Int. j. adv. multidisc. res. stud. 2025; 5(6):1760-1764

Received: 07-11-2025
Accepted: 17-12-2025

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Balancing Agriculture Costs and Production Efficiency: A Fuzzy Linear Programming Model for Wheat GW-513

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Abstract
This study introduces a linear programming model aimed at minimizing the costs associated with cultivating the GW-513 wheat variety in Gujarat. The regions differ in soil types, irrigation availability, and topography, influencing wheat production costs. The study proposes a fuzzy linear programming model to optimize wheat GW-513 production, accounting for uncertain parameters such as land availability, crop yield, and population growth rate. The results demonstrate the model's effectiveness in balancing wheat production with population demand, ensuring food security while minimizing waste.

Keywords: Wheat GW-513, Trapezoidal Fuzzy Number, Linear Membership Function, LINGO Solver

1. Introduction
Wheat is one of the most important staple crops in India. Gujarat, with its diverse agroclimatic conditions, is a significant wheat-producing state. While Gujarat is not among the top wheat-producing states, it still contributes significantly to India's total wheat production.
The suitability of land for cultivating GW-513 in Gujarat depends on soil characteristics, water availability, and climate. Fertile black and silty soils with good drainage are ideal for GW-513 cultivation. In regions with low fertility or acidic soils, improvements can be made through soil management, irrigation, and fertilizers. This research aims to use linear programming (LP) to optimize the cultivation costs for GW-513 by considering essential inputs—seed, fertilizer, labour, irrigation, and pesticides—that affect the overall cost of production.

2. Literature Review
Agricultural production systems often involve uncertainty and vagueness, which influence decision-making processes. Kruse and Meyer [1] examined agricultural crop planning in 1987 by employing a stochastic linear programming approach to address variability in crop values. Later, in 1997, Hulsurkar *et al*. [2] applied a fuzzy programming technique to optimize crop planning within multi-objective stochastic linear programming frameworks. Similarly, Lodwick *et al*. (2000) [3] compared fuzzy, stochastic, and deterministic methods for crop planning.
Kaur, Jagdeep, and Amit Kumar [4] (2016) utilized a possibility measure in crop planning to manage uncertainty, treating profit coefficients as discrete random variables. Toyonaga *et al*. [5] (2005) focused on crop planning by incorporating fuzzy random variables for profit coefficients. In 2018, Zhang *et al*. [6] applied a fuzzy mathematical programming approach to agricultural land cultivation, demonstrating its flexibility and ability to yield optimal solutions.
Most recently, BaniHabib *et al*. (2019) [7] developed a fuzzy multi-objective model for optimizing water allocation under uncertainty, showing that optimal policies outperform deterministic models. Wang (2020) [8] studied a fuzzy linear programming model under elastic constraints, obtaining optimal solutions. In 2023, Liu *et al*. [9] analysed crop cultivation in regions with highly variable soil properties, determining that appropriate crop allocation maximizes profits.

3. Linear Programming Model for Computing Optimum Agricultural Cost (LPMCOAC) of the GW – 513:
Meeting the demand for GW-513 wheat is a challenging problem studied for years with high effectiveness. This study uses fuzzy numbers to model uncertain factors affecting cultivation. The model outlines its parameters, decision variables, objective

function, and constraints as detailed below:
x_{ij} = different regions for cultivation of crop to fulfilled the demand,
c_{ij}^{k} = cost of cultivation of crop GW-513 i^{th} region to j^{th} demand, and k is fuzzy number,
a_i = the region available for growing crop GW-513,
b_j = the demand required for each region,
R_i = available region for cultivation of the crop GW-513.
The total cost of assigning wheat GW-513 is the objective function, as shown in Model 1.1. Constraints include balancing demand and availability across regions, and the solution is obtained using trapezoidal fuzzy numbers.

Model 1.1:

$$\text{Minimize } Z_k = [f_1(x), f_2(x), \ldots, f_n(x)], \tag{1}$$

$$f_k(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}^{r} x_{ij}, k = 1,2,\ldots,n \text{ and } r = 1,2,\ldots,n. \tag{2}$$

Subject to the constraints

$$\sum_{j=1}^{n} x_{ij} = a_i \, , i = 1,2,3, \ldots, m \, . \tag{3}$$

$$\sum_{i=1}^{m} x_{ij} = b_j \, , j = 1,2,3, \ldots, n \, . \tag{4}$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j (\text{Balance Condition}) \tag{5}$$

$$x_{ij} \geq 0 \text{ for all } i \text{ and } j \text{ (Positivity Condition)} \tag{6}$$

Using the ranking method of trapezoidal fuzzy number $\tilde{A} = (a, b, c, d)$ based on centroid G of $\tilde{A}$. The co-ordinates of G are $x(\widetilde{A}) = \frac{2a+b+c+2d}{6}$ (7)

4. Fuzzy programming technique-based Solution approach to solve LPMCOAC of the GW – 513:

To solve the model using a fuzzy programming technique, the process begins by solving the model for each individual objective function. For each objective, the positive ideal solution (PIS) and negative ideal solution (NIS) are identified. Next, a membership function, $\mu(Z_k)$, is defined for the k^{th} objective function based on the PIS and NIS values. Exponential membership functions are then applied to determine an efficient solution for this multi-objective land allocation problem. Using this membership function, the initial model is reformulated as follows:

Model 1.2:
Maximum λ,
Subject to the constraints:

$$\lambda \leq \mu(Z_k), k = 1,2,\ldots,n. \tag{8}$$

equation (3) to equation (6).
Utilize Linear membership function

$$\mu(Z_k) = \begin{cases} 1, & \text{if } f_k(x) \leq l_k, \\ \frac{u_k - f_k(x)}{u_k - l_k}, & \text{if } l_k < f_k(x) < u_k, \\ 0, & \text{if } f_k(x) \geq u_k, \end{cases} \text{ where } k = 1,2,\ldots,n. \tag{9}$$

Then model structure is as follows:

Model 1.3:
Maximum λ,
Subject to the constraints:

$$\lambda \leq \frac{(u_k - f_k(x))}{(u_k - l_k)} \text{ where, } k = 1, 2, 3, \ldots, n. \tag{10}$$

equation (3) to equation (6).

5. Steps for Linear Programming Model for Computing Optimum Agricultural Cost (LPMCOAC) of the GW – 513:

In this section, the cost optimization of GW-513 (wheat) is performed using fuzzy numbers, which may take triangular, trapezoidal, or mixed forms, depending on the problem. The optimal solution for the problem with fuzzy numbers is then derived in a crisp form. The step wise description of the proposed model with the following aspects of decision making is as follows:
Step-1: Read all the parameters related to formulate the LPMCOAC of the GW-513.
Step-2: Transform the proposed model into a crisp form.
Step-3: Determine the positive and negative ideal solutions for each objective function.
Step-4: Convert the crisp multi-objective optimization problem into a single-objective optimization problem.
Step-5: Solve the single-objective problem obtained in Step 4 using a linear membership function.
Step-6: If the solution meets the criteria, accept it and conclude.

6. Algorithm for Linear Programming Model for Computing Optimum Agricultural Cost (LPMCOAC) of the GW – 513:

Input: Parameters: $(Z_1, Z_2, \ldots, Z_k, n)$
Output: To find the solution of Proposed Model
Solve Proposed Model ($Z_k \downarrow, X \uparrow$)
begin
read: problem
while problem = Proposed Model do
for k=1 to n do
entre objectivesZ_k,

end
-| the positive ideal solution and negative ideal solution for each objective.
for k=1 to n do

$$z_k^{\text{PIS}} = min(Z_k),$$
$$z_k^{\text{PIS}} = min(Z_k^{a}), z_k^{\text{PIS}} = min(Z_k^{b}), z_k^{\text{PIS}} = min(Z_k^{c}), z_k^{\text{PIS}} = min(Z_k^{d})$$

Subject to the constraint (3) to (6)

end
for k=1 to n do

$$z_k^{\text{NIS}} = max(Z_k),$$
$$z_k^{\text{NIS}} = max(Z_k^{a}), z_k^{\text{NIS}} = max(Z_k^{b}), z_k^{\text{NIS}} = max(Z_k^{c}), z_k^{\text{NIS}} = max(Z_k^{d}),$$

Subject to the constraint (3) to (6)
end

-Define linear membership function for each objective
For k=1 to n do

$$\mu(Z_k) = \begin{cases} 1, & \text{if } f_k(x) \le l_k, \\ \dfrac{u_k - f_k(x)}{u_k - l_k}, & \text{if } l_k < f_k(x) < u_k, \\ 0, & \text{if } f_k(x) \ge u_k, \end{cases}$$

end

-find single objective optimization models under given constraints from multi-objective optimization models
For k=1 to n do

$$max\ \lambda, \lambda \le \frac{(u_k - f_k(x))}{(u_k - l_k)}$$

Subject to constraints (3) to (6)

end
|- find the solution SOPs using Lingo software.

7. Analysis of Linear Programming Model for Computing Optimum Agricultural Cost (LPMCOAC) of the GW – 513:
In year 2023 the total agriculture cost for the wheat GW-513 was approximate Rs. 15 thousand to Rs 140 thousand per hectare. Consider a fuzzy problem where rows represent the different agricultural areas within a specific region, and columns indicate the types of crops cultivated in these areas. Fuzzy numbers for the growing of wheat GW-513 in lakhs hectares are (8, 10, 11, 13), (12, 14, 15, 17), (7, 9, 10, 12), and (13, 15, 16, 18), and the demand for the population in lakhs hectares from the regions are (24, 26, 27, 29), (9, 11, 12, 14), (5, 7, 8, 10), and (2, 4, 5, 7) respectively. Applying the equation (7) the grow of wheat GW-513 for the regions R_1, R_2, R_3, and R_4 are 10.5, 14.5, 9.5, and 15.5 the demand of wheat for the regions R_1, R_2, R_3, and R_4 are 26.5, 11.5, 7.5, and 4.5.

Table 1: Fuzzy Agricultural Production Table with Trapezoidal Fuzzy Numbers

Cost of crop / Region	C_1	C_2	C_3	C_4	Grow (In thousand hectares)
R_1	Very High	Low	Fairly Low	High	10.5
R_2	Extremely Low	Fairly High	Low	Extremely High	14.5
R_3	Medium	Extremely High	Very Low	Extremely Low	9.5
R_4	Low	Very Low	High	Very High	15.5
Demand (In thousand hectares)	26.5	11.5	7.5	4.5	50

As per the available data of the four fields of four regions R_1, R_2, R_3 and R_4 are replaced by linguistic variable as shown in the Table 1. We have following fuzzy agriculture production Table 2.

Table 2: Linguistic variables and fuzzy numbers are used to represent the cost of cultivation.

Linguistic Variables	**Trapezoidal Fuzzy numbers**
Extremely Low	(15, 20, 30, 40)
Very Low	(20, 30, 40, 50)
Low	(30, 50, 60, 80)
Fairy Low	(40, 50, 70, 90)
Medium	(50, 70, 80, 100)
Fairly High	(60, 80, 90, 110)
High	(70, 80, 100, 120)
Very High	(80, 100, 110, 130)
Extremely High	(100, 110, 120, 140)

The linguistic variables are substituted with trapezoidal fuzzy numbers as shown in Table 3.

Table 3: Fuzzy Agricultural Production Table with Trapezoidal Fuzzy Numbers

Cost of crop / Region	C_1	C_2	C_3	C_4	Grow (In thousand hectares)
R_1	(80,100,110, 130)	(30,50,60, 80)	(40,50 70,90)	(70,80,100, 120)	10.5
R_2	(15,20,30, 40)	(60, 80, 90, 110)	(30,50,60,80)	(100,110,120, 140)	14.5
R_3	(50,70,80, 100)	(100,110, 120, 140)	(20,30,40,50)	(15,20,30, 40)	9.5
R_4	(30,50,60, 80)	(20,30,40, 50)	(70,80,100, 120)	(80,100,110, 130)	15.5
Demand (In thousand hectares)	26.5	11.5	7.5	4.5	50

From Table 3 the LPMCOAC of the GW-513 model objective funtion and constraints are as follow:
Objective function:

$$max\ \lambda,$$

$$\lambda \le \left(\frac{U_i - f_i(x)}{U_i - L_i}\right);\ i = 1,2,3\ and\ 4. \tag{11}$$

For $i = 1$

$$\lambda \le \left(\frac{\begin{array}{c}(3245 - (80x_{11} + 30x_{12} + 40x_{13} + 70x_{14} + 15x_{21} + 60x_{22} \\ +30x_{23} + 100x_{24} + 50x_{31} + 100x_{32} + 20x_{33} \\ +15x_{34} + 30x_{41} + 20x_{42} + 70x_{43} + 80x_{44})\end{array}}{3245 - 1155}\right) \tag{12}$$

For $i = 2$

$$\lambda \le \left(\frac{\begin{array}{c}4025 - (100x_{11} + 50x_{12} + 50x_{13} + 80x_{14} + 20x_{21} + 80x_{22} \\ +30x_{23} + 100x_{24} + 70x_{31} + 110x_{32} + 30x_{33} + \\ 20x_{34} + 50x_{41} + 30x_{42} + 80x_{43} + 100x_{44})\end{array}}{4025 - 1760}\right) \tag{13}$$

For $i = 3$

$$\lambda \leq \left(\frac{4645 - \begin{pmatrix} 110x_{11} + 60x_{12} + 70x_{13} + 100x_{14} + 30x_{21} + 90x_{22} \\ +60x_{23} + 120x_{24} + 80x_{31} + 120x_{32} + 40x_{33} \\ +30x_{34} + 60x_{41} + 40x_{42} + 100x_{43} + 110x_{44} \end{pmatrix}}{4645 - 2285} \right) \quad (14)$$

For $i = 4$

$$\lambda \leq \left(\frac{5645 - \begin{pmatrix} 130x_{11} + 80x_{12} + 90x_{13} + 120x_{14} + 40x_{21} + 110x_{22} \\ +80x_{23} + 1400x_{24} + 100x_{31} + 140x_{32} + 50x_{33} \\ +40x_{34} + 80x_{41} + 50x_{42} + 120x_{43} + 130x_{44} \end{pmatrix}}{5645 - 3010} \right) \quad (15)$$

Subject to the constraints:

$$x_{11} + x_{12} + x_{13} + x_{14} \leq 10.5; \quad (16)$$

$$x_{21} + x_{22} + x_{23} + x_{24} \leq 14.5; \quad (17)$$

$$x_{31} + x_{32} + x_{33} + x_{34} \leq 9.5; \quad (18)$$

$$x_{41} + x_{42} + x_{43} + x_{44} \leq 15.5; \quad (19)$$

$$x_{11} + x_{21} + x_{31} + x_{41} \geq 26.5; \quad (20)$$

$$x_{12} + x_{22} + x_{32} + x_{42} \geq 11.5; \quad (21)$$

$$x_{13} + x_{23} + x_{33} + x_{43} \geq 7.5; \quad (22)$$

$$x_{14} + x_{24} + x_{34} + x_{44} \geq 4.5; \quad (23)$$

and positivity condition $x_{ij} \geq 0$ where $i = 1,2 \ldots 4$ and $j = 1,2 \ldots 4$; (24)

Using the LINGO software we have the following Table 4. The value of Z obtained Rs.4127.50 (in thousand) using Lingo 17.0. The output of the above model is shown in below table.

Table 4: Total Cost of Cultivation of crop GW-513

Allocated Cell	f_1	f_2	f_3	f_4
x_{12}	30 x 8=240	50 x 8=400	60 x 8=480	80 x 8=640
x_{13}	40 x 2.5=100	50 x 2.5=125	70 x 2.5=175	90 x 2.5=225
x_{21}	15 x 14.5=217.5	20 x 14.5=290	30 x 14.5=435	40 x 14.5=580
x_{33}	20 x 5=100	30 x5=150	40 x5=200	50 x5=250
x_{34}	15 x 4.5=67.5	20 x 4.5=90	30 x 4.5=135	40 x 4.5=180
x_{41}	30 x 12= 360	50 x 12=600	60 x 12=720	80 x 12=960
x_{42}	20 x 3.5=70	30 x3.5=105	40 x3.5=140	50 x3.5=175
Total cost of cultivation (thousand)	1155	1760	2285	3010

8. Result and Discussion

As shown in Table 4, the most suitable region for the growing crop GW-513 to meet then demand is x_{12}, x_{13}, x_{21}, x_{33}, x_{34}, x_{41}, and x_{42}. Here the farmer can select the cost from the range ₹23,000 to ₹61,000 per hectare approximate for the region x_{12}. Similarly for the region x_{13}, farmer can select cost of cultivation from range ₹100 thousand to ₹225 thousand. For the region x_{21} farmer can select cost of cultivation from range ₹217.5 thousand to ₹580 thousand and for the x_{33} the range per hectare will be ₹10526 to ₹26315.7, for x_{34} the range per hectare will be ₹7105 to ₹14210.5, for x_{41} the range per hectare will be ₹23225.8 to ₹46451.6 for x_{42} the range per hectare will be ₹4516.1 to ₹9333.15. This all-allocated cell suggests that cultivation of crop GW-513 will meet the demand requirement.

9. Conclusion

GW-513 represents a significant breakthrough in modern agriculture by addressing global challenges such as food insecurity, promoting sustainable farming practices, and improving crop resilience. The fuzzy linear programming model optimizes the cost of cultivating GW-513, resulting in an estimated cost of ₹ 4127.50 per hectare. This model provides valuable insights for farmers to optimize their costs for GW-513 as per the region cost varies. It can also applied to other crops as well.

10. Future Work

Future research can apply exponential membership functions to generate multiple solutions for optimizing the cost of cultivating GW-513 or other crops by adjusting shape parameters.

11. References

1. Kruse Rudolf, Klaus Dieter Meyer. Statistics with vague data. Vol. 6. Springer Science & Business Media, 2012.
2. Hulsurkar Suwarna, Mahendra P Biswal, Surabhi B Sinha. Fuzzy programming approach to multi-objective stochastic linear programming problems. Fuzzy Sets and Systems. 1997; 88(2):173-181.
3. Lodwick Weldon, Dave Jamison, Steve Russell. A comparison of fuzzy, stochastic and deterministic methods in linear programming. PeachFuzz 2000. 19th International Conference of the North American Fuzzy Information Processing Society-NAFIPS (Cat. No. 00TH8500). IEEE, 2000.
4. Kaur Jagdeep, Amit Kumar. An introduction to fuzzy linear programming problems. Studies in Fuzziness and Soft Computing. 2016; 340:1-119.
5. Toyonaga Tasuku, Takesh Itoh, Hiroaki Ishii. A crop planning problem with fuzzy random profit coefficients. Fuzzy Optimization and Decision Making. 2005; 4:51-69.
6. Zhang Chenglong, Bernard A Engel, Ping Guo. An interval-based fuzzy chance-constrained irrigation water allocation model with double-sided fuzziness. Agricultural Water Management. 2018; 210:22-31.
7. Banihabib Mohammad Ebrahim, Mahmoud Mohammad Rezapour Tabari, Mohsen Mohammad Rezapour Tabari. Development of a fuzzy multi-objective heuristic model for optimum water allocation. Water Resources Management. 2019; 33(11):3673-3689.
8. Wang Yuping. Application of fuzzy linear programming model in agricultural economic management. Journal of Mathematics. 2022; 1:6089072.

9. Liu Li-Chang, Kang-Cong LV, Yu-Jun Zheng. Crop cultivation planning with fuzzy estimation using water wave optimization. Frontiers in Plant Science. 2023; 14:1139094.