| RESEARCH ARTICLE

Optimizing Land Use for Biopharmaceutical Plants to Support the Availability of Herbal Medicines in Majalengka Regency Using Mathematical Models

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| ABSTRACT

Biopharmaceutical plants are plants that are used as ingredients for medicines and cosmetics. This plant can be consumed directly or processed as herbal medicine. The use of herbal medicines has increased since the Covid-19 pandemic. The need for herbal medicines has increased along with increasing public awareness of the importance of increasing the body's immunity. Apart from that, people think that the side effects of herbal medicines are smaller than those of chemical medicines. Majalengka Regency has very diverse geographical conditions, ranging from lowlands to steep hills at the slope of Mount Ciremai. This diversity of geographical conditions creates great potential for the cultivation of biopharmaceutical plants. Cultivation of biopharmaceutical plants can support the availability of herbal medicines in Majalengka. Unfortunately, the land used for cultivating biopharmaceutical plants is decreasing every year. This limited land must be utilized optimally. Transportation models in mathematics are used to model land use for biopharmaceutical plants to obtain maximum harvest results. The results of mathematical model calculations show that the harvest of biopharmaceutical plants is 4,187,624 kg with land spread across various sub-districts in Majalengka Regency.

| KEYWORDS

Biopharmaceutical Plants; Herbal Medicines; Land Use Optimization; Mathematical Modeling; Transportation Model

| ARTICLE DOI:

I. INTRODUCTION

Biopharmaceutical plants, commonly known as medicinal plants, are widely used in various forms such as kitchen spices, food and beverage ingredients, herbal medicines, and cosmetics [1]. Examples of biopharmaceutical plants include ginger, galangal, turmeric, lime, and Java cardamom. The demand for herbal medicines has significantly increased since the Covid-19 pandemic, with the World Health Organization (WHO) estimating that 80% of the global population, or approximately 4 billion people, use herbal medicines [2]. In Indonesia, 75% of the elderly population relies on herbal medicine [3]. This growing demand is driven by increasing public awareness of the importance of immunity and the perception that herbal medicines have fewer side effects compared to chemical medicines. Majalengka Regency, with its diverse geographical conditions ranging from lowlands to hilly areas at the foot of Mount Ciremai [4], has great potential for biopharmaceutical plant cultivation. As of 2023, the total harvest area of biopharmaceutical plants in Majalengka was recorded at 1,320,538 m^2, with a total production of 4,228,187 kg [5][6]. However, the land available for cultivation has been decreasing annually, making it essential to optimize land use for sustainable production [7].

This study aims to optimize the use of limited land for biopharmaceutical plant cultivation to maximize harvest yields. A mathematical model is employed to analyze land use efficiency and determine the best allocation strategies. Mathematical modeling plays a crucial role in analyzing complex systems, optimizing decision-making, and predicting outcomes in agricultural management [8]. The transportation model, a specialized form of linear programming, is used in this research. It functions as a substitute for real-world distribution systems, aiming to allocate resources efficiently while minimizing transportation costs [9][10]. By simulating different allocation scenarios, the transportation model provides an optimal strategy for distributing biopharmaceutical plant cultivation across available land [11]. While previous studies have applied mathematical models to predict either the harvest area [15] or the production of biopharmaceutical plants [16][17], they have not considered both factors simultaneously. This study fills that gap by integrating land availability with production predictions to enhance yield optimization.

The contribution of this research lies in its application of the transportation model to predict and optimize the harvest yield of biopharmaceutical plants while considering land limitations. Unlike prior studies that focused solely on predicting either harvest area or production, this research integrates both aspects to provide a more comprehensive approach. The findings offer valuable insights for policymakers and farmers in determining which types of biopharmaceutical plants should be cultivated to achieve maximum yields with limited land. By providing an optimal planting strategy, this study supports sustainable agricultural practices and ensures the continued availability of herbal medicines in Majalengka.

II. METHODOLOGY

The study began with a literature review on transportation models, followed by the collection of secondary data on the harvested area and production of biopharmaceutical plants in Majalengka Regency. The data, obtained from the Central Statistics Agency of Majalengka Regency in 2023, included the harvested area, which refers to the land used for cultivating biopharmaceutical plants (m^2), and production, which represents the total harvested yield (kg). Data were collected for six types of biopharmaceutical plants: ginger, galangal, kencur, turmeric, lime, and cardamom. The harvested area and production data were recorded per plant type to provide a comprehensive overview of biopharmaceutical cultivation in the region. Based on the collected data, a transportation model was developed to optimize land use and maximize harvest yield.

The transportation model was built on several key assumptions. First, the location and area of land used for cultivating each type of biopharmaceutical plant were assumed to be the same within a given sub-district. Second, the total land used for cultivation represented the combined area for all plant types within each sub-district. Third, the harvested area was treated as the independent variable, while the production of biopharmaceutical plants served as the dependent variable. Lastly, external factors influencing production were not considered in the model. Once the transportation model was formulated, it was simulated and solved using QM software with the Vogel's Approximation Method (VAM). The results obtained from the model were then interpreted to derive conclusions regarding the optimal allocation of land for biopharmaceutical cultivation.

III. RESULTS AND DISCUSSION

Majalengka Regency produces various types of biopharmaceutical plants including lime, turmeric, cardamom, ginger, galangal, and east Indian galangal. Based on data taken from the website of the Central Statistics Agency of Majalengka Regency in 2023, the harvested area of 6 types of biopharmaceutical plants was 1,274,040 m2 with a production of 4,050,945 kg. The harvested area indicates the area of land used for cultivating biopharmaceutical plants (m2) and production is the amount of biopharmaceutical plant harvested (kg). Harvested area and production data are used to calculate the average harvest yield/m2 (kg) using the equation.

$$\text{average harvest yield/m}^2 = \frac{harvest\ yield}{harvested\ area} \tag{1}$$

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The data is transformed into a transportation matrix. The transportation matrix is adjusted to the land use of biopharmaceutical plants. The land use of biopharmaceutical plants matrix is shown in table 1

TABLE 1.
LAND USE OF BIOPHARMACEUTICAL PLANTS MATRIX

Sub-District	Types of Biopharmaceutical Plants						Capacity (kg)
	Lime	Turmeric	Java Cardamon	Ginger	Galanga	East Indian Galangal	
Argapura	0	3.00	0	3.50	0	0	30,000
Banjaran	0	2.80	0	2.83	0	0	37,000
Bantarujeg	0	0	0	2.40	0	0	50,000
Cigasong	0	3.20	0	0	5.57	0	23,750
Cikijing	0	0	0	4.00	0	0	110,000
Cingambul	0	0	0	3.60	0	0	5
Dawuan	0	0	0	0	0	0	0
Jatitujuh	0	0	0	0	0	0	0
Jatiwangi	0	0	0	0	0	0	0
Kadipaten	0	3.07	0	0	0	0	400,000
Kasokandel	0	3.20	0	0	0	0	14,000
Kertajati	0	0	0	0	0	0	0

Lemahsugih	0	0	5.90	1.43	0	0	120,000
Leuwimunding	0	0	0	0	1.20	0	2,500
Ligung	0	0	0	0	0	0	0
Maja	0	2.50	0	3.00	0	0	66,000
Majalengka	0	1.00	0	0	0	0	270
Malausma	0	0	0	0	0	0	0
Palasah	29.60	0	0	0	0	0	1,500
Panyingkiran	0	0	0	3.56	0	2.04	325
Rajagaluh	20.73	1.75	2.39	0	0	0	13,250
Sindang	8.00	2.50	1.40	3.00	4.00	0	301,343
Sindangwangi	5.00	2.40	0	0	2.81	0	9,197
Sukahaji	0	2.95	3.27	2.87	3.12	0	24,900
Sumberjaya	0	0	0	0	0	0	0
Talaga	0	0	0	4.57	0	0	70,000
Demand	2,200	682,820	6,6060	460,680	62,255	25	1,274,040

The mathematical model of land use of biopharmaceutical plants has an objective function to maximize the harvest yield of biopharmaceutical plants and the constraints are displayed in the matrix on Table 1. The matrix consists of 26 rows and 6 columns. The rows in the matrix indicate the sub-districts in Majalengka Regency (Origin) while the columns in the matrix indicate the types of biopharmaceutical plants (Destination). Each sub-district (origin) has a land capacity/harvested area listed in the Capacity column (m2). Each type of biopharmaceutical plant (destination) will be planted on a certain land area to meet the land requirements listed in the Demand row (m2). The matrix entry is the average harvest yield/m2 (Kg). For example, Argapura Sub-district has 30,000 m2 of land that can be planted with various types of biopharmaceutical plants. If the land is planted with turmeric, it will produce a harvest of 3 kg/m2 and if planted with ginger, it will produce a harvest of 3.5 kg/m2. This mathematical model then solved using QM software with Vogel's Approximation Method (VAM). The solution of the land use of biopharmaceutical plants mathematical model is shown in Table 2.

TABLE 2.
LAND USE OF BIOPHARMACEUTICAL PLANTS MODEL SOLUTION

Sub-District	Types of Biopharmaceutical Plants					
	Lime	Turmeric	Java Cardamon	Ginger	Galanga	East Indian Galangal
Argapura	0	0	0	30,000	0	0
Banjaran	0	37,000	0	0	0	0
Bantarujeg	0	0	0	50,000	0	0
Cigasong	0	0	0	0	23,750	0
Cikijing	0	0	0	110,000	0	0
Cingambul	0	0	0	5	0	0
Dawuan	0	0	0	0	0	0
Jatitujuh	0	0	0	0	0	0
Jatiwangi	0	0	0	0	0	0
Kadipaten	0	400,000	0	0	0	0
Kasokandel	0	14,000	0	0	0	0
Kertajati	0	0	0	0	0	0
Lemahsugih	0	0	66,060	53,940	0	0
Leuwimunding	0	2,475	0	0	0	25
Ligung	0	0	0	0	0	0
Maja	0	0	0	66,000	0	0
Majalengka	0	270	0	0	0	0
Malausma	0	0	0	0	0	0
Palasah	1,500	0	0	0	0	0
Panyingkiran	0	0	0	325	0	0
Rajagaluh	700	12,550	0	0	0	0
Sindang	0	182,428	0	80,410	38,505	0

Sindangwangi	0	9,197	0	0	0	0
Sukahaji	0	24,900	0	0	0	0
Sumberjaya	0	0	0	0	0	0
Talaga	0	0	0	70,000	0	0
Objective	4,187,642					

The mathematical model solution for land use in biopharmaceutical plant cultivation, as presented in Table 2, determines the optimal land allocation for each type of plant to achieve maximum harvest yields. The objective of this model is to maximize the total harvest of all biopharmaceutical plants across all sub-districts. The total harvest is calculated by multiplying the designated planting area (from Table 2) by the average harvest yield per square meter (from Table 1).

For instance, in Argapura Sub-district, the model suggests allocating 30,000 m^2 of land for ginger cultivation, resulting in a projected harvest of 105,000 kg of ginger. Similarly, in Lemahsugih Sub-district, 66,060 m^2 of land should be used for cardamom and 53,940 m^2 for ginger, yielding an estimated 389,754 kg of cardamom and 77,134.2 kg of ginger. The optimal land distribution for all types of biopharmaceutical plants, as shown in Table 2, results in a total projected harvest of 4,187,624 kg. This optimized allocation leads to an increase of 136,679 kg compared to the total harvest recorded in 2023, demonstrating the effectiveness of the mathematical model in improving agricultural productivity.

IV. CONCLUSION

The land use of biopharmaceutical plants in Majalengka Regency is modeled using a transportation model. The biopharmaceutical plants simulated are lime, turmeric, cardamom, ginger, galangal, and east indian galangal. The results of the mathematical model simulation show that the land used by 6 types of plants covers a total area of 1,274,040 m2 spread across 26 sub-districts in Majalengka. The total harvest from 6 types of biopharmaceutical plants planted is 4,187,624 kg, which is 136,679 kg more than the total harvest in 2023.

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