Optimization of land use of agricultural farms in Sumedang regency by using linear programming models

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Abstract. Land is one of the most important assets for farmers in Sumedang Regency. Therefore, agricultural land should be used optimally. This study aims to obtain the optimal land use composition in order to obtain maximum income. The optimization method used in this research is Linear Programming Models. Based on the results of the analysis, the composition of land use for rice area of 135,314 hectares, corn area of 11,798 hectares, soy area of 2,290 hectares, and peanuts of 2,818 hectares with the value of farmers income of IDR 2,682,020,000,000,-/year. The results of this analysis can be used as a consideration in decisions making about cropping patterns by farmers.

1. Introduction

Land is one of the most important assets for farmers. If a land has a good quality, it will have good potential also for the welfare of the surrounding population. If a land is used for non-agricultural development, it will cause some problems such as food self-sufficiency, environment, and employment. For example, declining agricultural yields, pollution from waste, floods, and increasing unemployment. Also bad for the health of local people, due to the pollution. In West Java, there are several types of land, namely Wetland, Non-Rice Farming Land, and Non-Agricultural Land. The paddy field consists of irrigated rice fields, which are not planted with rice, and while not cultivated. While non irrigated rice field consists of planted with rice, which is not planted with rice, and which temporarily not cultivated. A broad understanding of land is a surface area of the Earth whose characteristics encompass all the identifiers of both a sufficiently steady and predictable nature of the biosphere, atmosphere, soil, geology, hydrology and plant and animal populations, and the results of the activity human beings in the past and the present, as far as the identification marks have an influence over the human use of land in the present and future. [1]

Productive land use is crucial to the productivity of agricultural commodities, especially food crops, as a source of carbohydrates to ensure the food security of people in West Java. Food crops consist of grains and crops. Rice is one of the most important cultivation plants in civilization. Rice production in the world ranks third of all cereals, after maize and wheat. However, rice is a major source of carbohydrates for the majority of the world's population. [2]

A problem will be solved to obtain optimum results in accordance with the given constraints. If the problem is formulated appropriately, it can give the optimum decision variable value. Once the
optimum solution is obtained, the problem is often re-evaluated under different conditions to obtain a new settlement. [3]

Previous research that discusses the optimization of land use linear programming is Bisschop. Discusses a farmer who owns a plot of land and must make a decision about what type of plant to plant in the field. Limitations used are the area of land, the amount of labor comprised of family labor, wage labor, and temporary labor, and also constraints of water limitations. The ultimate goal is to maximize profits.

In this paper discuss about how to formulate optimization model of agricultural land use in order to obtain optimal results.

2. The basic concept of optimization
Optimization is the act of getting the best results under certain circumstances. In the design, construction, and maintenance of engineering systems, engineers must take many technological and managerial decisions at several stages. The ultimate goal of all decisions is to minimize the effort required or to maximize the desired benefits. [4] In everyday life, whether consciously or unconsciously, people always do the optimization to meet their needs. The optimization done by ordinary people is more based on intuition than optimization theory.

Linear programming is a way to solve the problem of allocation of limited resources such as labor, raw materials, machine work hours and the like in the best way possible to obtain optimal results. [5] Linear programming has become the basis of manufacturing decisions, marketing, bank loans, stock quotes, taxi fares, coordination transport, telephone charges, computer access, optimization of land and other practical issues. [6]

The general form of Linear programming model can be described as follows:

Objective function: max/min \[ Z = \sum_{j=1}^{n} C_j x_j \] (1)

Subject to
\[ \sum_{i=1}^{m} a_{ij} x_j \{\leq, =, \geq\} b_j \]
\[ x_j \geq 0 \]

The solution to meet these linear constraints is called a feasible solution. Three elements in linear programming are decision variables, constraints and objective functions.

3. Model of Land Use Optimization
The model of land use optimization is implemented on Sumedang Regency Farm where the parameters are:

3.1. Parameterization
Index
- \( c \) plants / commodities
- \( t \) month
Parameter of the plant
- \( P_c \) plant price [Rp / ton]
Parameter of land
- \( L \) available land area [ha]
- \( L_{ct} \) land area in month \( t \) [ha]
Labor parameters
- \( V \) available labor [people]
$v_c$ labor needed $c$ plant [person]
$V^P$ female labor [person]
$V^L$ male labor [person]
$r^P$ annual wage rate for female labor [Rp / person]
$r^L$ annual wage rate for male labor [Rp / person]
Parameter of fertilizer
$F$ annual amount of fertilizer available [kg]
$f^c$ fertilizer needed for plant $c$ [kg]
$p^F$ fertilizer price [Rp / kg]
Decision Variables
$x_c$ the number of each $c$ plant grown [ha]
$V^P$ number of female workers [people]
$V^L$ number of men [man]
$s_c$ sale from $c$ plant [ton]
$p_c$ the price of each plant $c$ [Rp / ton]

3.2. Numerical Calculation
Sumedang has a land area of 152.220 hectares consisting of rice fields and non-rice fields. While, the data used in the agricultural land use model of Sumedang Regency are as follows:

| Table 1. Planting area (ha) |
|-----------------------------|
| Rice                        | 80.261 |
| Corn                        | 11.798 |
| Soy                         | 2.290  |
| Peanuts                     | 2.818  |
| **Total**                   | **97.167** |

| Table 2. Cropping area (ha) |
|-----------------------------|
| Rice                        | 74.933 |
| Corn                        | 10.207 |
| Soy                         | 2.288  |
| Peanuts                     | 2.915  |
| **Total**                   | **90.343** |

| Table 3. Analysis of Farming. |
|------------------------------|
| Commodity | Result (kg) | Price (Rp/Kg) | Value of Results / Production (Rp) | Total Production Cost (Rp) | Farm Income (Rp) | R/C |
|-----------|-------------|---------------|----------------------------------|---------------------------|----------------|-----|
| Rice      | 5.510       | 4.800         | 26.448.000                      | 16.910.000                | 9.538.000      | 1.56 |
| Corn      | 6.500       | 1.800         | 11.700.000                      | 8.215.000                 | 3.485.000      | 1.42 |
| Soy       | 1.571       | 3.800         | 5.969.800                       | 5.570.000                 | 399.800        | 1.07 |
| Peanuts   | 1.230       | 8.300         | 10.209.000                      | 9.480.000                 | 729.000        | 1.08 |
The purpose of this study is to maximize the profits of farmers for a year, with revenue from sales minus the costs incurred. While the obstacles used in this study are limited land, labor needs, and fertilizer needs.

Based on (1), and referring to [7], the above problem can be formulated as follows:

\[
\text{Maximize} \quad \sum_{c} p_{c} x_{c} - r^{L} V^{L} - r^{P} V^{P} - p^{F} f_{c} x_{c}
\]

subject to

\[
\begin{align*}
\sum_{c} x_{c} & \leq L \\
\sum_{c} l_{c} x_{c} & \leq L \quad \forall t \\
\sum_{c} v_{c} x_{c} & \leq L \left( V^{L} + V^{P} \right) \quad \forall t \\
\sum_{c} f_{c} x_{c} & \leq LF \\
x_{c} & \geq 0 \quad \forall c \\
V^{P} & \geq 0 \\
s_{c} & \geq 0
\end{align*}
\]

Based on data obtained from Dinas Pertanian, Peternakan, dan Perikanan Kabupaten Sumedang in 2016 which has been described above, it can be obtained a formula for Linear Programming optimization model as follows:

Objective function: Max

\[
z = 19128000x_{1} + 6985000x_{2} + 3149800x_{3} + 1459000x_{4}
\]
subject to:

\[
\begin{align*}
x_1 + x_2 + x_3 + x_4 & \leq 152220 \\
x_1 & \geq 80261 \\
x_2 & \geq 11798 \\
x_3 & \geq 2290 \\
x_4 & \geq 2818 \\
225x_1 + 145x_2 + 67x_3 + 292x_4 & \leq 110968380 \\
425x_1 + 300x_2 + 250x_3 + 400x_4 & \leq 209302500 \\
x_1, x_2, x_3, x_4 & \geq 0
\end{align*}
\]

where

- \(x_1\) = Rice land area
- \(x_2\) = Corn land area
- \(x_3\) = Soy land area
- \(x_4\) = Peanuts land area

The optimal solution of equation (3) is obtained by using the simplex table to arrange the equations in a table, the simplex table. The initial simplex table for this problem is as follows:

| VB | \(z\)   | \(x_1\) | \(x_2\) | \(x_3\) | \(x_4\) | \(s_1\) | \(s_2\) | \(s_3\) | \(s_4\) | \(s_5\) | \(s_6\) | \(s_7\) | NK     |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| \(z\) |  1   | -      | -      | -      | -      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0     |
|     | 19128000 | 6985000 | 3149800 | 1459000 |        | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0     |
| \(s_1\) |  0   |  1    |  1    |  1    |  1    |  0    |  0    |  0    |  0    |  0    |  0    |  0    |  0     |
| \(s_2\) |  0   |  1    |  0    |  0    |  0    |  0    |  1    |  0    |  0    |  0    |  0    |  0    |  0    |
| \(s_3\) |  0   |  0    |  1    |  0    |  0    |  0    |  0    |  1    |  0    |  0    |  0    |  0    |  0    |
| \(s_4\) |  0   |  0    |  0    |  1    |  0    |  0    |  0    |  0    |  1    |  0    |  0    |  0    |  0    |
| \(s_5\) |  0   |  0    |  0    |  0    |  1    |  0    |  0    |  0    |  0    |  1    |  0    |  0    |  0    |
| \(s_6\) |  0   |  225  |  145  |  67   |  292  |  0    |  0    |  0    |  0    |  0    |  0    |  1    |  0    |
| \(s_7\) |  0   |  425  |  300  |  250  |  400  |  0    |  0    |  0    |  0    |  0    |  0    |  1    |  209302500 |

To get the optimal result, the above problem is solved by 4 iteration process. Thus, using the help of LINDO’s software, obtained optimal results of the area of rice area of 135.314 ha, corn area of 11.798 ha, soy area of 2.290 ha, and peanuts area of 2.818 ha. The optimal income obtained from the pattern of land area is IDR 2.682.020.000,00,-/year.

4. Conclusion

From the description above can be concluded that the income earned by farmers of IDR 2.682.020.000,00,-/year, if farmers grow rice, corn, soy, and peanuts with the following land size: 135.314 ha of rice area, 11.798 ha of corn area, 2.290 ha of soy area, and 2.818 ha of peanuts. Thus, it can be used as a consideration of the farmers for the planning of land use patterns.

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