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# THE OPTIMIZATION OF PLANTING PATTERN IN FOOD CROPS USING MULTI OBJECTIVE GOAL PROGRAMMING

**Suci Permata Sari**[1], **Rina Filia Sari**[2], **Sri Ulfa Rahayu**[3]

[1,2,3]Department of Mathematics, Universitas Islam Negeri Sumatera Utara, Medan, Indonesia

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**ABSTRACT**

In the agricultural sector, food crops are very important in human life because the results of food crops are basic human needs. This study discusses planting patterns to meet the availability of food crops. Planting patterns are very important to implement because it is to increase food production, so that food remains available and does not lack food needs. The study aims to determine the planting pattern in food crops so that the availability of food crops is met. The method used is Multi objective goal programming. Multi objective goal programming has more than one goal function to be achieved by minimizing deviations from the goal. The research obtained with a land area of 72525 Ha, the number of workers is 1000000, the need for organic fertilizer is 639000 kg/Ha, and the need for urea fertilizer as much as 14000000 kg/Ha can optimize planting patterns by planting types of food crop commodities in the of paddy and green beans.



***Corresponding Author:***
Suci Permata Sari,
Department Of Mathematics,
Universitas Islam Negeri Sumatera Utara Medan
Email: suci0703181068@uinsu.ac.id

## 1. INTRODUCTION

The agricultural sector is a crucial element in the development of a nation, particularly in developing countries like Indonesian. A majority of Indonesians are engaged in farming. Agricultural activities fulfill the needs of the local community by generating employment and supplying food within the country [1].

One of the regions that produce food crops is Deli Serdang Regency. The Deli Serdang Regency is approximately 2,497.72 hectares, with coastal, lowland, and highland regions [2]. This area has many sources of income, including food agriculture, large plantations, smallholder plantations, livestock farming, industry, trade, and inland fisheries The Deli Serdang Regency region features food crops, including Wetland Paddy, which is rice cultivated in paddy fields with a harvest duration of 3 to 3.5 months. Dryland Paddy refers to rice cultivated in fields, gardens, or arid land, with a maturation period of 3 to 3.5 months [1]. Corn (maize) is a carbohydrate-rich food crop, alongside rice and wheat, with a maturation period of two months. Cassava is a tuberous plant rich in carbs and fiber, with a harvest duration of 6 to 8 months. Sweet potatoes are tubers abundant in carbs, vitamins, and minerals, with a maturation time of 3 to 3.5 months. Peanuts are legumes characterized by low carbohydrate content and high levels of protein and fiber, with a maturation period of 3 to 3.5 months. Soybeans are a nutrient-dense legume with a maturation time of 2 to 2.5 months [3]. Green beans are a leguminous crop rich in protein, with a maturation period of 3 to 3.5 months. In this case, several food crops in Deli Serdang Regency are harvested according to their harvest periods, which are around 3-3.5 months, including rice, sweet potatoes, mung beans, and peanuts. The demand for food crops is very important, as their output constitutes a fundamental necessity for humans, consistently enhanced through the optimization of these crops [4] [5].

In mathematical model, optimization is referred to as optimization. Optimization is a method of expressing as mathematical model used to solve problems in the best possible way to achieve optimal results [6], [7] . George Dantzig, an American Statistician, is recognized developing Linear Programming. The mathematical framework describing problems is linear programming. The strategic planning for linear programming to produce the best results. The optimal outcome is attained when the most favorable objectives are realized (employing a mathematical model) [8]. The objective function and the constraint function are two categories of functions recognized in the linear programming framework [9].

In the agricultural sector, especially in food crops, they are very important in human life because the results of food crops are a basic necessity for humans [10] [11]. Almost all areas in Indonesia are planted with food crops. Because of the daily use of food crops, the demand for food crops will always be present [12]. The availability of food crops must be maintained by adjusting the land and the culture of the community to enhance the types of food crops. To ensure the availability of food crops, it can be done through planting patterns [13], [14].

Crop rotation is a farming technique involving the systematic arrangement of plant species on a specific parcel of land over time. The planting pattern is crucial to adopt since it enhances food output, guaranteeing that food availability meets supply demands. This planting method for food crops can optimize yields, decrease labor requirements, and lessen fertilizer usage. This issue can be addressed with multi-objective goal programming. Multi-objective goal programming is an optimization problem that modifies linear programming. Multi-objective goal programming encompasses multiple functions that contribute to the intended result. Multi-objective goal programming (MOGP) is distinct from multi-objective linear programming (MOLP). Multi-objective linear programming is an optimization issue originating from linear programming. Linear programming is inapplicable when a problem presents many objective functions; nonetheless, goal programming is suitable for such scenarios [15].

## 2. RESEARCH METHOD

This research uses a quantitative approach. One of the research methods whose requirements are systematic, organized, and clearly defined from the beginning to the development of the research design is the quantitative method [16]. According to another definition, all types of quantitative research heavily rely on statistics, from data collection to data interpretation to the presentation of results. Thus, it would be very helpful if photos, tables, graphs, or other displays are included when the research has reached its conclusion. According to Sugiyono, quantitative research techniques are positivism-based techniques used to study a specific population or group. The hypothesis that is formulated is tested through random sampling methods, data collection using research instruments, and quantitative and statistical data analysis [17].

## 3. RESULT AND ANALYSIS

### 3.1 Data Collecting

The data sources is food crop commodities, land area, harvest period, labor force, and amount of fertilizer. Data collection on the optimization of planting patterns for food crops aims to maximize the planting patterns of food crop commodities and minimize the use of fertilizers and the number of laborers. In this case, the data required are as follows:

a Data on food crop commodities (rice, peanuts, mung beans, and sweet potatoes) in the Deli Serdang Regency in 2021

b The land area, organic fertilizer, urea fertilizer on food crops in the Deli Serdang Regency in 2021

Table 1: The commodities area on food crops in Deli Serdang Regency 2021 per Ha

| No | Regency The Explanation | The varieties of foods crop | | | |
|---|---|---|---|---|---|
| | | Rice | Peanuts | Sweet potato | Mung beans |
| 1 | Gunung Meriah | 1158.2 | 0 | 0 | 0 |
| 2 | Sinembah Tanjung Muda Hulu | 1095.7 | 0 | 0 | 0 |
| 3 | Sibolangit | 520.9 | 0 | 0 | 0 |
| 4 | Kutalimbaru | 1076.4 | 0 | 0 | 0 |
| 5 | Pancur Batu | 595.9 | 0 | 0 | 0 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 22 | Pagar Merbau | 4636.3 | 0 | 0 | 76.9 |
| **Area** | | 72336 | 3.8 | 45.2 | 140.3 |
| **Total Area** | | 72,525 | | | |

Commodities data of food crop (rice, peanuts, mung beans, and sweet potatoes) in 2021 of table 2

Table 2: Commodities data of foods crop

| No | The Explanation | The varieties of foods crop | | | |
|---|---|---|---|---|---|
| | | Rice | Peanuts | Sweet potato | Mung beans |
| 1 | Processed (days) | 100 | 100 | 100 | 100 |
| 2 | The Labour (people) | 175,000 | 175,000 | 175,000 | 175,000 |
| 3 | Organic Fertilizer (kg/Ha) | 800,000 | 118,000 | 118,000 | 113,000 |
| 4 | Urea Fertilizer (kg/Ha) | 8,000,000 | 2,000,000 | 2,000,000 | 2,000,000 |

## 3.2 Data processing

The data will processed with using multi objective goal programming for optimasize food crop commodities. It can be formulated in multi objective goal programming.

The area:

$$72525X_1 \ + 72525X_2 \ + 72525X_3 \ + 72525X_4 \ + \ {d_1}^- - {d_1}^+ = 72525$$

Growth time:

$$100X_1 \ + 100X_2 \ + 100X_3 \ + 100X_4 \ + \ {d_2}^- - {d_2}^+ = 100$$

The labour:

$$175000X_1 \ + 175000X_2 \ + 175000X_3 \ + 175000X_4 \ + \ {d_3}^- - {d_3}^+ = 1000000$$

Organic fertilizer:

$$300000X_1 \ + 113000X_2 \ + 113000X_3 \ + 113000X_4 \ + \ {d_4}^- - {d_4}^+ = 639000$$

Urea fertilizer:

$$8000000X_1 \ + 2000000X_2 \ + 2000000X_3 \ + 2000000X_4 \ + \ {d_5}^- - {d_5}^+ = 14000000$$

Solving Model:

The solution of multi objective goal programming for optimasize food crop commodities using method simplex.

Model formulation:

Objective function:

Minimize:

$$Z = P_1\left(d_1{}^{+} + d_1{}^{-}\right) + P_2\left(d_2{}^{-}\right) + P_3\left(d_3{}^{-}\right) + P_4\left(d_4{}^{+} + d_4{}^{-}\right) + P_5\left(d_5{}^{+} + d_5{}^{-}\right)$$

Constraint:

$$72525X_1 + 72525X_2 + 72525X_3 + 72525X_4 - (d_1^{+} - d_1^{-}) = 72525$$

$$100X_1 + 100X_2 + 100X_3 + 100X_4 - (d_2^{+} - d_2^{-}) = 100$$

$$175000X_1 + 175000X_2 + 175000X_3 + 175000X_4 - (d_3^{+} - d_3^{-}) = 1000000$$

$$300000X_1 + 113000X_2 + 113000X_3 + 113000X_4 - (d_4^{+} - d_4^{-}) = 639000$$

$$8000000X_1 + 2000000X_2 + 2000000X_3 + 2000000X_4 - (d_5^{+} - d_5^{-}) = 14000000$$

$$X_1, X_2, X_3, X_4, d_1^{+}, d_1^{-}, d_2^{+}, d_2^{-}, d_3^{+}, d_3^{-}, d_4^{+}, d_4^{-}, d_5^{+}, d_5^{-} \geq 0$$

Ttarasi 1. Commodities data of foods crop

| Cj | VS | X1 | X2 | X3 | X4 | The varieties of foods crop | | | | | | | | RHS | Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Z_1$ | $Z_{11}$ | 72525 | 72525 | 72525 | 77525 | X1 | X2 | $d_1^{+}$ | $d_1$ | $d_2$ | $d_1^{+}$ | $d_3^{+}$ | $d_5^{+}$ | | |
| $X_5$ | $X_\iota$ | 0 | 0 | 0 | 0 | 200 | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 72525 | 72525 |
| $X_6$ | $X_\iota$ | 0 | 0 | 0 | 0 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 10 |
| $X_6$ | $X_6$ | 17500 | 17500 | 17500 | 17500 | 1000 | 1005 | 0 | 1 | 1 | 0 | 0 | 0 | 100000 | 91,970 |
| $X_6$ | $X_2$ | 17500 | 17500 | 17500 | 17500 | 1000 | 1005 | 0 | 0 | 0 | 0 | 0 | 0 | 113 | 843,325 |
| $X_6$ | $X_9$ | 839000 | 839000 | 639000 | 839000 | 175000 | 129000 | 0 | 0 | 0 | 0 | 0 | 0 | 639000 | 5,714,286 |
| $X_0$ | $X_{13}$ | 443280 | 643260 | 643260 | 623200 | 623000 | 629000 | 0 | 0 | 0 | 0 | 0 | 0 | 622560 | 5.464868 |
| $Q_1$ | $Q_2$ + | 647438 | 647499 | 647499 | 647725 | 723225 | 725225 | 0 | 0 | 0 | 0 | 0 | 0 | 433000 | 1.75 |
| | | | | | | | | | | | | | | | Belum Optimal |

**Iterasi 1**

Iterasi 1. Commodities data of foods crop

| Cj | VS | X1 | X2 | X3 | X4 | The varieties of foods crop | | | | | | | | RHS | Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Z_1$ | $Z_{11}$ | 72525 | 72525 | 72525 | 72525 | X1 | X2 | $d_1^{+}$ | $d_1^{+}$ | $d_2^{-}$ | $d_4^{-}$ | $d_3^{+}$ | $d_5^{-}$ | | |
| $X_5$ | $X_\iota$ | 1 | 0 | 0 | 0 | 15 | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 72525 | 72525 |
| $X_\iota$ | $X_7$ | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 100 |
| $X_a$ | $X_6$ | 17500 | 12500 | 17500 | 17500 | 175 | 17500 | 0 | 1 | 1 | 0 | 0 | 0 | 100000 | 135.4 |
| $X_6$ | $X_9$ | 17500 | 17500 | 17500 | 17500 | 1 | 12500 | 0.1 | 47 | -48 | 42 | 0 | 0 | 113 | 135,7026 |
| $X_3$ | $X_8$ | 639000 | 639000 | 639000 | 639000 | 113 | 173000 | 0 | 0 | 0 | 0 | 0 | 0 | 639000 | 5,5714286 |
| $X_a$ | $X_9$ | 643500 | 643500 | 643560 | 649600 | 4 | 649500 | 0 | 0 | 0 | 0 | 0 | 0 | 622550 | 5,464368 |
| $Q_4$ | $Q_3$ | 647459 | 647459 | 647459 | 647459 | 3844 | 434888 | 0 | 0 | 0 | 0 | 0 | 0 | 140000 | 1.75 |
| | | | | | | | | | | | | | | | Belum Optimal |

**Iterasi 2**

Iterasi 2. Commodities data of ftods crop

| Cj | VS | X1 | X2 | X3 | X4 | The varieties of foods crop | | | | | | | | RHS | Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Z_\iota$ | $Z_{13}$ | 72525 | 72525 | 72525 | 72525 | X1 | X2 | $d_1^{+}$ | $d_1^{+}$ | $d_2^{+}$ | $d_4^{+}$ | $d_3^{+}$ | $d_5^{-}$ | | |
| $X_5$ | $X_\iota$ | 0 | 0 | 0 | 0 | 175000 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 72525 | 12374336 |
| $X_6$ | $X_6$ | 0 | 0 | 0 | 0 | 175 | 4.250 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 43.750 |
| $X_a$ | $X_6$ | 175000 | 17500 | 17500 | 17500 | 175000 | 113000 | 0 | 1 | 1 | 0 | 0 | 0 | 100000 | 5645.132 |
| $X_6$ | $X_6$ | 175000 | 17500 | 17500 | 17500 | 1.5 | 139730 | 0.1 | 47 | -48 | 42 | 0 | 0 | 113 | 5936,700 |
| $X_5$ | $X_9$ | 839000 | 639000 | 639000 | 699000 | 413 | 129000 | 0 | 0 | 0 | 0 | 0 | 0 | 639000 | 5,576,486 |
| $X_6$ | $X_8$ | 643500 | 645500 | 645500 | 645500 | 8 | 642566 | 0 | 0 | 0 | 0 | 0 | 0 | 623050 | 5,664368 |
| $Q_1$ | $Q_2$ | 647459 | 647459 | 647459 | 647459 | 133800 | 3074358 | 0 | 0 | 0 | 0 | 0 | 0 | 143000 | 1,75 |
| | | | | | | | | | | | | | | | Belum Optimal |

**Iterasi 3**

Iterasi 3. Commodities data of foods crop

| Cj | VS | X1 | X2 | X3 | X4 | The varieties of foods crop | | | | | | | | RHS | Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Z_\iota$ | $Z_{13}$ | 72525 | 72525 | 72525 | 72525 | X1 | X2 | $d_1^{+}$ | $d_1^{+}$ | $d_2^{+}$ | $d_4^{-}$ | $d_4^{+}$ | $d_5^{-}$ | | |
| $X_5$ | $X_7$ | 0 | 1 | 1 | 0 | 1230475 | 885 | 1 | 0 | 0 | 0 | 0 | 0 | 72525 | 12374326 |
| $X_a$ | $X_c$ | 0 | 0 | 0 | 0 | 33.8 | 585 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 32.18 |
| $X_a$ | $X_9$ | 14550 | 1.986 | 1.936 | 113 | 2118,57 | 2115 | 0 | 1 | 1 | 0 | 0 | 0 | 100000 | 5645,132 |
| $X_c$ | $X_a$ | 18500 | 17500 | 17500 | 3 | 40- | 596.8 | 0.1 | 47 | -42 | 41 | 0 | 0 | 113 | 5986,709 |
| $X_5$ | $X_9$ | 639000 | 639000 | 639000 | 639000 | 344.1 | 123008 | 0 | 0 | 0 | 0 | 0 | 0 | 639000 | 5,576,486 |
| $X_c$ | $X_8$ | 643500 | 642900 | 643300 | 643300 | 1 | 643566 | 0 | 0 | 0 | 0 | 0 | 0 | 629950 | 5.454368 |
| $Q_4$ | $Q_2$ | 647459 | 647459 | 647459 | 647459 | 433060 | 3024338 | 0 | 0 | 0 | 0 | 0 | 0 | 140000 | 1,75 |
| | | | | | | | | | | | | | | | Belum Optimal |

**Iterasi 4**

| Cj | VS | X1 | X2 | X3 | X3 | X4 | $d_4^{+}$ | $d_4^{+}$ | $d_3^{-}$ | $d_5^{+}$ | $d_5^{-}$ | $d_3^{+}$ | $d_5^{+}$ | RHS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_3$ | $X_6$ | 1 | 0 | 0 | 0 | 175267 | 1 | 0 | 4.1 | 0 | 0 | 0 | 0 | 14057134 |
| $X_2$ | $X_7$ | 3.3 | 1.9.1 | 3.22 | 5.1 | 89.8 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 201.3 |
| $X_c$ | X4 | 351 | 331 | 0 | 4.1 | 30.1/3 | 12.8 | 1.1 | 1 | 3.1 | 3.7 | 0 | 0 | 2115.064.83 |
| $X_9$ | X1 | 0.0779 | 662.324 | 668.566 | 652.239 | 75245 | 351 | 32- | 5 | 354.0 | 585 | -36 | 365 | 6675596.1083 |
| $Q_1$ | $Q_2$ | 0 | 0 | 0 | 0 | 3.239000 | 1 | 0 | 1 | 3 | 3 | 0 | 0 | Sufah Optimal |

For steps 1 and 2, which VB looking for the identity (1,0 atau 0,1) and $C_{bi}$ given from $C_j$ of the value $C_{bi}$ on VB. Then for value $Z_j$ given from $(C_{bi} \times X_1) + \ldots + (C_{bi} \times d_i{}^{-}), Z_j$ as optimal when the value is optimal is zero ar positive.

If $Z_j$ has the negative value, so $Z_j$ is looking for $C_j - Z_j$, if the is get value $C_j - Z_j$, the determine is the key number which is negatively. Then, key row getting from ratio, ratio of $\frac{RHS}{Angka\ kunci}$ after the given the smallest value.

The method to find the value in one iterartion using the formulation (new value = old value − (key number × new value)). The tabel can be optimal, if the $C_j - Z_j$ there is no negative value , zero ar positive value. The calculation from the fourth iteration get:

$X_1 = 0,428571$

$X_4 = 5,285714$

${d_1}^+ = 341903,6$

${d_1}^- = 0$

${d_2}^+ = 0$

${d_2}^- = -471,4286$

${d_4}^+ = 86857,14$

${d_4}^- = 0$

${d_5}^+ = 0$

${d_5}^- = 0$

${d_3}^+ = 0$

${d_3}^- = 0$

| Decision Variable | Z | |
|---|---|---|
| $X_1 = 0,428571$ | 428289,3114 | |
| $X_4 = 5,285714$ | | |
| Deviasional Variable | Objective | Explanation |
| $d_1^+$ | 341903.6 | Achieved |
| $d_1^-$ | 0 | Achieved |
| $d_2^-$ | -471.4286 | Loss achieved |
| $d_3^-$ | 0 | Achieved |
| $d_4^+$ | 86857.14 | Achieved |
| $d_4^-$ | 0 | Achieved |
| $d_5^+$ | 0 | Achieved |
| $d_5^-$ | 0 | Achieved |

The objective 1 ${d_1}^+ = 341903,6$ the target was achieved because there is no deviation from the target $\leq 72525$

The objective 2 ${d_4}^+ = 86857,14$ the target was achieved because there is no deviation from the target $\leq 639000$

The objective 3 ${d_5}^+ = 0$ the target was achieved because there is no deviation from the target $\leq 14000000$

The objective 4 ${d_2}^- = -471,4286$ the target was no achieved because there is deviation from the target $\geq 100$

The objective 3 ${d_3}^- = 0$ the target was no achieved because there is deviation from the target $\geq 1000000$

The positive deviation values for the first, fourth, and fifth target constraints have been attained based on the deviation variable's value. This indicates that the objective has been accomplished. Simultaneously, the lower for the secondary target constraint remains unfulfilled. The third target is attained at zero, so the objective is accomplished. The positive deviation values for the first, fourth, and fifth target constraints have been attained based on the deviation variable's value. This indicates that the objective has been accomplished. Simultaneously, lower deviation value for the secondary target constraint remains unfulfilled. The third target is attained at zero, so the objective is accomplished.

## 4. CONCLUSION

Analysis of food crop commodities, including mung beans, peanuts, sweet potatoes, and rice, indicates that the optimization of planting patterns in Deli Serdang Regency employs multi-objective programming. This approach utilizes a land area of 72,525 hectares, a harvest duration of 100 days, a labor force of 1,000,000 individuals, an organic fertilizer requirement of 639,000 units, and a urea fertilizer requirement of 14,000,000 units, all corresponding to the same land area of 72,525 hectares. The cultivation system involves planting rice first, which has a harvest duration of 100 days, followed by mung beans. The optimization of planting patterns for food crops is governed by five objective constraints: land area, harvest time, labor, organic fertilizer, and urea fertilizer. Derived from the five objective constraints with a deviation value of zero from the established targets. Sensitivity analysis was performed to identify parameters and ascertain the optimal solution, yielding the result. The distance at which the dual value (shadow price) is applicable is referred to as the sensitivity distance for the constraint quantity value. The fifth target constraint aligns more effectively with the objectives, as its shadow price is zero, in contrast to the first target constraint, which has a shadow price of -1.00000.

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