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Research Article

Multi-objective Optimization of Production Using Simplex, Goal Programming, and Pareto Front Models

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Abstract

Farmers are the essential actor in the productivity chain. However, they can also be the weakest ones. In Indonesia, the distribution chain is mostly a long process that impacts farmers, collectors, wholesalers, retailers, and consumers. An ideal distribution chain needs an optimization model involving good decision-making from governments in planning, production, warehouse, and transportation. Simulation-based optimization aims to provide adequate consumer stock, increase farmers' profits, and minimize production costs. The proposed framework integrated three methods of Optimization Simplex using POM QM, Optimization Goal Programming using POM QM, and Pareto Front using Phyton. This research focuses on optimization using the simplex method to fulfill the objective function with a maximum limit of more than one variable. The parameters are market demand, stock, harvest season, and price. Re-optimization using goal programming is also used to minimize the deviation for the goal function and Pareto front. An optimization model or Multi-Objective Optimization is the solution for multiple problems using linear programming. This method is the development from the previous research purposed at finding the answer to the product optimization problem by cutting the distribution transaction into four; farmers sell products to KUD (Cooperatives Village Unit), KUD holds buying and selling process between farmers, farmers, and distributors sell products to KUD, and consumers purchase the product from KUD. The research shows the optimization results of the average price are up to 8913060, and the middle market hole is up to 17741000.

Keywords: Optimization production; Multi-objective; Simplex; Pareto front; Goal programming.

1. Introduction

Farmers are essential actors in the productivity chain. However, they can also as the weakest actor due to unsuccessful sales, unreasonable prices depending on traders and intermediaries, long trading chains, unfair margin distribution, lack of information, and inadequate market access. An alternative market of a short trading chain is needed to create a solid and rooted farmer organization. (Perberasan et al., no date) (Purnomo et al., no date)b (Daud et al., no date) (Susanawati et al., 2021) It requires distribution control for product availability. Indonesia's agricultural products chain currently involves distributors, farmers, small collectors, huge collectors, wholesalers, sellers in traditional markets, retail traders in conventional markets, and consumers. The long chain creates a low price for farmers and a high price for consumers. A new production optimization method determines how many products farmers must produce based on the distribution chain.

Related research on this topic (Peng, Economics, and 2019 n.d.) optimized agricultural supply chains from the government's subsidized contracts to deal with the uncertainty of yields, suppliers, and distributors by involving three contract chains: farmers, suppliers, and distributors. The price is determined by distributors who buy products from farmers at wholesale prices. A supply chain design planning product using a decision-making method (Mohammed, Economics, and 2017 n.d.) can minimize the cost of a layered chain, including inventory and transportation costs, to reduce inventory uncertainty. A multi-agent system based on a supply chain management model can be used to choose the best decision design in planning a dynamic distribution supply chain of uncertain parameters.(Sadeghi et al. 2014)("Investigating Organizational Readiness for Implementation... - Google Scholar" n.d.) Optimizing the food supply chain is aimed at deciding the best supplier and parameters quality of each production level. To maximize the expected profit, the MDP Model supply chain, for a decision based on a not easily recognized market condition factor, can be used as a recommendation for the supply chain. (Kappelman, Research, and 2021 n.d.) Another way of optimizing production and distribution separately is already done (Putri, and, and 2020 n.d.) (Esmaeilikia et al. 2016) , but this approach limits the possibility of increasing profit. The use of architecture using Hyperledger Blockchain Technology supports the development of a new supply chain optimization system.(Arif et al. n.d.) The agricultural supply chain optimization strategy from government subsidies increases production results. (Peng, Economics, and 2019 n.d.) Integrated production and customers demand optimization can minimize order uncertainty using linear programming. (Aouam, Research, and 2013 n.d.) At the same time, the impact of agricultural

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coordination can increase farmer profits using agent-based model coordination ("Impacts of Farmer Coordination Decisions on Food... - Google Scholar" n.d.) by integrating production planning problem solving and collaborative distribution in supply chain systems. (Gokilakrishnan, …, and 2021 n.d.)

Result production optimization is done to integrate production and distribution planning with different approaches to Supply Chain Management to maximize net profits using optimization and heuristics methods as well as a mixed-integer model.(Patil et al. 2021)The integrated model-based of production planning and order acceptance decision is classified based on the satisfactory, marginal income class of the customers class by providing several options to avoid waiting production times using Linear Programming (LP) method to make it easy to get the optimum value of the linear goal function under constraint conditions and Robust Optimization.(Aouam, Research, and 2013 n.d.)

This article develops on previous research since several related journals have not been completed using optimization methods in optimizing agricultural production.(Thakur, Wang, and Hurburgh, 2010), (Jain, Ramesh, and Bhattacharya, 2021), (Sarker and Ray, 2009), (Margolis et al., 2018), Aouam, Research, and 2013 n.d and 2021 n.d., Gokilakrishnan, …, and 2021 n.d, Ishigaki, Management, and 2016 n.d., (Davtalab-Olyaie, Operational, and 2021). The simplex method can be used to fulfill market demand and production and manages time for planting and harvesting. Programming objectives can minimize grouping from each plan with the right priority level from existing constraints. The constraint inequalities are added to the equation of production maximization to solve linear programming problems. The weighted sum method combines all objectives to maximize production into an objective function in which every objective function is weighted and given Pareto front.The simplex often produces multi-purpose problems that needs the optimization method to maximize farmer production.

2. Problem Statement

This research aims to propose, simulate, collaborate, and develop smart agriculture by optimizing production results resulting from distribution chain cuts so that farmers can maximize their production based on market demand and price using the simplex method. The multi-problem decision or Multi-Objective Optimization with fulfilled stock output based on customer's demand and price using linear programming is developed from previous research.(Ishigaki, Management, and 2016 n.d.)A goal programming method to minimize deviations from specific goals (Davtalab-Olyaie, Operational, and 2021 n.d.) by considering priority hierarchy and Pareto front optimization method as the optimum solution to get the solution of problems with optimum goals by cutting the distribution chain from six to four chains, namely farmers, KUD (Cooperatives Village Unit), distributors and consumers, using consumer need/demand, farmers and KUD production/stock, price, season, and planting time as the parameter of variables.

Table 1
Related Work on Multi-objective optimization of production

References	Topic	Method
(Thakur, Wang and Hurburgh, 2010)	minimizing traceability effort by minimizing the food safety risk	Multi-objective optimization
(Jain, Ramesh and Bhattacharya, 2021)	crop pattern optimization in agriculture	Combining crov algorithm (CSA particle swarm optimization (PS
(Sarker and Ray, 2009	An improved evolutionary algorithm	multi-objective and non-linear
(Margolis *et al.*, 2018)	A multi-objective optimization model for designing resilient supply chain networks	multi-objective network design and accompanyi optimization-ba decision suppor
Aouam, Research, and 2013 n.d	Integrated Production Planning and Order Acceptance	A Robust Optim Approach.
Gokilakrishnan, …, ar 2021 n.d	Production Distribution Planning Models	Supply chain
Ishigaki, Managemen and 2016 n.d.	Two-Objective Optimizatic Supply Chain Network	Simplex Methoc
Davtalab-Olyaie, Operational, and 2021	Pareto	Optimality in th Cross-Efficiency Evalı

3. Multi-objective Optimization Modeling

Production activities optimization means that producers always make optimum decisions, covering input-output, input-input, and output-output, to company optimization. An optimum decision is related to product quantity and price that brings maximum profit, or the loss must be minimized if it is a loss. (Gavidia-Calderon et al. n.d.)

To solve the optimization problem, a model is built. Modelling means describing the problem with various mathematical abilities and relationships to simulate the optimization problem and to develop a mathematical model of the optimization problem (Sohrabi and Azgomi 2020). Research on minimizing total chain cost (Sadeghi et al. 2014) minimized uncertain stock using a multi-agent-based supply chain management model.(Jabeur et al. n.d.)Optimizing the food supply chain is used in deciding supplier selection.(Kappelman, Research, and 2021 n.d.) Supply chain design using suitable decision-making methods of Multi-objective optimization (MOO) and pareto fronts on supply chain management by using the pareto front optimization method as a goal.(Mohammed, Economics, and 2017 n.d.)

To develop a mathematical optimization problem model, these four components must be fully characterized (Sohrabi and Azgomi 2020):

1. The set of optimization variables x_1, x_2…, x_n.
2. The objective function f(x) applies to the optimization variables and returns an actual value. This objective function must be

minimized or maximized (optimized) during the optimization process.

3. The optimization variables should adhere to equivalence or non-equality constraints.
4. Domain sets $D_1, D_2, \ldots, D_n$ as the domain of optimization variables $x_1, x_2, \ldots, x_n$.

Most optimization problems can be fully explained by specifying the four components. It is also possible that the optimization problem has no constraint or that the optimization variable domain is the entire space (Sohrabi and Azgomi 2020)

The optimization problem is divided into two, with constraints and without constraints. On optimization with restrictions, the constraint factors of the objective function are essential in determining the objective function's maximum or minimum points. Meanwhile, on the optimization without restrictions, the constraints factors or the limitations of the objective function are ignored, so there is no limit to the available choices in determining maximum or minimum value.

Previous studies suggested that it is necessary to integrate supply chain management and optimization to maximize farmers' production. Collaborating and developing smart agriculture by optimizing production results resulting from distribution chain cuts using supply chain management from farmers and consumers is needed to maximize farmers' profit. It uses the simplex method and goal programming using the pareto front method as Aouam's research development about production optimization using linear equations that are developed from Ishigaki's research of production optimization using broad linear equations. (Aouam, Research, and 2013 n.d.)(Ishigaki, Management, and 2016 n.d.)

3.1. Simplex Optimization on Production

The simplex method solves objective functions with more than one constraint with inequality as the constraint. The inequality constraint is added to the equation by adding a primary variable. At the same time, other variables are called non-basic variables, with another variable as a non-basic variable. When a constraint has an equation, the system of the problem is made into a table named simplex table. (Chavan, Engineering and 2019, no date),(Aouam, Research and 2013, no date)The detail of the simplex method is described by showing the numerical steps needed to solve linear programming problems.(EDITION, 2012) The constraints were usually limitations related to maximizing production: consumer demand data, farmers and KUD stock, price, harvest season, and planting season.

Linear programming problems can be found in various fields and can be used to make decisions to choose the most appropriate alternative and the best solution. (Rajak *et al.*, 2022)(*Gunantara, N.(2018).Teknik Optimasi - Google Scholar*, no date)

$$Z = \text{Maximize } C_1 X_1 + ... + C_i X_n \quad (1)$$

Constraints are barriers that must be fulfilled. The equation for constraint function of simplex method is written using equation:

$$a_{ij} X_1 + a\,(i+1)\,(j+1)\, X_2 + ... + a(i+n)(j+n)\, X_n \leq b_n \quad (2)$$

The simplex method is aimed at reaching two goals, namely:

1. Optimizing farmers profit based on average agricultural prices

$$Z = \text{Maximize} \sum \overline{V_1\, X_1} + \sum \overline{V_1 X_2} \quad (3)$$

$$\text{Constraint Function : } X_1 + X_2 \leq V_2 \quad (4)$$

$$4V3_1 + 3V3_2 \leq V_2 \quad (5)$$

2. Optimizing farmers profit based on average consumer demand

$$Z = \text{Maximize} \sum \overline{V6\, X_1} + \sum \overline{V6 X_2} \quad (6)$$

$$\text{Constraint Function: } X_1 + X_2 \leq V_4 \quad (7)$$

$$4X_1 + 5X_2 \leq V_4 \quad (8)$$

This study uses a dataset of price, stock, and market demand using Chili Data from the Indonesian Ministry of Agriculture from January 2021 to May 2021. The resulting output is optimized with the second goal of maximizing the farmer's profit based on total production, estimated consumer demand, and planting time.

Table 2
Optimization Variables

Term	**Description**
X_1	Big chili
X_2	Cayenne pepper
V_1	Average price
V_2	Consumer demand
V_3	Harvest season in 1 year
V_4	Average consumer demand
V_5	Time from planting to harvesting in 1 year
V_6	Average demand for consumers
w_1	Farmers profit decision weighting
w_2	Remaining stock decision weighting on demand

3.2. Goal Programming on Production

Goal Programming is done to minimize plan deviations from each goal. Its objective function is expressed as minimizing deviations from the goal achievement function. (Selim *et al.*, no date)

$$\text{Min } Z = p_1\, d_1^- d_1^+,\ p_2\, d_2^- d_2^+,\ p_3\, d_3^- d_3^+,\ p_4\, d_4^- d_4^+ \quad (9)$$

With Function:

Table 3
Terms of Production Optimization Function in Goal Programming

Term	Description
P_1	Target production result, to be used based on consumer demand
P_2	Target production result, to be used based on planting time
P_3	Target production result, to be used based on harvest season
P_4	Target production result, to be used based on price
X_1	Amount of request in January
X_2	Amount of request in February
X_3	Amount of request in March
X_4	Amount of request in April
X_5	Amount of request in May
X_6	Price in January
X_7	Price in February
X_8	Price in March
X_9	Price in April
X_{10}	Price in May
X_{11} X_{12}	Planting time
X_{13} X_{14}	Harvest season
α_{11} , α_{12},..... α_{1n}	Big chili production capacity
α_{21} , α_{22},..... α_{2n}	Cayenne pepper production capacity
d_1^-	Amount of production, to be used based on consumer demand which is set below target
d_1^+	Amount of production, to be used based on consumer demand which is set above target
d_2^-	Amount of production, to be used based on planting time which is set below target
d_2^+	Amount of production, to be used based on planting time which is set above target
d_3^-	Amount of production, to be used based on harvest season which is set below target
d_3^+	Amount of production, to be used based on harvest season which is set above target
d_4^-	Amount of production, to be used based on price which is set below target
d_4^+	Amount of production, to be used based on price which is set above target

Goal Programming and Definition:
Goal 1: minimize constraints on production based on consumer demand, price, season, and planting time on big chili.
Goal 2: minimize constraints on production based on consumer demand, price, season, and planting time on cayenne pepper.

3.3. Pareto front on production

An optimization method facilitates the decision-making of multiple problems or MOO. Pareto Front Method is needed to optimize the optimization method since the simplex method resulted in a MOO problem. The development of the Pareto front resulted in the Weighted-Sum Method, a combination of all goals of maximizing production into a single objective function in which each objective function is weighted and then added (+) with an efficient set obtained from parametric variations of the weights. e.g., problem maximizing production with q as the goal that must be maximized:

$$\text{Max } w_1 z_1(x) + w_2 z_2(x) + \dots\dots\dots + w_q z_q(x) \qquad (10)$$

$$\text{subject to: } x \in f$$

$$w \geq 0$$

The values of z1 and z2 are two objective functions obtained from z1 average price and z2 average consumer demand.The parametric linear programming model is:

$$\text{Max } w_1 (34.821x_1 + 34.361\, x_2) +$$

$$w_2 (86226\, x_1 + 78850\, x_2) \qquad (11)$$

$$\text{subject to: } x \in f$$

$$w_1 , w_2 \geq 0$$

Multi-Objective Optimization problems are often solved by combining several objectives into a single objective scalar function. The simplest and most common approach of the weighted-sum or scalarization method (*Multiobjective optimization and advanced topics.... - Google Scholar*, no date) is defined as:

$$\text{minimize } u(x) = \sum_{i=1}^{q} WiFi\ (x) \qquad (12)$$

$$x \in S$$

W (weighting) is a decision maker's preference for each goal, not stating the importance of each goal. W is a parameter that can be varied systematically to produce an efficient set. This method is in between goal programming. This method works to minimize deviation (Aouni, computation and 2010, no date) by setting: $w_1 + w_2 = 1$ and varying it parametrically to obtain the following in table 4.

Table 4
Weighting Decision

Optimal Point	w_1 (Price)	w_2 (Consumer Demand)
a	0,1 – 0,4	0,6 – 1.0
b	0,1 – 0,4	0,6 – 1.0
c	0,1 – 0,4	0,6 – 1.0

4. Methods

The optimization design model application uses a supply chain management system in which every part of the physical flow is involved in a single supply chain. Flowchart modelling design shows the production optimization process using the simplex method. The function is to meet consumer needs based on price. The design is shown with a diagram design model that shows farmers' production optimization process using the simplex method, goal programming, and Pareto front. It is shown in Fig.1.

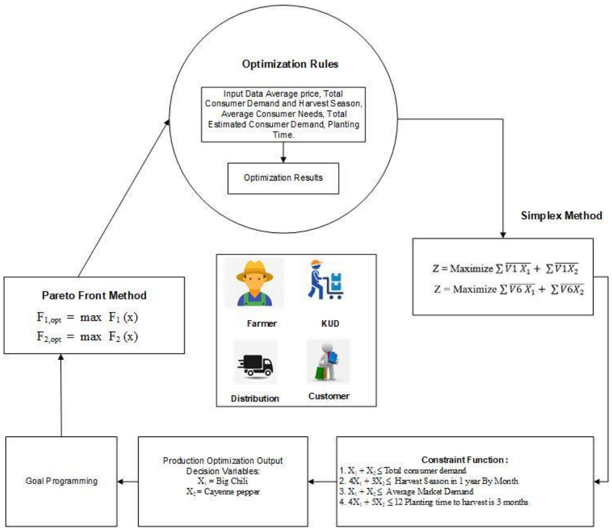

Fig.1. Multi-objective modeling optimization design of production with the novel simplex, goal programming and pareto front

5. Result

5.1.Simplex Optimization Outcomes Based on Market Price and Demand

a. Decision Variable

The expected decision variable of the problem is the optimal amount of product inventory, X_1 = Big Chili and X_2 = Cayenne Pepper.

b. Function Formulation

The objective function to be maximized is farmers' profit. The variable coefficient of the decision variable is based on the average price. The price of big chilli is Rp. 30,227 (kg), and cayenne pepper is Rp. 27,025 (kg). Consumer demand for big chilli is 86226, and cayenne pepper is 78850. The objective function of the linear programming model is maximizing farmer's production based on price and consumers demand, which is formulated as follows

$$Z = \text{Maximize} \sum \overline{X_1} + \sum \overline{X_2} \tag{13}$$

Z_1 = Maximize based on Average Price $\sum 30.227\, X_1 + \sum 27.025\, X_2$

Z_2 = Maximize based on Average Consumer Demand $\sum 86226\, X_1 + \sum 78850\, X_2$

c. Formulation of Constraint Function

The constraint function consists of storage capacity and some requests.

1. Constraint Function Model of Production
   A big chilli and cayenne pepper's total production stock capacity is 864,682 quintals. Constraints can be defined by: $X_1 + X_2 \geq 1040$
2. Constraint Function Model of Harvest Season in 1 year
   Farmers harvest chillies in one year. The number of months is defined in this constraint model as $4X_1 + 3X_2 \geq 1040$
3. Constraint Function Model of Consumer Demand Farmers have a variable amount of demand. To not lose the opportunity to gain profit, farmers must provide the amount of product based on the demand data from big chilli and cayenne pepper data. X_1 (Consumer Demand for big chilli) and X_2 (Consumer Demand for Cayenne Pepper) must not exceed the amount of consumer requests $X_1 + X_2 \geq 823{,}879$
4. Constraint Function Model from Planting Time to Chili Harvest Season for 1 Year Farmers generally harvest chillies about 3 to 4

Times yearly for each crop. It is done to form constraints based on the growing season to the harvest season if, in 1 year, three months once harvested, then four times for big chilli, then $4X_1$ and $5X_2$ for cayenne pepper $4X_1 + 5X_2 \geq 823{,}879$. The multi-objective optimization method modelling with simple technique can be appropriately used for optimization model in maximizing farmer's profit to meet the stocks. The description of the first objective equation in determining the constraints using the simplex method is shown in Table 5 :

Table 5
The Form of Simplex Optimization Problem System at Average Price

	X_1	X_2		RHS	Dual
Maximize	34281	34361			Max 34281 X_1 + 34361 X_2
Constraint 1	1	1	<=	1040	$X_1 + X_2 <= 1040$
Constraint 2	4	5	<=	1040	$4x1 + 5X_2 <= 1040$

The second optimization problem is based on the average consumer demand, the equation that changes the objective function, and the existing constraints using the data of big chili and cayenne pepper for X_1 and X_2. It is shown in Table 6.

Table 6
The Form of Simplex Optimization Problem System at Consumer Demands

	X_1	X_2		RHS	Dual
Maximize	86226	78850			Max 86226 X_1 + 78850 X_2
Constraint 1	1	1	<=	823	$X_1 + X_2 <=823$
Constraint 2	4	5	<=	823	$4X_1 + 5X_2 <= 823$

After the constraints were arranged on the table above, the changes are made to reach the optimal point by interacting three times on the simplex optimization table for the first goal.

Table 7
Simplex Optimization at Average Price

Cj	Basic Variables	Quantity	X_1 (34281)	X_2 (34361)	0 Slack 1	0 Slack 2
Int. 1						
0	Slack 1	1.040	1	1	1	0
0	Slack 2	1.040	4	5	0	1
	Zj	0	0	0	0	0
	Cj-zj		34.281	34.361	0	0
Int. 2						
0	Slack 1	832	0,2	0	1	-0,2
33461	X_2	208	0,8	1	0	0,2
	Zj	7.147.088	27488,8	34361	0	6872,2
	Cj-zj		6.792,2	0	0	-6.872,2
Int. 3						
0	Slack 1	780	0	-0,25	1	-0,25
34281	X_1	260	1	1,25	0	0,25
	Zj	8.913.060	34281	42851,3	0	8570,3
	Cj-zj		0	-8.490,25	0	-8570,25

The next step is improving the table that has been used with the interaction of the objective function until there is no negative value using two iterations.

Table 8
Simplex Optimization at Consumer Demands

Cj	Basic Variables	Quantity	X_1 (86226)	X_2 (78850)	0 Slack 1	0 Slack 2
Int.1						
0	Slack 1	823	1	1	1	0
0	Slack 2	823	4	5	0	1
	Zj	0	0	0	0	0
	Cj-Zj		86.226	78.850	0	0
Int 2						
0	Slack 1	617,25	0	-0,25	1	-0,25
86226	X1	205,75	1	1,25	0	0,25
	Zj	17.741.000	86226	107782,5	0	21556,5
	Cj-zj		0	-28.932,5	0	-21.556,5

The final result from the three interactions is shown in Table 9 If there is no change, the optimum solution for the average price is 8913060. While the optimum solution for consumer demand is 17741000, as shown in Table 10.

Table 9
The Result of Simplex Optimization at Average Price

Variabel	Status	Value
X_1	Basic	260
X_2	Non Basic	0
Slack 1	Basic	780
Slack 2	Non Basic	0
Optimal Value (Z)		8913060

Table 10
The Result of Simplex Optimization at Consumer Demands

Variabel	Status	Value
X_1	Basic	205,75
X_2	Non Basic	0
Slack 1	Basic	617,25
Slack 2	Non Basic	0
Optimal Value (Z)		17741000

$$A'B' = \frac{f\,A(X') - f\,A(X'\prime)}{f\,B(X') - f\,B(X'\prime)} \quad (14)$$

$f\ A(X')$ *and* $f\ B(X')$ are the two objective functions; therefore, the trade-off between Price and total Consumer Demands of A' B'is

$$Z\ A'B' = \frac{53.969 - 16.444}{93{,}284 - 70{,}005} = 37.525 / 23{,}279 = 3.921{,}14$$

1.2. Outcomes pareto front

The efficient variable is the transformation curve that measures the correlation between two objective functions. The slope of the A'B' and B'C' lines reflects the trade-off (opportunity cost) between the two goals. For example, z each chili price/kg resulted in consumers' demand for big chili and cayenne pepper, that is 3,921.14 Rp/kg. The amount of this trade-off should be considered when making decisions. The Pay-off matrix for the two objectives is shown in Table 11 below

Table 11
Pay-off Matrix

	Consumer Demands	Price
Consumer Demands	93,284	53.969
Price	70.555	16.444

The first row is the maximum value of consumer demand (93.284) based on the chili price (Rp. 53,969),The second row is the minimum value of consumer demand (70,555) based on the chili price (Rp. 16,444).

The conflict between the production goals and the price is maximum. Because the production resulted in a high price, and the minimum price resulted in low production. The main diagonal elements of the pay-off matrix are called ideal points (solutions in which all goals reach their optimum value). The ideal points are not feasible if there is a conflict between goals. The opposite of the ideal point is the "anti-ideal" or "nadir point".(Hamta, Ehsanifar and Sarikhani, 2021)(Adisusilo *et al.*, 2020)

The difference between the ideal point and the nadir point is the value range of the goal function. The basic idea of this method is to optimize one of the goals while the other goals are considered "restraints." Efficient variables are obtained by weighting the goals constraints that are considered restraints. For example, problematic mop with the objective function. (Inayati, Integratif and 2020, no date).

Max : z_k (x)

Subject to : x € f

zj (x) lj j = 1, 2, ……., k-1, ……k+1, …., q

z_k (x) : optimized objective

lj : the variable is varied parametrically

For the implementation, the examples of consumers demand as the goal must be optimized. This constraint method resulted in a linear programming below:

Max : $34.821x_1 + 34.361\, x_2$ (price)

Max : $86226\, x_1 + 78850\, x_2$ (consumers demand)

Subject to: x € f (technical problem)

Table 12
Interpretation of efficient variables with extreme points

Coordinate Weight	X_1	X_2	Z_1	Z_2
a	84,209	71,555	2156377.1776	7741870.1904
a	94,583	82,954	2457542.8148	8817861.9948
b	103,06	119,648	3079950.8752	10992417.816
c	115,311	126,022	3338194.5092	11927784.5916
c	105,404	137,245	3354459.2516	11946200.1324

The optimal Pareto fronts sketch in criterion space is the design space for plotting a finite problem. (Soykan and Rabadi, 2022) The optimization result of using the simplex and Pareto front methods from farmers' profits is shown in table 12 and Pareto Front Optimal Diagram using Phyton based and publicly available via github in Fig.2

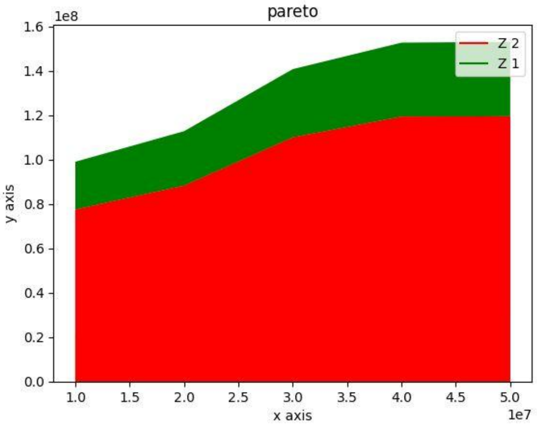

Fig. 2. Pareto Front Optimal Diagram

1.3. Output Goal programming

In a goal programming model, the objective function is formed after determining the priority and sequence in minimizing constraints; for instance (Jones and Tamiz, 2016) :

$x_1 + x_2 \geq 1040$ (total production)
$x_1 + x_2 \geq 823{,}879$ (consumer demand estimation)
$4x_1 + 3x_2 \geq 1040$ (planting time)
$4x_1 + 5x_2 \geq 823$(harvest season)
Minimize $z = p_1\, d_1^- d_1^+,\ p_2\, d_2^- d_2^+,\ p_3\, d_3^- d_3^+,\ p_4\, d_4^- d_4^+$
with objective constraints :
Objective constraint 1 for big chili using variables of demand, production, price, planting time, harvest season in June:

$q_1 = 85\, x_1 + d_1^- - d_1^+ = 84$ g_1
$77\, x_2 + d_2^- - d_2^+ = 94$ g_2
$86\, x_3 + d_3^- - d_3^+ = 103$ g_3
$88\, x_4 + d_4^- - d_4^+ = 115$ g_4
$93\, x_5 + d_5^- - d_5^+ = 105$ g_5
q_2 = rp 53.969 x_6 + rp 51.913 x_7 + rp 32.275 x_8 + rp 19.507 x_9+ rp 16.444 x_{10} + $d_6^- - d_6^+$ = rp 58.036 g_6
$q_3 = 1x_{11} + 1x_{12} = 502$ g_7
$q_4 = 1x_{13} + 1x_{14} = 431$ g_8

Objective constraint 1 for cayenne pepper using variables of demand, production, price, planting time, harvest season in June:

$Q_1 = 77\, X_1 + d_1^- - d_1^+ = 71$ g_1
$70\, X_2 + d_2^- - d_2^+ = 82$ g_2
$77\, X_3 + d_3^- - d_3^+ = 119$ g_3
$81\, X_4 + d_4^- - d_4^+ = 126$ g_4
$86\, X_5 + d_5^- - d_5^+ = 137$ g_5
Q_2 = Rp 52.159 X_6 + Rp 40.863 X_7 + Rp 34.280 X_8 + Rp 25.344 X_9 + Rp 18.800 X_{10} + $d_6^- - d_6^+$ = Rp 58.036 g_6
$Q_3 = 1X_{11} + 1X_{12} = 1040$ g_7
$Q_4 = 1X_{13} + 1X_{14} = 823$ g_8

Non-Negative Constraints:
$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}\ d_1^-, d_1^+, d_2^-, -d_2^+, d_3^-, -d_3^+, d_4^-, -d_4^+, d_5^-, d_5^+ \geq 0$

Decision variables and objective function formulation are determined for parameters that influence decisions on forming a goal programming problem system. Constraints for big chilies are illustrated in Table 13

Table 13
Goal Programming Problems System Forms for Big Chili Constraints

	Wt(d+)	Prty(d+)	Wt(d-)	Prty(d-)	X_1	X_2	X_3	X_4	X_5		RHS
Goal/Cnstrnt 1	1	1	1	1	85	0	0	0	0	=	84
Goal/Cnstrnt 2	1	2	1	2	0	77	0	0	0	=	94
Goal/Cnstrnt 3	1	3	1	3	0	0	86	0	0	=	103
Goal/Cnstrnt 4	1	4	1	4	0	0	0	88	0	=	115
Goal/Cnstrnt 5	1	5	1	5	0	0	0	0	93	=	105
Goal/Cnstrnt 6	1	6	1	6	53969	51913	32275	19507	164333	=	58036
Goal/Cnstrnt 7	1	7	1	7	1	0	0	1	0	=	502
Goal/Cnstrnt 8	1	8	1	8	1	1	1	0	0	=	431

Decision variables and objective function formulation are determined for parameters that influence decisions on forming a goal programming problem system. Constraints for cayenne pepper are illustrated in Table 14

Table 14
Goal Programming Problems System Forms for Cayenne Pepper Constraints

	Wt(d+)	Prty(d+)	Wt(d-)	Prty(d-)	X_1	X_2	X_3	X_4	X_5		RHS
Goal/Cnstrnt 1	1	1	1	1	77	0	0	0	0	=	71
Goal/Cnstrnt 2	1	2	1	2	0	70	0	0	0	=	82
Goal/Cnstrnt 3	1	3	1	3	0	0	77	0	0	=	119
Goal/Cnstrnt 4	1	4	1	4	0	0	0	81	0	=	126
Goal/Cnstrnt 5	1	5	1	5	0	0	0	0	86	=	137
Goal/Cnstrnt 6	1	6	1	6	52519	40863	34280	25344	18800	=	57268
Goal/Cnstrnt 7	1	7	1	7	3	1	1	0	1	=	1040
Goal/Cnstrnt 8	1	8	1	8	1	0	1	0	1	=	823

The absolute goal choosen is the goals that must be fulfilled and determined as priorities that forming accomplishments function for big chili constraints. It is shown in Table 15

Table 15
Goal Programming determines the goal at the proper priority level for Big Chili Constraints

	X_1	X_2	X_3	X_4	X_5	d-1	d-2	d-3	d-4	d-5	d-6	d-7	d-8	d+1	d+2	d+3	d+4
Goal/ Cnstrnt 1	1	0	0	0	0	,01	0	0	0	0	0	0	0	-,01	0	0	0
Goal/ Cnstrnt 2	0	0	0	0	0	634,93	674,19	375,29	0	0	-1	0	0	-634,93	-674,19	-375,29	-221,67
Goal/ Cnstrnt 3	0	0	1	0	0	0	0	,01	0	0	0	0	0	0	0	-,01	
Goal/ Cnstrnt 4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-,01
Goal/ Cnstrnt 5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Goal/ Cnstrnt 6	0	1	0	0	0	0	,01	0	0	0	0	0	0	0	-,01	0	0
Goal/ Cnstrnt 7	0	0	0	0	0	0	0	,01	0	0	0	1	0	0	0	-,01	,01
Goal/ Cnstrnt 8	0	0	0	0	0	-,01	0	-,01	0	0	0	0	1	,01	0	,01	0
Priority8	0	0	0	0	0	-,01	0	-,01	0	0	0	0	0	,01	0	,01	0
Priority7	0	0	0	0	0	0	0	-,01	0	0	0	0	0	0	0	,01	,01
Priority6	0	0	0	0	0	634,93	674,19	375,29	221,67	1767,02	-2	0	0	-634,93	-674,19	-375,29	-221,67
Priority5	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0
Priority4	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	-1
Priority3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0
Priority2	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	-1	0	0

The absolute goal choosen is the goals that must be fulfilled and determined as priorities that forming accomplishments function for cayenne pepper constraints. It is shown in Table 16

Table 16
Goal Programming for Cayenne Pepper Constraints

	X_1	X_2	X_3	X_4	X_5	d-1	d-2	d-3	d-4	d-5	d-6	d-7	d-8	d+1	d+2	d+3	d+4
Goal/Cnstrnt 1	0	0	0	0	0	,01	0	0	0	0	0	0	0	-,01	0	0	0
Goal/Cnstrnt 2	0	0	0	0	0	682,06	583,76	445,19	312,89	218,6	-1	0	0	-682,06	-583,76	-445,19	-312,89
Goal/Cnstrnt 3	0	0	1	0	0	0	0	,01	0	0	0	0	0	0	0	-,01	0
Goal/Cnstrnt 4	0	0	0	1	0	0	0	0	,01	0	0	0	0	0	0	0	-0,1
Goal/Cnstrnt 5	0	0	0	0	0	,01	0	,01	0	,01	0	0	-1	-,01	0	-,01	0
Goal/Cnstrnt 6	0	1	0	0	0	0	,01	0	0	0	0	0	0	0	-,01	0	0
Goal/Cnstrnt 7	0	0	0	0	0	-,02	0	0	,01	-,01	0	1	0	,02	0	0	-,01
Goal/Cnstrnt 8	0	0	0	0	1	0	0	0	0	,01	0	0	0	0	0	0	0
Priority 8	0	0	0	0	0	,01	0	,01	0	,01	0	0	-2	-,01	0	-,01	0
Priority 7	0	0	0	0	0	-,02	0	0	,01	,01	0	0	0	,02	0	0	-0,1
Priority 6	0	0	0	0	0	682,06	583,76	445,19	312,89	218,6	-2	0	0	-682,06	-583,76	-445,19	-312,89
Priority 5	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0
Priority 4	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	-1
Priority 3	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	-1	0
Priority 2	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	-1	0	0

The final result in determining priority is shown in Table 16 if there is no change, it produces a priority solution. Big chilli = $X_1 = 0{,}99$, $X_2 = 1{,}22$, $X_3 = 1{,}2$, $X_4 = 1{,}31$, X_5=1,13. $d_1^- = d_1^+ = d_2^- = d_2^+ = d_3^- = d_3^+ = d_4^- = d_4^+ = d_5^- = d_5^+ = d_6^- = d_7^+ = d_8^+ = 0$. $d_6^+ = 308356{,}7$, $d_7^- = 0{,}48$, $d_8^- = 1{,}81$ and analysis of the beginning goal programming for big chili.

Table 17
Goal Programming Results for Big Chili Constraints.

Item			
Decision Variable Anaysis	Value		
X_1	,99		
X_2	1,22		
X_3	1,2		
X_4	1,31		
X_5	1,13		
Priority Analysis			
Priority 1	0		
Priority 2	0		
Priority 3	0		
Priority 4	0		
Priority 5	0		
Priority 6	308356,7		
Priority 7	505,73		
Priority 8	430,01		
Constraint Analysis	RHS	d+(row i)	d-(row i)
Goal /Cnstrnt 1	84	0	0
Goal /Cnstrnt 2	94	0	0
Goal /Cnstrnt 3	103	0	0
Goal /Cnstrnt 4	115	0	0
Goal /Cnstrnt 5	105	0	0
Goal /Cnstrnt 6	58036	308356,7	0
Goal /Cnstrnt 7	502	0	499,79
Goal /Cnstrnt 8	431	0	30,01

The final result in determining priority for cayenne pepper is shown in Table 18 if there is no change, it produces a priority solution.

Table 18
Goal Programming Results for Cayenne Pepper Constraints

Item			
Decision Variable Anaysis	Value		
X_1	,92		
X_2	1,17		
X_3	1,55		
X_4	1,56		
X_5	1,59		
Priority Analysis			
Priority 1	0		
Priority 2	0		
Priority 3	0		
Priority 4	0		
Priority 5	0		
Priority 6	161377,7		
Priority 7	,87		
Priority 8	,06		
Constraint Analysis	RHS	d+(row i)	d-(row i)
Goal /Cnstrnt 1	71	0	0
Goal /Cnstrnt 2	82	0	0
Goal /Cnstrnt 3	119	0	0
Goal /Cnstrnt 4	126	0	0
Goal /Cnstrnt 5	137	0	0
Goal /Cnstrnt 6	57268	161377,7	0
Goal /Cnstrnt 7	1040	0	1032,92
Goal /Cnstrnt 8	823	0	818,94

6. Discussion

In this study, using chili data, prices were stable, and stock requirements were always met because when harvesting chilies, it could only last 3-5 days, so it could not be stockpiled in warehouses and minimized the risk of chilies rotting. Originality and contribution proposed three optimization methods to solve production optimization problems: Simplex, Goal Programming, and Pareto. The objective function simplex method then needs to be re-optimized using the Pareto method. This is because it has multiple problem decisions or MOO, namely Adequate Consumer Demand Stock and Price Stability, and uses linear programming, which is a development from research. (Ishigaki, Management and 2016, no date)(Davtalab-Olyaie, Operational and 2021, no date) In general, Pareto is the optimal method. One way to find solutions to multi-objective problems where Pareto optimal results can make at least as good and at least better farming The limitation of the problem used for the new method lies in this variable using variable development from(Seren, Scientific and 2019, no date)(Parreño-Marchante, … and 2014, no date) (Soykan and Rabadi, 2022), which will be used to include: Parameters of Consumer Needs / Demand, Parameters of Production/ Stock at Farmers and KUD, Parameters of Price, Parameters of Harvest Season, Parameters of Planting Time.

7. Conclusion

This research contributes a new multi-objective methodology model using the simplex optimization method, goal programming, and Pareto front as optimization solutions for farmers' production within the distribution chain cut. This experiment uses a dataset of price, stock, market demand, planting time, and harvest time from the Indonesian agriculture office. The chili dataset calculation takes the maximum value based on consumer demand with the highest average and average price. The experiment resulted in an efficient deviation variable optimum solution or alternative Pareto front to optimize production with suitable weight based on the relative interest of each goal. Thus, farmers could provide stock based on price and market demand. They can also sell their product at an acceptable price and meet consumer needs. The result of using the simplex method as a solution to constraints in inequalities is added to the equation in solving linear programming problems such as production limitations. The goal programming can minimize deviations from each goal plan with the right priority level on production constraints. The weighted sum method combines all objectives into a single objective function in which each objective function is given a weight and a Pareto front since the simplex method produces multi-objective problems. The big chili: Priority I = Achieved, Priority II = Achieved. The Cayenne Pepper, Priority I = Achieved, Priority II = Achieved. The Simplex Optimization Results: the Average Price is 8913060, and the Average Market Demand is 17741000.

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