institute during winter season 2014-15, data about crops sown, area occupied by crop, and cost involved in Mandays,

Table 1: Input data of Institute Sabajpura farm

Crop	Area (ha)	Man Days (Rs. 191/day)	No. of Irrigations	Urea (Rs. 284/50 Kg)	MOP (Rs. 930/50 Kg)	DAP (Rs. 1263/ 50 Kg)	Total Yield (Quintal)	Sell Price (Rs/ Quintal)
				Fertilizer (Quantity, Kg and Rate)				
Wheat	6.5	75	4	1094	429	809	171.5 Wheat 90 Hey	1350 180
Mustard	0.85	20	1	47	47	93	5.75	2600
Lentil	0.90	25	1	33.5	4	8	5.5	3400

irrigation, and other inputs (i.e. seeds, insecticide, fungicide used), quantity of Urea, DAP and MOP applied along with cost, yield of main product and byproduct as well as sell price was collected as given below in Table 1.

Note:
- Cost of other inputs like seeds, insecticide fungicide etc. for Wheat, Mustard and Lentil crops are Rs. 4120, 1300 and 958, respectively.
- Cost of one irrigation has been considered as Rs. 2000/ha (based on assumption that around 20 hrs are taken to irrigate 1 ha area and farmer pays Rs. 100 per hour for irrigating farm land through tube well.)
- Net benefits have been calculated after subtracting cost of inputs (seed, insecticide, fungicide etc.), cost of irrigation, Mandays charges, costs of fertilizers, form income, form output.

With the above data, optimization problem with objective function and constraints was formulated as given below.

Maximize Net benefits i.e. $6339\,X1 + 6361.96\,X2 + 12526.16\,X3$

Subject to constraints

$168.31\,X1 + 55.29\,X2 + 37.22\,X3 \leqslant 1306.25$ (Urea)

$66\,X1 + 55.29\,X2 + 4.44\,X3 \leqslant 506$ (MOP)

$124.46\,X1 + 109.41\,X2 + 8.89\,X3 \leqslant 902$ (DAP)

$X1, X2, X3 \geqslant 0$

Here X1, X2 and X3 denote area under Wheat, Mustard and Lentil crops.

RESULTS AND DISCUSSION

This problem was solved employing LINPROG of optimization tool box (simplex method of solving linear programming) through MATLAB and results obtained are given below in Table 2.

From the above analysis, it is evident that existing practice is giving net benefits of Rs. 57884.71only, which is not optimal and ranks at XI. On the other hand, if in total land of 8.25 ha, lentil is sown then optimum benefits of Rs. 103340.82 can be obtained, which is 1.785 times higher than the present net benefits. If there is essential requirement of seed production of Wheat and Mustard, decision may be taken from the above

Table 2: Area allocated under different winter crops and net benefits

Area under Wheat crop (ha) X_1	Area under Mustard crop x crop $_2$	Area under Lentil crop (ha) X_3	Net benefits (Rs.)	Remarks/ Rank (Optimum solution)
0	0	8.25	103340.82	I
0	1	7.25	97176.62	II
1	0	7.25	97153.66	III
0	1.25	7.0	95635.57	IV
1.25	0	7.0	95606.87	V
0	1.5	6.75	94094.52	VI
1.5	0	6.75	94060.08	VII
1	1	6.25	90989.46	VIII
1.5	1.5	5.25	84813.78	IX
2.0	2.0	4.25	78638.1	X
6.5	0.85	0.90	57884.71	Existing situation, XI

mentioned options by compromising with net benefits. Further, above finding may be applicable to particular locations, because the economic condition of eastern region of India epically Bihar (Bharati *et al.,* 2014) may not be identical and replicable.

CONCLUSIONS

Linear Programming (LP) is one of the easiest ways of solving the problems related to agriculture. Applying LINPROG toolbox in MATLAB software it can be solved easily and optimum as well as other possible solutions can be generated. This paper very clearly indicates 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.

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