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RESEARCH PAPER

Application of fuzzy goal programming approach in the real-life problem of agriculture sector

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ABSTRACT

Goal: The present study aimed to demonstrate the applicability of the fuzzy goal programming to frame the decision support system for the decision-makers to deal with the real-life problem of the agriculture sector namely the apple cultivation planning problem and to obtain an optimum solution.

Design / Methodology / Approach: The proposed method occurred within the apple-producing sector in the Kashmir valley of India and included the collection of data through interviews and surveys with various farmers. Also, the results were drawn with the help of LINGO 18.0.

Results: The current finding implies that all of the desired objectives have been met, as well as an optimal solution. The proposed model offers a significant approach for designing plans to determine various agricultural activities in a fuzzy decision environment. Finally, the current study conducts a case study in the apple cultivation sector to obtain various competing objectives. Sensitivity analysis was also performed on its preferential weight parameters.

Limitations of the investigation: It should be noted that the parameters related to production cost, transportation cost, and cost of material may change over the years. The selling price may also vary according to the quality of apples and over the years. Because of natural factors, the annual production of apples may also vary.

Practical implication: The current study shows that using fuzzy goal programming techniques in an apple production process has a huge potential to increase farmers' income. It can be concluded that the current study can help decision-makers to deal with real-life planning issues in the agricultural sector. Future research can also take advantage of other initiation strategies.

Originality/Value: The study looks at the applicability of the fuzzy goal programming paradigm in a new field of apple production in the agriculture sector. According to our knowledge, this is the first time the optimization model has been used in the apple cultivation sector.

Keywords: Fuzzy goal programming, Mathematical programming, Conflicting objectives, Agriculture sector, Crop production, Apple production.

Mathematics Subject Classification (2010): 90C29, 90C90, 62A86.

1. INTRODUCTION

India is at the seventh-largest apple-producing country in the world in which Jammu and Kashmir state is producing about 80% share of that quantity and this production is predominantly kept by the Kashmir region. The economy of Jammu and Kashmir gets a boost due to its agriculture sector because Kashmir Valley is famous for its fruits not only in India but throughout the world and leads a positive effect on the livelihood of the rural population. Its fruits gained popularity among people all over the world because of their richness and quality. Apple is the famous fruit of

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Kashmir Valley and its cultivation in the state is fast increasing as having virtual benefit over other crops. This region has a tremendous potential to enhance the maximum production and export of quality apples. The farmers face a lot of problems especially in planning and packaging during the apple production process. As in the apple production environment, various desired goals are to be set, but in different real-world decision-making situations, it may not be easy to reduce all such desired goals into a single objective. With the help of virtuous and suitable production planning, a production sector attains success. Different traditional ways are available to overcome such difficulties but mathematical programming plays an effective and efficient role to tackle these kinds of problems in production planning. In this study, the fuzzy goal programming model is used to encounter these kinds of problems. In the fuzzy goal programming technique, goals fuzziness is much related to the originality of objectives during decision-making situations.

In 1976 Zimmermann given the optimization of fuzzy sets. To gratify the fuzzy objective, a decision in a fuzzy situation with the help of the solution technique of fuzzy mathematical programming is consequently defined as the intersection of those membership functions corresponding to the required fuzzy objectives studied by Zimmermann (1978). Zimmermann (1985) proposed that the optimal decision could be an alternative in such a decision space that can maximize the minimum attainable aspiration levels in decision-making, represented by those corresponding membership functions. This fuzzy goal programming model is expected to outperform the goal programming model because in this method, goals and constraints can be fuzzy or deterministic, as well as the achievement of several objectives simultaneously (Chalam 1994).

The fuzzy goal programming technique is a form of goal programming approach that has been utilized by various decision-makers in the manufacturing industry to uncover various advantages. Belmokaddem et al. (2009) proposed the fuzzy goal programming approach with several important priorities to reduce production and labour force costs with inventory costs and rates of variations in the labour force. Chen et al. (2009) applied the fuzzy goal programming to meet goals such as the total number of machines, floor space engaged by machines, buying cost, and production of a specific part family in the equipment’s purchasing problem of a Flexible Manufacturing Cell (FMC). Modiri et al. (2010) applied linear goal programming in a fuzzy and absolute approach to model the objectives such as: avoiding the shortage or surplus of demand, maximum income, having the normal volume of production, and forming the inventory of a warehouse in the cement industry. Gupta and Bhattacharjee (2012) formulated two new techniques to obtain a solution to the fuzzy goal programming problem by weighting approach. Seneviratne and Daundasekera (2013) studied the Use of the Zimmermann Multi-Objective Fuzzy Linear Programming (MOFLP) model to grow endorsements to maximize rice production in Sri Lanka. Bhargava et al. (2014) formulated a fuzzy goal programming approach in a bakery production factory to maximize the profit, minimize labour time and maximize machine time, and determined the weights of the goals using an analytical hierarchy process. Bhargava et al. (2015) applied the fuzzy goal programming technique to maximize the product capacity, reduce additional finishing costs, maximize profit and certify the manufacturing volume.

Dutta and Kumar (2015) suggested a multi-objective linear fractional inventory model for a multi-item inventory issue with no shortages using the fuzzy goal programming approach. Taghizadeh et al. (2015) expanded the discussion on fuzzy goal programming in the production planning problems and used the TIVARY collective model for the realization of Beta purposes. Mosadegh et al. (2017) formulated fuzzy goal programming in the multi-objective aggregate production planning problem to encounter certain conditions like shortage & inventory, overtime & idle time, manpower level, and currency saving in the planning horizon. Medeiros and Vidor (2018) established the ideal number of pages and the optimal number of advertisements of each size that a magazine should have in order to maximize profit in a publishing firm. Komsiyah et al. (2018) applied the fuzzy goal programming problem to a planning problem in a furniture company to maximize profit, reduce production cost and reduce raw material cost. Mohammadian and Heydari (2019) represented the theory and application of fuzzy goal programming in the determination of optimal cultivation patterns with different goals.

Arani and Sadeghieh (2020) applied fuzzy goal programming to determine the demand and supply variables simultaneously of the dynamic cell formation with an objective to capitalize on profit for firms and maximize the operation rate of machine capacity. Rivaz et al. (2020) developed a fuzzy goal programming approach to multi-objective transportation problems, and they provide numerical examples to demonstrate the applicability and strengths of the proposed model. Silva et al. (2020) optimized hydrogen networks using mathematical programming. Vinsensia et al. (2021) formulated a fuzzy goal programming technique to optimize the production planning system with achieving different objectives simultaneously. Khalifa et al. (2021a) demonstrated a novel approach for tackling quadratic fractional programming problems in a neutrosophic environment. Yu et al.

(2021) set out to develop a novel and unified intuitionistic fuzzy multi-objective linear programming solution for portfolio selection problems. They developed non-membership functions utilizing pessimistic, optimistic, and mixed strategies to improve the standard intuitionistic fuzzy (IF) inequalities and IF theory. Khalifa and Kumar (2022) suggested a fuzzy multi-objective linear fractional programming (FMOLFP) problem and used the goal programming approach to solve it. To cope with the uncertainty of the model parameters, they addressed the left and right probabilistic variables to the proposed model (FMOLFP).

Fuzzy goal programming strategies have been studied in the literature to deal with production planning problems, however, there has been little implementation of this methodology in many domains of agriculture. To illustrate the application of fuzzy goal programming in the agricultural sector, one field of agriculture has been investigated, namely apple cultivation, because there is a conspicuous gap in the adoption of mathematical models in the apple production sector to find optimal solutions. Thus, the purpose of this study is to fulfil this gap and formulate the fuzzy goal programming approach in the apple production sector with a fuzziness nature of goals to obtain a few intended goals such as maximizing the profit, reducing the production cost, utilizing the raw material, optimizing the use of manpower and other important desired goals.

2. MATHEMATICAL FORMULATION AND ANALYSIS

Fuzzy Goal Programming (FGP)

The Fuzzy Goal programming model can be framed as;

Find X $(x_1, x_2, x_3 \dots x_n)$

To satisfy

$$H_k(X) \begin{pmatrix} \gtrsim \\ \cong \\ \lesssim \end{pmatrix} P_k \qquad (2.1)$$

Subject to:

$$CX \begin{pmatrix} \gtrsim \\ \cong \\ \lesssim \end{pmatrix} b, \quad X \geq 0 \qquad (2.2)$$

Where $H_k(X)$ is the kth goal of fuzzy and P_k is the objective level related to $H_k(X)$. These symbols $\gtrsim$, $\cong$ and $\lesssim$ refers to the fuzziness of aspiration level (i.e., approximately greater than or equal to, approximately equal to, and approximately less than or equal to) and CX ($\gtrsim$, $\cong$, $\lesssim$) b reflects a set of constraints in vector notation.

In a fuzzy decision-making situation, the goals are defined by the membership function associated with them which are attained by the definition of tolerable variations of up and down, and the type of membership function is dependent on the kind of goal. The aspiration level of fuzzy goal in equation (2.1) expresses that the decision-maker is satisfied up to a certain tolerance limit if the goal is not fully achieved. A linear membership function $\mu_k(X)$ can be expressed according to Zimmermann (1976, 1978).

For the limitation of this type $\gtrsim$, μ_k will be framed algebraically as follows:

$$\mu_k = \begin{cases} 1 & if\ H_k(X) \geq P_k \\ \dfrac{H_k(X) - L_k}{P_k - L_k} & if\ L_k \leq H_k(X) \leq P_k \\ 0 & if\ H_k(X) \leq L_k \end{cases} \qquad (2.3)$$

Where L_k is the lower tolerance limit for the fuzzy goal $H_k(X)$.

For the limitation of this type $\lesssim$, μ_k will be framed algebraically as follows:

$$\mu_k = \begin{cases} 1 & if\ H_k(X) \leq P_k \\ \frac{U_k - H_k(X)}{U_k - P_k} & if\ P_k \leq H_k(X) \leq U_k \\ 0 & if\ H_k(X) \geq U_k \end{cases} \qquad (2.4)$$

Where U_k is the upper tolerance limit for the fuzzy goal $H_k(X)$.

For the limitation of this type ≅, μ_k will be framed algebraically as follows:

$$\mu_k = \begin{cases} 1 & if\ H_k(X) = P_k \\ \frac{U_k - H_k(X)}{U_k - P_k} & if\ P_k \leq H_k(X) \leq U_k \\ \frac{H_k(X) - L_k}{P_k - L_k} & if\ L_k \leq H_k(X) \leq P_k \\ 0 & if\ H_k(X) \geq U_k \\ & if\ H_k(X) \leq L_k \end{cases} \quad (2.5)$$

The membership function form of equations (2.3), (2.4), and (2.5) can be drawn as in Figure 1.

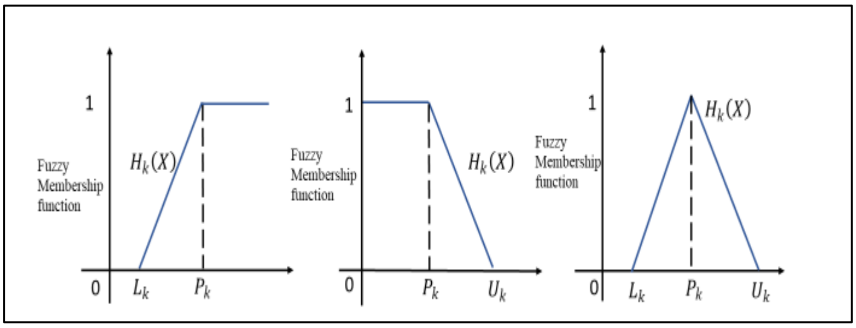

Figure 1. Membership function form

By adding the membership functions (2.3, 2.4, 2.5) together with the fuzzy goal programming problem (2.1) the additive model can be framed as:

Maximize:

$$Z(\mu) = \sum_{k=1}^{m} f_k \mu_k$$

Subject to:

$$\mu_k = \frac{H_k(X) - L_k}{P_k - L_k}, \mu_k = \frac{U_k - H_k(X)}{U_k - P_k}$$
$$CX \leq b$$
$$\mu_k \leq 1$$

$X, \mu_k \geq 0, k = 1,2,3 \ldots m,$

where $Z(\mu)$ is fuzzy decision function or fuzzy achievement function and f_k represents preferential weight.

3. FORMULATION OF THE PROBLEM

To show the applicability and mathematical validation of the proposed technique in the apple production environment a production planning problem was exemplified and the small size apple orchard in the Kashmir region (India) was taken as a case study. To acquire statistics, several apple farmers were surveyed and interviewed. In this study, one hector of land was considered, which would produce at an average of 41200kg apples of different varieties. The decision-maker needs a flawless strategy to maximize profit, cut labour expenses, utilize all apple varieties, and reduce production costs with available resources. The production cost, transport cost, cost of material, and selling price may vary from year to year (2019) and according to the quality of apples and this is a limitation to the current research work. This study also considered the average initial production cost, transport cost (from Kashmir to Delhi), final selling price, cost of material, and labour time per kilogram of apples. The outline of the data set is given in Table 1, Table 2, Table 3, Table 4 and Table5.

This section formulates the fuzzy goal programming problem and presents conclusions, which are given in the following steps:

Step 1: Consider the real-life production planning problem of the agriculture sector and choose one area namely apple cultivation.

Step 2: Select the mathematical model (Fuzzy Goal Programming) to tackle this planning problem represented as.

Maximize:

$$Z(\mu) = \sum_{k=1}^{m} \text{f}_k \upmu_k$$

Subject to:

$$\mu_k = \frac{H_k(X) - L_k}{P_k - L_k}, \mu_k = \frac{U_k - H_k(X)}{U_k - P_k}$$
$$CX \leq b$$
$$\mu_k \leq 1$$

$X, \mu_k \geq 0, k = 1,2,3 \ldots m$, f_k represents preferential weight.

Step 3: Collection of data accordingly by interviewing and surveying different farmers.
Step 4: Data formulation and sequential layout.
Step 5: Choose the limitation of the desired goals set by the decision-maker.
Step 6: Convert the data in tabular form to a fuzzy goal programming problem.
Step 7: Draw the results with the help of LINGO 18.0 computer software.
Step 8: Check the optimality of the solution, if not achieved go to step 5 and choose the limitation of desired goals wisely and if the solution is optimal then go to step 9.
Step 9: Stop.
Figure 2 depicts a flow chart of these (1 - 9) steps.

Table 1 - The initial production cost, packing & transport cost, selling price, commission cost, and profit per kilogram of apples (Indian Rs)

Variety	Variable Notation	Production Cost (Fertilizers / Pesticides / Labour / Irrigation)	Packing Cost & Transport Cost	Selling Price	Commission Cost 8% per kg	Total Cost	Profit
Red Delicious	x_1	12.36	10.43	53.125	4.25	27.04	26.085
Kullu Delicious	x_2	12.36	11.36	55	4.4	28.12	26.88
American	x_3	12.36	10.34	51.562	4.125	26.825	24.737
Ambri	x_4	12.36	10.66	47.058	3.764	26.784	20.274
Maharaji	x_5	12.36	11	46.31	3.704	27.064	19.246
Treal	x_6	12.36	8	44	3.52	23.88	20.12

Table 2 - The required material for packaging apples per box

Variety	Kg/Box (Approx.)	Wooden Box (unit)	Cardboard Box (unit)	Small Cardboard Box (unit)	Wrapping Paper (grams)	Tape (meters)	Paddy Straw (grams)	Nails (grams)
x_1	16	0.00	1.00	0.00	85.00	2.00	900	0.00
x_2	18	1.00	0.00	00.00	110.00	0.00	1100	2.30
x_3	16	0.00	1.00	0.00	85	2.00	900	0.00
x_4	17	1.00	0.00	0.00	110.00	0.00	1100	2.30
x_5	19	1.00	0.00	0.00	110.00	0.00	1100	2.30
x_6	7.5	0.00	0.00	1.00	45.00	1.50	450	0.00

Table 3 - The contributed required material by each kg of apples in the box, obtained from table 2

	Variety					
	x_1	x_2	x_3	x_4	x_5	x_6
Wrapping Paper (gram)	5.312	6.111	5.312	6.470	5.789	6.000
Tape (meter)	0.125	0.000	0.125	0.000	0.000	0.200
Paddy Straw (gram)	56.250	61.111	56.250	64.705	57.894	60.000
Nails (gram)	0.000	0.127	0.000	0.135	0.121	0.000

Table 4 - The total available material

	Wooden Boxes (unit)	Cardboard Boxes (unit)	Small Cardboard Boxes (unit)	Wrapping Paper (gram)	Tape (meter)	Paddy Straw (gram)	Nails (gram)
Total	800	1600	200	233000	3500	2440000	1840

Table 5 -The required labour time while packing apples

Variety →	x_1	x_2	x_3	x_4	x_5	x_6
Labour Time per kg (minutes)	0.890	0.900	0.880	0.732	0.815	0.870

The decision-maker wants to achieve the following goals:

Goal 1: Attain a satisfactory profit level of 1030000 Rs from all varieties of apples with their available resources.

Goal 2: Minimize the total costs and do not want to utilize over 1107500 Rs.

Goal 3: Minimize labour overtime during packing of apples and do not want to use more than 36000 minutes.

Goal 4: Ensure that at least 14400 kg of Red Delicious apples should utilize.

Goal 5: Ensure that at least 10800 kg of Kullu Delicious apples should utilize.

Goal 6: Ensure that at least 11200 kg of American apples should utilize.

Goal 7: Ensure that at least 1800 kg of Ambri apples should utilize.

Goal 8: Ensure that at least 1900 kg of Maharaji apples should utilize.

Goal 9: Ensure that at least 1500 kg of Treal apples should utilize.

Let the tolerance limit of the above goals be 1020000, 1128000, 36300, 14200, 10600, 10900, 1550, 1850 and 1450.

Now the above problem is formulated in fuzzy goal programming (with equal weights) as;

Maximize:

$$Z(\mu) = \sum_{k=1}^{9} \mu_k$$

Subject to:

Goal Constraints:

$$\mu_1 = (26.085x_1 + 26.88x_2 + 24.737x_3 + 20.274x_4 + 19.246x_5 + 20.12x_6 - 1020000)/(1030000 - 1020000)$$

$$\mu_2 = (1128000 - 27.04x_1 - 28.12x_2 - 26.825x_3 - 26.784x_4 - 27.064x_5 - 23.88x_6)/(1128000 - 1107500)$$

$$\mu_3 = (36300 - 0.890x_1 - 0.900x_2 - 0.880x_3 - 0.732x_4 - 0.815x_5 - 0.870x_6)/(36300 - 36000)$$

$$\mu_4 = (x_1 - 14200)/(14400 - 14200)$$

$$\mu_5 = (x_2 - 10600)/(10800 - 10600)$$

$$\mu_6 = (x_3 - 10900)/(11200 - 10900)$$

$$\mu_7 = (x_5 - 1550)/(1800 - 1550)$$

$$\mu_8 = (x_5 - 1850)/(1900 - 1850)$$

$$\mu_9 = (x_5 - 1450)/(1500 - 1450)$$

$\mu_k \leq 1, \ (k = 1,2,3 \dots 9)$

Hard constraints

$$5.312x_1 + 6.111x_2 + 5.312x_3 + 6.470\,x_4 + 5.789x_5 \ + 6.000x_6 \leq 233000$$
$$0.125x_1 + 0.000x_2 + 0.125x_3 + 0.000x_4 + 0.000x_5 + 0.200x_6 \leq 3500$$
$$56.250x_1 + 61.111x_2 + 56.250x_3 + 64.705\,x_4 + 57.894x_5 + 60.000x_6 \leq 2440000$$
$$0.000x_1 + 0.127x_2 + 0.000x_3 + 0.135x_4 + 0.121x_5 + 0.000x_6 \leq 1840,$$
$$0.00x_1 + 0.055x_2 + 0.000x_3 + 0.0.58x_4 + 0.052x_5 + 0.000x_6 \leq 800,$$
$$0.062x_1 + 0.00x_2 + 0.000x_3 + 0.062x_4 + 0.00x_5 + 0.000x_6 \leq 1600,$$
$$0.00x_1 + 0.00x_2 + 0.000x_3 + 0.00x_4 + 0.00x_5 + 0.133x_6 \leq 200,$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0, \qquad \mu_k \geq 0, \qquad (k = 1,2,3 \dots 9)$$

Where, x_1 = Quantity of Red Delicious variety of apples in kilograms; x_2 = Quantity of Kullu Delicious variety of apples in kilograms; x_3 = Quantity of American variety of apples in kilograms; x_4 = Quantity of Ambri variety of apples in kilograms; x_5 = Quantity of Maharaji variety of apples in kilograms; x_6 = Quantity of Treal variety of apples in kilograms.

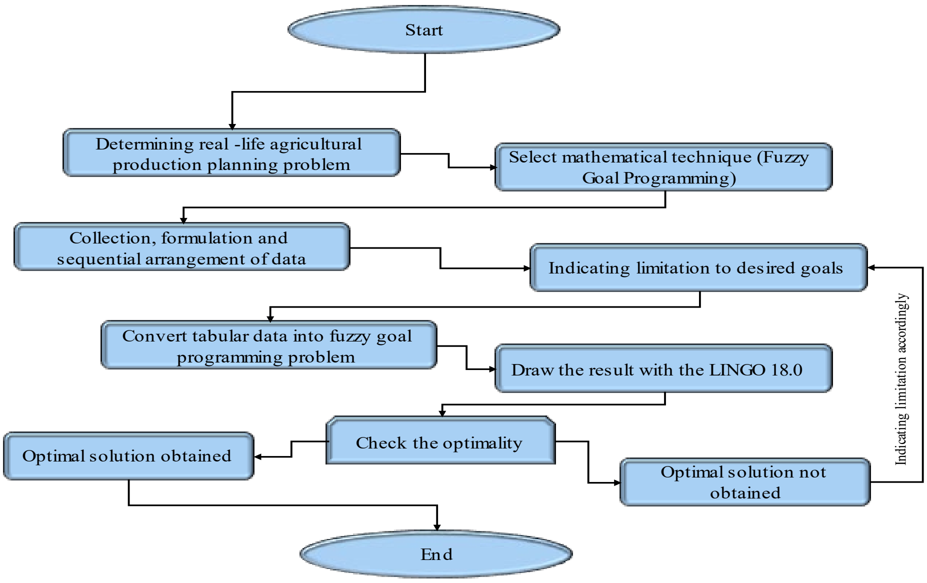

Figure 2 - Flow chart of FGPP presentation

4. RESULTS AND DISCUSSION

The result is drawn with the help of LINGO.18.0 computer software as shown below:

$x_1 = 14311.34, \ x_2 = 10600, \ x_3 = 10900, \ x_4 = 1745.093, \ x_5 = 1900, \ x_6 = 1500$

$\mu_1 = 1.0, \ \mu_2 = 0.8085228, \ \mu_3 = 1.0, \ \mu_4 = 0.5566977, \ \mu_5 = 0.00, \ \mu_6 = 0.00, \ \mu_7 = 0.7803705,$ $\mu_8 = 1.0, \mu_9 = 1.0$

Objective value = 6.145591

Table 6 - Output result of the above-noted fuzzy goal programming problem (FGPP)

Goal	Desired Target	Tolerance Limit	Achieved Value	Satisfied
1	1030000	1020000	1030000	Fully
2	1107500	1128000	1111425.3	Partially
3	36000	36300	36000	Fully
4	14400	14200	14311.34	Partially
5	10800	10600	10600	Partially
6	11200	10900	10900	Partially
7	1800	1550	1745.093	Partially
8	1900	1850	1900	Fully

9	1500	1450	1500	Fully

As evident from the result shown in Table 6 of the formulated fuzzy goal programming problem, in the present study the decision-maker would obtain the optimum solution with some goals being partially met. The farmer earns a profit of 1030000 Rs for 42000kg of apples per hector. Another aspect that is worthy of detailed analysis is the fact that the utilization of apple varieties, utilizing labour time during packaging apples and utilization of production costs are also obtained. Also, the present study focussed on all other important objectives of production planning in addition to maximizing profit and obtaining them at their desired level. The Red Delicious (x_1) apple variety yields the most profit, followed by the Kullu Delicious (x_2) apple variety and the profit share of these apple varieties are illustrated in Figure 3.

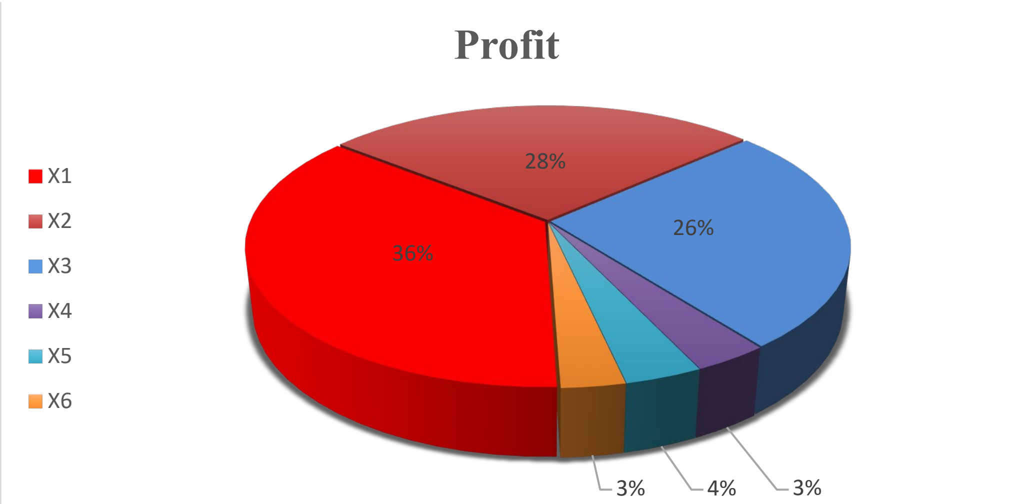

Figure 3 - Profit Share

Furthermore, comparing the results to the linear programming models reveals that the suggested model utilizes all of the varieties of apples. The use of the linear programming model results in the utilization of only three varieties of apples and the utilization amount is out of reach to the decision-maker, as well as the failure to meet several other specified targets, which is not an adequate option for the decision-makers. In light of this, the fuzzy goal programming approach performs better than linear programming.

The sensitivity analysis is used to investigate the influence of preferential weights on a fuzzy goal programming problem, as well as how much the optimal solutions and goal values differ when the preferential weights are modified. The LINGO software was then used to generate the solutions to fuzzy goal programming problems with various preference weights, as shown in Table 7.

Table 7 - Results of sensitivity analysis on preferential weights parameters (f_k)

$\sum_{k=1}^{9} f_k$	Goal 1	Goal 2	Goal 3	Goal 4	Goal 5	Goal 6	Goal 7	Goal 8	Goal 9	Obj. Value
1, 1, 1, 1, 1, 1, 1, 1, 1	1030000	1111425.3	36000	14311.34	10600	10900	1745.093	1900	1500	6.14
0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9	1030000	1111758	36001	14200	10666.6	10900	1800	1900	1500	3.12
0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,0.1	1029980.8	1111723.5	35999.35	14200	10670	10900	1800	1900	1494.55	2.83
0.3,0.4,0.5,0.6,0.7,0.	103	111	360	142	106	109	180	189	150	2.55

8,0.9,0.1,0.2	0000	1715.2	00	00	71.12	00	0	3.72	0	
0.4,0.5,0.6,0.7,0.8,0.9,0.1,0.2,0.3	1030000	1110589	36000	14200	10637.79	11136.24	1550	1900	1500	2.78
0.5,0.6,0.7,0.8,0.9,0.1,0.2,0.3,0.4	1030000	1111425.3	36000	14311.34	10600	10900	1745.09	1900	1500	2.98
0.6,0.7,0.8,0.9,0.1,0.2,0.3,0.4,0.5	1030000	1111425.3	36000	14311.34	10600	10900	1745.093	1900	1500	3.60
0.7,0.8,0.9,0.1,0.2,0.3,0.4,0.5,0.6	1029967.9	1111725.4	36000	14200	10665.44	10900	1800	1900	1500	3.79
0.8,0.9,0.1,0.2,0.3,0.4,0.5,0.6,0.7	1029999.9	1111758.9	36001	14200	10666.63	10900	1800	1900	1500	3.51
0.9,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8	1029999.9	1111758.9	36001	14200	10666.63	10900	1800	1900	1500	3.41

To summarise, the current findings show that fuzzy goal programming provides decision-makers with an acceptable and effective approach for dealing with production planning problems in their agricultural domains. In addition, future research might be expanded to neutrosophic type characteristics to address these production planning problems. Using the indeterminacy degree, the neutrosophic set theory allows for the determination of unknown information in the proposed model, potentially assisting decision-makers in making better judgments (Khalifa et al., 2021b).

5. CONCLUSION

The current study, based on the case study, shows that there is a huge potential to increase farmers' revenue with a fuzzy goal programming approach in an apple production process. The suggested model provides a method for determining the various agricultural operations in a fuzzy decision environment. So, by incorporating all of the desired objectives into the suggested model at the same time, it has been demonstrated that the proposed technique improves cropping planning design in the apple production (agricultural sector), which has previously been lacking. As a result, it offers the decision-maker a plausible and appropriate solution. Thus, the current findings provide a feasible paradigm for farmers to address various agricultural production planning challenges. Many additional researchers and production decision-makers who are interested in dealing with multi-objective challenges in their production sectors are likely to be piqued by the current research.

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