An input-output model of integrated farming system

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Abstract. The increase in the human population caused a decrease in the world agricultural area. Meanwhile, the agriculture sector is the biggest contributor to world food production. The integrated farming system is integrating plants, livestock and fisheries management in a single harvesting cycle. The integrated farming system is one of the solutions to increase the efficiency of food production. Plants are able to become food sources for livestock and fish. In this case, the output from plants turned into input for livestock. Meanwhile, fish and livestock excrement that used as plant fertilizer mean that livestock’s output becomes the input for the plants. The major purpose of the integrated farming system is to yield optimization. Optimization stands for minimizing of feeding and fertilizer cost and to optimize the yield of crops and livestock production. The simulation-based on the secondary data of integrated organic vegetables and livestock farming that has been done in Gapoktan Pandan Wangi in Village of Karehkel, District of Bogor. Leontief input-output economic model used to calculate the output of a component to meet the input of corresponding components. For the increase of vegetable sector demand of Rp500.000,00 required the increase of vegetable sector production of Rp46.915,097. For the increase of livestock demand od Rp200.000,00 required the increase of production in amount of Rp867.488.41. Thereby for Bokashi sector, in the increase of demand of Rp400.000,00 required the increase of production of Rp975.322,00. For the increase of silase sector demand of Rp30.000,00 required the increase of production of Rp76.456,00.

1. Introduction
World population growth has increased by time. There was an increase of 1.08\% of the world population from 7.6 billion people in 2018 to 7.7 billion people in 2019 [1]. This event caused an increase in world food demand [2]. Agriculture is the biggest contributor to fulfill world food demand [3]. The increasing of human population leads to the increase of housing and land. Hence, it decrease the amount of land used for agriculture [4]. Along with the overuse of chemical-based fertilizer, soil quality decrease [5]. The integrated farming system provides a solution for several issues explained above [6].

Integrated farming is a practice of farming that integrates plants, livestock, and fish management in a single unit [7]. Plants produce forages as secondary product to feed on livestock and fishes. The waste product of livestock and fish are used as plant fertilizer [8] It is based on the output availability of a component, in example: forage from plants Forage can be used as an input to another component, in example: to feed on livestock. The components enable to perform a calculation of a component’s need to meet another component’s need; also used to maximize the obtained result. The problems can be solved using the Leontief input-output economic model, which published by Wassley Leontief in 1936 [9]. The model is able to analyze the interdependence among several economy sectors.
2. Implementation input-output Leontief model in integrated farming system

2.1. Input output Leontief Model
Leontief economic model based on economic transaction which depend to relation of production sectors. In [9] the relation explained in modest way. Leontief economic divided into two major models: closed model and open model [9]. In the closed model, all production results are used by the industry itself without any outside request. For example, there are n industries, during a fixed period of time each n industry production is used by n industries in a way that was agreed upon in advance. The important issue is how to find a suitable price to be paid for this production so that the total expenditure of each industry will be the same as the total income. In the Leontif open economic model, production from each industry is not only used by each of these industries but also seeks to meet outside demand. In the closed model industrial production has been established so that the problem is determining the appropriate price so that income equals expenditure. In the open model, the price is determined by the problem of how to determine the level of production of an industry to meet outside demand.

In Leontif’s open economic model, per industrial production was not merely used by each industry, yet to fulfill external demand. Meanwhile, Leontief closed economic model did not fulfill external demand In [10] served the input-output relationship:

Table 1. General input output table

| Purchases by Sectors/Industries | Intermediate Users Sectors/Industries | Final Demands | Total Demands |
|---------------------------------|--------------------------------------|--------------|--------------|
| 1                               | X_{11}                               | C \_1        | G \_1        | E \_1        | X \_1        |
| 2                               | X_{21}                               | C \_2        | G \_2        | E \_2        | X \_2        |
|                                  | 3                                     | C \_3 ... C \_n | G \_3 ... G \_n | E \_3 ... E \_n | X \_3 ... X \_n |
| n                               | X_{n1}                               | C \_n        | G \_n        | E \_n        | X \_n        |
| Value Added Imports             | W \_1                                 | W \_2 ... W \_n | W \_c ... W \_G | W \_G        | W \_G        |
| R                               | R \_1                                 | R \_2 ... R \_n | R \_1 ... R \_n | R \_1 ... R \_n | R \_1 ... R \_n |
| M                               | M \_1                                 | M \_2 ... M \_n | M \_1 ... M \_n | M \_1 ... M \_n | M \_1 ... M \_n |
| Total Supply                    | X \_1                                 | X \_2 ... X \_n | C \_1 ... C \_n | G \_1 ... G \_n | E \_1 ... E \_n |

where:

\( X_i \) = production amount of sector \( i \)

\( X_{ij} \) = production amount of sector \( j \) used by sector \( i \) in amount of \( X \)

\( W_j \) = wages in sector \( j \)

\( R_j \) = interest and profit sector \( j \)
2.2. Integrated farming system

Integrated farming system is a management system of plants, livestock, and fishes within their surrounded to produce optimized product which tends to enclosed against external input. [11]. Integration activity held also oriented on zero waste farming in yield on 4F (Food, Feed, Fertilizer, and Fuel) [12].

Major activities developed in integrated farming system were vegetable sector and livestock sector [13] . As exemplification, integrated farming system in Karehkel village developed lettuce, caisim, kale, red spinach, and green spinach. Meanwhile, developed livestock were sheep and rabbit [14].

Vegetable sector produced vegetables to comply market demand. Vegetable wastes processed to animal feed: silage [15]. While vegetable production and waste processing required production expense in the form of external addition and labor.

Livestock sector as issued in [14] produced sheep meat and bunny to meet external demand; also produce sheep dung, rabbit dung, and rabbit urine. Dung or livestock waste was used as basic material of Bokashi fertilizer production [16].

Per sector relation on integrated farming system explained by diagram below:

![Diagram of Input-output system of integrated farming system](image)

**Explanation:**
- : Production sector
- : Intermediate production
- : Production cost
Diagram above showed the requirement of labor and external additional material to produce vegetables, livestock, silage, and bokashi fertilizer. Livestock itself require additional field forage for feed. This matter was based on research [17] which silage treatment in 50% content resulted in best production of livestock which also safe for livestock feed.

3. Connecting Leontief economic model and integrated farming system

Following the explanation of Leontief economic model and integrated farming system, this part would connect Leontief economic model and integrated farming system. According to Table 1 and Figure 1, Table 1 produced to demonstrate input and output of integrated farming system as follows:

Table 2. Table input output integrated farming systems

| Sectors  | Vegetable | Livestock | Bokashi | Silage | Final Demand | Total Demand |
|----------|-----------|-----------|---------|--------|--------------|--------------|
| Vegetable| \(X_{11} = 0\) | \(X_{12} = 0\) | \(X_{13} = 0\) | \(X_{14} = 0\) | \(F_1\) | \(X_1\) |
| Livestock| \(X_{21} = 0\) | \(X_{22} = 0\) | \(X_{23} = 0\) | \(X_{24} = 0\) | \(F_2\) | \(X_2\) |
| Bokashi  | \(X_{31} = 0\) | \(X_{32} = 0\) | \(X_{33} = 0\) | \(X_{34} = 0\) | \(F_3\) | \(X_3\) |
| Silage   | \(X_{41} = 0\) | \(X_{42} = 0\) | \(X_{43} = 0\) | \(X_{44} = 0\) | \(F_4\) | \(X_4\) |
| Production costs | \(P_1\) | \(P_2\) | \(P_3\) | \(P_4\) | | \(P\) |
| Labor | \(T_1\) | \(T_2\) | \(T_3\) | \(T_4\) | | \(T\) |
| Profit | \(W_1\) | \(W_2\) | \(W_3\) | \(W_4\) | | \(R\) |
| Total Supply | \(X_1\) | \(X_2\) | \(X_3\) | \(X_4\) | | \(X\) |

Where

- \(x_{ij}\) = production of \(i\) sector used by \(j\) sector.
- \(X_i\) = total production of sector \(i\)
- \(P_i\) = additional production cost of \(i\) sector gained extra-system
- \(T_i\) = labor cost of \(i\) to produce in amount of \(X_i\)
- \(W_i\) = profit or payment to owner of sector \(i\)
- \(F_i\) = Total final demand for the output of sector \(i\)

According to Table 2 showed that

\[ X_i = \Sigma_{j=1}^{n} x_{ij} + F_i \quad , i,j = 1,2,3,4 \]  

(1)

Define a number

\[ a_{ij} = \frac{x_{ij}}{X_j} \quad , \text{where} \quad i,j = 1,2,3,4 \]  

(2)

called an input-output coefficient can be interpreted as the amount of input \(i\) used per unit of product \(j\) [10] and

\[ \frac{T_j}{X_j}, \frac{P_j}{X_j}, \frac{W_j}{X_j} \quad \text{when} \quad j = 1,2,3,4 \]  

(3)

are the amount of output for labor, cost production, and profit of sector \(j\) per total output of sector \(j\) respectively.

Equation (1) can be written as follows [18]
Equation (4) can be demonstrated in matrix as:

$$X_i = \sum_{j=1}^{j=n} a_{ij}X_j + F_i \quad i,j = 1,2,3,A.$$  

Equation (4) can be demonstrated in matrix as:

$$x = Ax + F$$  

where \( x \geq 0, A \geq 0, F \geq 0 \), \( A \) called as consumption matrix.

Consumption matrix said as productive if the amount of line and column entries are smaller than one [19]. The solution of equation (4) is

$$x = (I - A)^{-1} F$$  

where \((I - A)^{-1} = L\) is a Leontief inverse matrix which is the total production of sector \( i \) to meet demands from other sectors and external demand [19].

By describing equation (6) it is obtained

$$X_1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}^{-1} \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{bmatrix}$$

then

$$X_i = \alpha_{i1}F_1 + \alpha_{i2}F_2 + \alpha_{i3}F_3 + \alpha_{i4}F_4 = \sum_{j=1}^{j=4} \alpha_{ij}F_j$$

where \( \alpha_{ij} \) matrix entry \( L = (I - A)^{-1} \).

4. Simulation and Discussion

Data simulation used on this work is data processes from Gapoktan Pandan Wangi of Karehkel Village [14]. Every requirement converted to rupiah. Karehkel village is one of several locations that developed integrated farming system of organic vegetable and livestock in regional scale [14]. Gapoktan Pandan Wangi of Karehkel village developed organic vegetables and livestock integrated farming system based on available farming potency: vegetable food waste, sheep dung, rabbit dung, and rabbit urine that have not been used yet. Input-output table of Karehkel village integrated farming system demonstrated in following Table 3.
Table 3. Table input output pertanian terpadu Desa Karehkel

| Sectors     | Vegetable (Rp) | Livestock (Rp) | Bokashi (Rp) | Silage (Rp) | Output demand (RP) | Total Demand (Rp) |
|-------------|----------------|----------------|--------------|-------------|--------------------|------------------|
| Vegetable   | 0              | 0              | 0            | 0           | 15364              | 10708956         |
| Livestock   | 0              | 0              | 353250       | 0           | 275750             | 629000           |
| Bokashi     | 928000         | 0              | 0            | 0           | 16760              | 944760           |
| Silage      | 0              | 28347          | 0            | 0           | 23405              | 51752            |
| Production  | 5048622        | 46038          | 84558        | 0           | 6421               |                  |
| Labor       | 2934375        | 129225         | 354654       | 0           | 10950              |                  |
| Provit      | 1813323        | 425390         | 152298       | 0           | 19017              |                  |
| Total Supply| 10724320       | 629000         | 944760       | 51752       |                    |                  |

First column of Table 3 above show the total requirement or outcome of vegetable sector against other sectors, including labor, production cost, and profit of vegetable sector. For example, livestock sector require Rp28,347,00 of silage, Rp46,038,00 of production cost, and Rp129,225,00 of labor; to produce Rp629,000,00 of silage with profit of Rp425,390,00.

Using Equation (2) entries of coefficient matrix of Table 3 were determined, thus demonstrated in following coefficient matrix

\[
A = \begin{bmatrix}
0 & 0 & 0 & 0.296877 \\
0 & 0 & 0.373904 & 0 \\
0.086532 & 0 & 0 & 0 \\
0 & 0.045067 & 0 & 0
\end{bmatrix}
\]

thus obtaining

\[
\begin{bmatrix}
X_1 \\
X_2 \\
X_3 \\
X_4
\end{bmatrix} = \begin{bmatrix}
1.0004331 & 0.0133851 & 0.0050048 & 0.2970056 \\
0.0323687 & 1.0004331 & 0.3740659 & 0.0096095 \\
0.0865695 & 0.0011582 & 1.0004331 & 0.0257005 \\
0.0014588 & 0.0450865 & 0.016858 & 1.0004331
\end{bmatrix} = L \text{ is Leontief inverse matrix.}
\]

where

\[
\begin{bmatrix}
1.0004331 & 0.0133851 & 0.0050048 & 0.2970056 \\
0.0323687 & 1.0004331 & 0.3740659 & 0.0096095 \\
0.0865695 & 0.0011582 & 1.0004331 & 0.0257005 \\
0.0014588 & 0.0450865 & 0.016858 & 1.0004331
\end{bmatrix}
\]

It is shows that primary diagonal L entry positive and bigger than 1, and other elements also positive [20]. Since in economy system every nonnegative final demand induces a vector of nonnegative industrial production.

For example, market demand \( F_i \) of each sectors respectively were increased Rp500.000,00; Rp200.000,00; Rp400.000,00; Rp30.000,00; thus \( F \) matrix shifted to:
\[
\begin{bmatrix}
F_1 \\
F_2 \\
F_3 \\
F_4 \\
\end{bmatrix} = \begin{bmatrix}
11224320 \\
829000 \\
1344760 \\
81572 \\
\end{bmatrix}
\]
and required production of each sector in amount of

\[
\begin{bmatrix}
X_1 \\
X_2 \\
X_3 \\
X_4 \\
\end{bmatrix} = \begin{bmatrix}
1,000,043,31 \\
0,032,368,7 \\
1,000,043,31 \\
0,086,569,5 \\
0,014,588 \\
0,045,086,5 \\
0,001,158,2 \\
1,000,433,1 \\
\end{bmatrix} \begin{bmatrix}
11224320 \\
829000 \\
1344760 \\
81572 \\
\end{bmatrix} = \begin{bmatrix}
1,127,123,5 \\
169,648,8 \\
232,008,2 \\
158,028,0 \\
\end{bmatrix}
\]

For the increase of vegetable sector demand of Rp500,000,00 required the increase of vegetable sector production of Rp46,915,097. For the increase of livestock demand od Rp200,000,00 required the increase of production in amount of Rp867,488,41. Thereby for Bokashi sector, in the increase of demand of Rp400,000,00 required the increase of production of Rp975,322,00. For the increase of silase sector demand of Rp30,000,00 required the increase of production of Rp76,456,00.

To calculate the amount of production cost, total labor, and total profit, the calculation of production cost coefficient, labor, and profit should be performed first. Coefficient of production cost, labor, and profit of vegetable sector, livestock sector, bokashi sector, and silase sector according to equation (3) respectively is:

\[
\begin{align*}
P_1/X_1 &= 0.470764; \\
P_2/X_2 &= 0.073192; \\
P_3/X_3 &= 0.089502; \\
P_4/X_4 &= 0.124072 \\
T_1/X_1 &= 0.470764; \\
T_2/X_2 &= 0.073192; \\
T_3/X_3 &= 0.089502; \\
T_4/X_4 &= 0.124072 \\
W_1/X_1 &= 0.470764; \\
W_2/X_2 &= 0.073192; \\
W_3/X_3 &= 0.089502; \\
W_4/X_4 &= 0.124072
\end{align*}
\]

Thus total production cost is

\[
\begin{bmatrix}
P_1/X_1 \\
P_2/X_2 \\
P_3/X_3 \\
P_4/X_4 \\
\end{bmatrix} = Rp. 565,750,00
\]

Using similar method, total labor obtained as Rp4.366.934,30 with total profit of Rp3.957.499,00

5. Conclusion and further research

Combination of several plant varieties or livestock within integrated farming system have been argued. However, Leontief economic model classified the varieties into a single sector. In example, lettuce, caisin, and kale classified as vegetable sector. The classification conducted since each vegetable variety require a same resource: bokashi fertilizer. Without the classification, the model would result in two or more multiple consumption matrix line. The matrix determinant thus being zero and had no inverse. The issue caused an absence of Leontief economic matrix. With the result of that, further research aimed to study the method of optimized the yield of each component within sector. It is conducted to gain optimum result before determining amount of production of each sector to comply market and external sector demand using Leontief economic model.

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