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Optimization of Resources using Sen's Multi Objective Programming (MOP) Model for Potato Growers of Nalanda District, Bihar

Suman Kumari, Mukesh Maurya

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ABSTRACT

An appropriate resource use planning is required for the development of farming sector. Increasing income, employment with lesser use of irrigation, fertilizer may be the major objectives to be achieved. There are several mathematical models for achieving multiple objectives. Sen's Multi Objective Programming (MOP) model is most popular for achieving several objectives simultaneously. In the present study, an optimal cropping plan was proposed for potato growers of Nalanda district of Bihar for increasing income, employment with lesser use of fertilizer.

Keywords Maximization, Minimization, Optimization, Linear programming, Multi objective programming.

Suman Kumari[1]*, Mukesh Maurya[2]

[1]Research Scholar, [2] Assistant Professor

[1,2]Department of Agricultural Economics, SHUATS, Prayagraj 211007, UP, India

Email: sumanshandilya2@gmail.com
*Corresponding author

INTRODUCTION

The objective of an efficient farming system is to develop optimal combinations of enterprises for greater integrations of farming activities. Agricultural planning has to be carefully organized at the farm level itself to make better use of the agricultural land of the region, to sustain farming families and to produce crops on a sustainable basis. Most of the farmers of the area follow diversified farming system. They grow multiple crops in a season to meet the consumption needs of their families as well as generate sufficient income for other household expenses. Therefore, enhancement of farmer's income was made an important consideration for formulating alternative farming plan. Farmers are using less organic manure in their crops and more chemical fertilizers, which is harmful for the soil health. The reduction of the use of chemical fertilizers was another consideration for appropriate farm planning. More opportunities for employment for the rural laborers should also be generated through improved farm planning.

The application of multi objective optimization is required to achieve multiple objectives simultaneously. Sen's MOP model (Sen and Dubey1994) is very popular and efficient in providing an optimal solution with multiple conflicting objectives. This method has been successfully used in many research studies (Gangwar 1994, Gautam 2013, Kumar 2012), Kushwaha *et al.* 1992, Kumari *et al.* 2017, Maurya *et al.* 2019 and Sen 1983) for formulating the suitable farm

plans to achieve several objectives simultaneously.

MATERIALS AND METHODS

Multistage sampling technique was adopted for selection of potato growers. District Nalanda has been selected specifically for the study to represent the farming system. Based on the highest acreage and agricultural output, the Bihar sharif block and Noor Sharai block were selected. Finally, five village from each sample block and 25 farmers from each sample village have been selected for the present study. The required information about cropping pattern, costs and returns from the crops have been collected from the sample farmers through personal interviews.

The study's major goal was to create alternative cropping strategies for both rain-fed and irrigated farming systems in order to increase income and employment while using less fertilizer. For the average size of holdings, 1.51 hectares of farming, linear programming was utilized to create effective cropping plans. As constraints, the model now takes into account the other resources, such as labor and capital, that are accessible to farmers as well as how they behave when changing the area planted with different crops. Following is a description of the linear programming model.

Analytical tools

It was decided to formulate an appropriate farm plan for increasing their income and employment with lesser use of fertilizer.

Mathematical formulation of the model

The theoretical frame work of the mathematical model is detailed below:

i. Maximization of income

$$Maximize\ Z_1 \sum_{j=1}^{n} I_j X_j$$

ii. Maximization of employment

$$Maximize\ Z_2 = \sum_{j=1}^{n} E_j\ x_j$$

iii. Minimization of fertilizer use

$$Minimize\ Z_3 = \sum_{j=1}^{n} F_j X_j$$

Subject to the constraints,

$$\sum_{j=1}^{n} a_{ij}\, x_j \geq \leq b_i$$

$$x_j \geq 0 \qquad j = 1, 2\ldots..., n \qquad i = 1, 2,\ldots\ldots., m$$

Where, Z_1 = Net returns from all crop included in the model.
I_j = Income from j^{th} activity measured in rupees per hectare of land.
Z_2 = Total employment in days.
E_j= Employment of j^{th} activity measured in man-days/ha.
Z_3 = Total fertilizer use on the farm in kg.
F_j = Fertilizer use per unit of j^{th} activity in kg/ha
X_j= Area of j^{th} crop in ha.
a_{ij}= Quantity of i^{th} input required per unit of j^{th} crop.
b_i= Quantity available of the i^{th} resource.

iv. Sen's multi-objective programming model

All the three objectives have been achieved using linear programming technique. It was observed that all the three results were different. Hence, Sen's Multi-Objective Programming (MOP) model was applied in the study to achieve all the objectives simultaneously. The Sen's MOP model is explained as below:

$$Max.\ Z^* = \frac{\sum_{j=1}^{n} I_j X_j}{W_1} + \frac{\sum_{j=1}^{n} E_j X_j}{W_2} - \frac{\sum_{j=1}^{n} F_j X_j}{W_3}$$

Subject to the constraints,

$$\sum_{j=1}^{n} a_{ij}\, x_j \geq \leq b_i$$

$x_j \geq 0$ i=1, 2……., m j=1, 2…..,n

Where, Z* = Multi-objective function
W_1 = Maximum income (I)
W_2 = Maximum employment (E)
W_3 = Minimum fertilizer use (F)

The above-mentioned Sen's MOP model has been applied for developing an appropriate farm plan for increasing farm income and employment with lesser use of fertilizer.

Objective functions and constraints

The details of the objective functions and the constraints are detailed below:

Max income (Rs) $Z_1 = 62938\ X_1 + 57753\ X_2 + 31724\ X_3 + 90055\ X_4 + 53127\ X_5 + 35613\ X_6$

Max employment (Days) $Z_2 = 58X_1 + 63X_2 + 43X_3 + 63X_4 + 65X_5 + 37X_6$

Min fertilizer use (kg) $Z_3 = 230X_1 + 190X_2 + 150X_3 + 240X_4 + 200X_5 + 160X_6$

Subject to,

$X_1 + X_2 + X_3 + 0X_4 + 0X_5 + 0X_6 \leq 1.51$ (*kharif* Land in ha)

$0X_1 + 0X_2 + 0X_3 + X_4 + X_5 + X_6 \leq 1.51$ (*rabi* Land in ha)

$X_1 + 0X_2 + 0X_3 + 0X_4 + 0X_5 + 0X_6 \geq 0.30$ (Minimum area under Paddy)

$0X_1 + X_2 + 0X_3 + 0X_4 + 0X_5 + 0X_6 \geq 0.22$ (Minimum area under Maize)

$0X_1 + 0X_2 + X_3 + 0X_4 + 0X_5 + 0X_6 \geq 0.22$ (Minimum area under Red Gram)

$0X_1 + 0X_2 + 0X_3 + X_4 + 0X_5 + 0X_6 \geq 0.42$ (Minimum area under Potato)

$0X_1 + 0X_2 + 0X_3 + 0X_4 + X_5 + 0X_6 \geq 0.20$ (Minimum area under Wheat)

$0X_1 + 0X_2 + 0X_3 + 0X_4 + 0X_5 + X_6 \geq 0.13$ (Minimum area under Lentil)

Where X_1, X_2, X_3, X_4, X_5 and X_6 are the land allocated to crops Paddy, Maize, Red Gram, Potato, Wheat and Lentil respectively

RESULTS AND DISCUSSION

All the three objective functions have been achieved using linear programming. The results of individual optimization are presented in Table 1. It is clear from the table that maximization of income has increased in income by 12.98 percent over its existing level. However, the employment increased by 4.09 percent and fertilizer use increased by 7.96 percent. The employment maximization has increased by 7.02 percent over its existing level.

However, the income and employment has decreased by 4.39 and 1,95 percent respectively over their existing levels. The minimization of fertilizer use decreased the fertilizer use by 21.86 percent with decrease in income and employment by 22.46 and 14.62 respectively over their existing levels. None of the above mentioned three solutions are favourable and acceptable to the farmers of Nalanda district. However, Sen's MOP has generated a compromise solution as mentioned in last column of the table. The income level of farmers has increased by 10.82%

Table 1. Individual and multi-objective optimization.

Item	Existing level	Max of income	Max of employment	Min of fertilizer use	Multi-objective optimization
Income (Rs)	184592	208549 (12.98)	176491 (-4.39)	143138 (-22.46)	204556 (10.82)
Employment (days)	171	178 (4.09)	183 (7.02)	146 (-14.62)	181 (5.85)
Fertilizer use (kg)	616	665 (7.96)	604 (-1.95)	543 (-21.86)	634 (2.92)

Note: Figures in parentheses shows the percentage increase/decrease over the existing levels.

Table 2. Existing and optimal cropping pattern.

Crops	Existing area (ha)	Optimal area (ha)
Paddy	0.61	0.30
	(20.26)	(9.93)
Maize	0.44	0.99
	(14.62)	(32.78)
Red Gram	0.45	0.22
	(14.95)	(7.29)
Potato	0.84	1.18
	(27.91)	(39.07)
Wheat	0.40	0.20
	(13.29)	(6.62)
Lentil	0.27	0.13
	(8.97)	(4.31)
Sown by the gross cropped area	3.01 (100.00)	3.02 (100.00)

over its existing level and very close to its individual maximum of Rs 208549. The employment has also increased by 5.85% over its existing level. However, the fertilizer use has not decreased but increased by 2.92% only. The minor increase in fertilizer use is acceptable with favorable increase in income and employment in the proposed cropping plan. The existing and optimal cropping plan is mentioned in Table 2. The farmers in the study area were growing six major crops of Paddy, Maize and Red Gram in *kharif* season and Potato, Wheat and Lentil in the *rabi* season in their average holding of 1.51 hectares.

Paddy in *kharif* and Potato in *rabi* season were the major crops grown by the farmers of the study area. However, in the proposed cropping plan, the area under Paddy and Red Gram has decreased significantly and shifted in the area of Maize. There is significant increase in the area of Maize from 0.44 ha in the existing cropping plan to 0.99 ha in the proposed cropping plan. Similarly, in the rabi season the area under Potato has increased from 0.84 ha in the existing cropping plan to 1.18 ha in the proposed cropping plan. The area under Wheat and Lentil has reduced significantly in the proposed cropping plan.

CONCLUSION

The present study indicated the possibilities of improving farming practices for the welfare of the farmers. The existing farming plan can be altered for achieving multiple objectives using Sen's MOP technique. The proposed cropping plan improved the income and employment as desired. However, the fertilizer used has not reduced as desired. The improvement in fertilizer application techniques is required.

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