

Original Research Article

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## Application of Sen's Multi-Objective Programming (MOP) for Vegetable Based Cropping Plan in Eastern Uttar Pradesh

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### ABSTRACT

#### Keywords

Linear Programming, Sen's Multi-Objective Programming (MOP), Cropping Plan, Eastern Uttar Pradesh

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The risks involved in agriculture urges the need for insulating the farm profits through income optimization management. The study has attempted an evolving suitable strategy for increasing farm income and employment through vegetable crops with less use of irrigation water in eastern Uttar Pradesh. The objective was fulfilled using Sen's Multi-Objective Programming (MOP) model. The estimates of MOP have been found as a better solution over the individual optimization but as a compromised one. The optimal cropping plan was also found superior over the existing cropping plan for increasing income and employment with lesser irrigation.

### Introduction

Indian agriculture is now dominated by horticultural production. Total horticultural production of 315 million tons is greater than 297 million tons of food grain production. Indian farmers are producing 190 million tons of vegetables and small and marginal farmers are the main contributors to vegetable production. For exploring the possibilities of increasing income and employment with lesser irrigation, the optimization of limited resources for developing a suitable cropping

plan seems to be essential. Optimization techniques like applied math, wise choice of best allocation of land and water to attain maximum returns by increasing production per unit area, and per drop of water (Gadge *et al.*, 2014). It is a technique of high importance with profit-maximizing and costminimization through a combination of farm enterprises that is possible to carry out with the given farm constraints. The optimized farm plan may assist the farmer to improve efficiency in a dynamic economic and technological atmosphere along with increasing food

security (Otoo *et al.*, 2015). This paper is drawn out of the Ph.D. thesis entitled, Possibilities of Increasing Farmers' Income through Production and Marketing of High-Value Horticultural Crops in Varanasi District of Eastern Uttar Pradesh of the first author submitted to the Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, in 2020

Within the agriculture sector, in-depth studies have been done on the application of applied math techniques for the allocation of restricted resources (Igwe *et al.*, 2011; Majeke, 2013; Bamiro *et al.*, 2015). This can be done through the development of linear programming models for maximization of profit and minimization of cost thus ensuring profits to be on the higher side. Of the various techniques available in the literature, the application of Multi-Objective Programming (MOP) is pivotal for optimum resource allocation.

The objective of this study was to develop an appropriate cropping plan for increasing income and employment with lesser irrigation. This has necessitated the use of Sen's MOP model (1983) for achieving the desired goals. The optimized cropping plan developed using Sen's MOP technique has increased farm income and employment with lesser irrigation. The paper consists of four sections, an introduction followed by data and methodology describing the collection and analysis of data, results, and discussion giving the details of results obtained and inferences drawn and last section of conclusion followed by references.

## **Materials and Methods**

Uttar Pradesh is the largest state of India with the highest population (220.7 million) and the fourth largest in space (24.1 Mha). Agriculture forms an integral part of the

state's economy and also the state is popularly called the storage or bread-basket of Asian country i.e. India. Given its giant size, varied geography, climate, and topography, the state has been divided into four regions, specifically Western, Central, Eastern, and Bundelkhand. The Eastern region having 29 districts covers 35 percent of the total geographical of the state. The typical traditional annual precipitation in the region is 1025 millimeters to 1214 millimeters. Linear unit and also the atmospheric condition square measure damp sub wet to dry sub-humid.

The most soil sorts found within the region square measure sandy soil, loam, calcareous, clayey deep deposit, light-weight deposit chalky clay, sandy soil, red yellow clay. Despite smart average annual precipitation, 40percent of the land is rain-fed and 60 percent is irrigated. The farming is dominated by the marginal farmers (87%) with the average holding size less than 2 ha.

The study relies on the first information on cropping patterns, input use, and yields of major vegetable crops. For the study, 10 vegetables and major cereal and pulse crops are grown by the sample farmers have been selected. The information about various expenses incurred in the cultivation of the selected crops by the sample farmers in eastern Uttar Pradesh has been collected.

## **Analytical tools**

### **Sen's Multi-Objective Programming Model**

The main aim of the present study to formulate a suitable cropping plan for increasing income and employment with lesser irrigation on an average farm in Eastern Uttar Pradesh. Therefore, the following three objectives have been formulated as described below:

**Maximization of farm income**

$$\text{Maximize } Z1 = \sum_{j=1}^n C_j X_j$$

Subject to the constraints,

$$\sum_{j=1}^n a_{ij} X_j \leq b_i \quad (i=1, 2, 3, \dots, m)$$

$$X_j \geq 0 \quad (j=1, 2, 3, \dots, n)$$

Where,

- Z<sub>1</sub>= Income (returns over variable costs)
- C<sub>j</sub> = net returns from j<sup>th</sup> activity
- X<sub>j</sub>= level of j<sup>th</sup> activity (I = 1, 2, 3 ....m)
- a<sub>ij</sub> = the number of i<sup>th</sup> resources required by one unit of j<sup>th</sup> activity
- b<sub>i</sub> = quantity available of the i<sup>th</sup> resource

**Maximization of employment**

$$\text{Maximize } Z2 = \sum_{j=1}^n E_j X_j$$

Subject to the constraints,

$$\sum_{j=1}^n a_{ij} X_j \leq b_i \quad (i=1, 2, 3, \dots, m)$$

$$X_j \geq 0 \quad (j=1, 2, 3, \dots, n)$$

Where,

- Z<sub>2</sub>= Employment in mandays
- E<sub>j</sub> = Labourman-days required per unit of j<sup>th</sup> activity
- X<sub>j</sub>= level of j<sup>th</sup> activity (I = 1, 2, 3 ....m)
- a<sub>ij</sub> = the number of i<sup>th</sup> resources required by one unit of j<sup>th</sup> activity
- b<sub>i</sub> = quantity available of the i<sup>th</sup> resource

**Minimization of irrigation water use**

$$\text{Maximize } Z3 = \sum_{j=1}^n W_j X_j$$

Subject to the constraints,

$$\sum_{j=1}^n a_{ij} X_j \leq b_i \quad (i=1, 2, 3, \dots, m)$$

$$X_j \geq 0 \quad (j=1, 2, 3, \dots, n)$$

Where,

- Z<sub>3</sub> = Water used in irrigation (Million cubic meters)
- W<sub>j</sub> = Irrigation water(million cubic meters) used by j<sup>th</sup> crop
- X<sub>j</sub>= level of j<sup>th</sup> activity (I = 1, 2, 3 ....m)

- a<sub>ij</sub> = the number of i<sup>th</sup> resources required by one unit of j<sup>th</sup> activity
- b<sub>i</sub> = quantity available of the i<sup>th</sup> resource

All three objective functions have been achieved using a simple linear programming technique. The individual optimization has achieved one objective only ignoring the other two objectives. The conflicts amongst objectives have been observed. Therefore, Sen's MOP has been used for achieving all three objectives simultaneously.

Sen's MOP model is explained as below:

$$Z^* = \frac{\sum_{j=1}^n C_j X_j}{Z_1} + \frac{\sum_{j=1}^n E_j X_j}{Z_2} - \frac{\sum_{j=1}^n W_j X_j}{Z_3}$$

Subject to the constraints,

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

$$x_j \geq 0 \quad i=1, 2 \dots m; j=1, 2 \dots n$$

Where,  $Z^*$  = Multi Objective Function

$Z_1$  = Maximum income in income maximization (I)

$Z_2$  = Maximum employment in employment maximization (E)

$Z_3$  = Minimum water use in water use minimization (W)

All the major vegetable crops grown in eastern Uttar Pradesh have been considered in the optimization plan.

**Results and Discussion**

All three objectives have been achieved individually to verify the presence of conflicts amongst objectives. Results of individual optimization are presented in table.1. The maximization of income has increased income by 73.35 percent over the existing level of income. The employment has also increased by 19.73 percent but the use of irrigation water has increased which is not desirable. The employment maximization has increased employment by 24.82 percent and income by

66.67 with increased irrigation water use by 7.29 percent over the existing level. The minimization of irrigation water use has reduced the requirement water use by 12.49 with the increase in the income and employment by 44.88 and 3.33 percent respectively over the existing levels. The above results indicate the conflicts amongst the objectives of maximization of income and employment with minimum use of irrigation water use. However, the Sen's MOP has increased Income by 68.79 percent, employment by 22.96 percent, and reduced the use of irrigation water by 7.81 percent over the existing level. The Sen's MOP has optimized all the three objectives simultaneously.

The cropping plan generated by Sen's MOP model has been recommended for Eastern Uttar Pradesh. The existing and optimal cropping plans are presented in the table.2. The above table reveals that of the Gross cropped area of 1.94 ha. Wheat has the highest area under cultivation (0.68) in the existing cropping plan in Eastern U.P., which has declined to 0.53 ha in the optimal cropping plan.

**Table.1 Individual and Multi-Objective Optimization**

Item	Existing	Individual Optimization			Sen's MOP
		Max. $Z_1$	Max. $Z_2$	Min. $Z_3$	
$Z_1$ (Income in Rs.)	239318	414873 (73.35)	398861 (66.67)	346727 (44.88)	403937 (68.79)
$Z_2$ (Employment in Days)	270	323 (19.63)	337 (24.82)	279 (3.33)	332 (22.96)
$Z_3$ (Water Use)Million cubic meters	6046	6506 (7.61)	6487 (7.29)	5291 (-12.49)	5574 (-7.81)

Figures in parenthesis show the percentage increase/decrease over the existing level

**Table.2** Existing and Optimal Cropping Plan

Crop	Code	Existing Cropping Plan	Optimal Cropping Plan
<b>KharifRice</b>	X <sub>1</sub>	0.684	0.539
<b>Maize</b>	X <sub>2</sub>	0.061	0.054
<b>Jowar</b>	X <sub>3</sub>	0.04	0.03
<b>Bajra</b>	X <sub>4</sub>	0.049	0.039
<b>Sugarcane</b>	X <sub>5</sub>	0.044	0.034
<b>Brinjal</b>	X <sub>6</sub>	0.094	0.276
<b>Rabi Cauliflower</b>	X <sub>7</sub>	0.038	0.03
<b>Cabbage</b>	X <sub>8</sub>	0.042	0.031
<b>Capsicum</b>	X <sub>9</sub>	0.036	0.031
<b>Gram</b>	X <sub>10</sub>	0.013	0.0101
<b>Pea</b>	X <sub>11</sub>	0.019	0.0181
<b>Potato</b>	X <sub>12</sub>	0.023	0.01979
<b>Wheat</b>	X <sub>13</sub>	0.68	0.53
<b>Mustard</b>	X <sub>14</sub>	0.0132	0.0104
<b>Sugarcane</b>	X <sub>15</sub>	0.044	0.034
<b>Barley</b>	X <sub>16</sub>	0.007	0.0132
<b>Chilli</b>	X <sub>17</sub>	0.029	0.0191
<b>Tomato</b>	X <sub>18</sub>	0.03	0.22
<b>Onion</b>	X <sub>19</sub>	0.0028	0.003
<b>Garlic</b>	X <sub>20</sub>	0.00088	0.00088
<b>Gross cropped Area</b>		<b>1.94</b>	<b>1.94</b>

Rice has the second-highest percent area under cultivation of about 0.684 ha in the existing cropping plan but declined to 0.539 ha in the optimized cropping plan. In Kharif season, all crops have observed a decline in their area in cultivation from existing one to optimized one, except for brinjal, which has observed the increase in area under cultivation from 0.094 ha in the existing to 0.276 ha in optimized cropping plan. In Rabi season, a similar pattern has been observed where the area under cultivation has decreased from the existing cropping plan to the optimized cropping plan, except for tomato. The area under cultivation in the tomato has significantly increased from 0.03 ha in the existing to 0.22 ha. In the optimal cropping plan.

In conclusions and Policy implication the study has attempted to develop an optimal cropping plan for enhancing farm income and employment with lesser use of irrigation water using Sen's Multi-Objective Programming (MOP) model. The cropping plan obtained using Sen's MOP has been found suitable for improving the economy of the farming community of the study area.

Based on the results the following recommendations are made:

Cultivation of water-intensive crops (Cauliflower, Cabbage, Capsicum, and chili) should be restricted for judicious use of irrigation water.

The Government should encourage crop diversification (by including less

water-demanding crops) in the region for efficient and sustainable use of groundwater resources and improving the agricultural economy of the region.

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