Technical Efficiency in Bitter Melon Plants Using Data Envelopment Analysis (DEA) Model in Tanah Laut District

Rana Pertiwi Pohan [1], Yudi Ferrianta [2*], Nuri Dewi Yanti [3]

[1] Master of Agricultural Economics, Faculty of Agriculture, Lambung Mangkurat University, Indonesia
[2,3] Agribusiness Study Program, Faculty of Agriculture, Lambung Mangkurat University, Indonesia
*Corresponding Author:
Email: yudi_ferrianta@ulm.ac.id

Abstract.

Farm technical efficiency involves maximizing output while minimizing input costs. In Tanah Laut Regency, bitter melon production fluctuates annually due to climatic factors and inefficient input use. On average, farmers use 0.47 hectares of land, 166 grams/ha of seeds, 2,659 kg/ha of organic fertilizer, 208 kg/ha of inorganic fertilizer, 7.08 liters/ha of liquid pesticides, 7.24 kg/ha of solid pesticides, and 339 HKSP of labor. Data Envelopment Analysis (DEA) indicates that farmers are technically inefficient, with average technical efficiencies of 80.8% (CRS-DEA), 89.9% (VRS-DEA), and 89.8% (SE-DEA). Among the farmers, 32% operate under increasing returns to scale (IRS), 26% under constant returns to scale (CRS), and 42% under decreasing returns to scale (DRS). A logit regression model reveals that education level, farming experience, and number of family members significantly impact technical efficiency, while age, land ownership status, and off-farm income do not. To enhance efficiency, farmers should reduce input use by emulating the practices of their more efficient peers.

Keywords: *Technical Efficiency, Bitter Melon Production, Data Envelopment Analysis (DEA), Input Utilization and Lodit Regression.*

I. INTRODUCTION

The bitter melon plant or *Momordica charantia L*., is known by various names in Indonesia, and in South Kalimantan it is called papare or pare. Despite its promising cultivation prospects, this crop is still rarely grown by local farmers. Bitter melon cultivation is relatively easy, including pest and disease management compared to other horticultural crops. Increasing bitter melon production is important to meet the increasing demand as the population grows. Efforts to increase production can be made through intensification, extensification, and efficient use of production inputs, in Tanah Laut district, many people work in the agricultural sector, including in Takisung and Tambang Ulang sub-districts. Bitter melon grows optimally at an altitude of 1-1,500 meters above sea level and soil pH 5-6. However, limited land and conversion of agricultural land are challenges in extensification. Technological advances can increase production, but require support from farmers, access to capital, and farm size. Unfortunately, farmers tend to revert to simple technologies after government training programs end.Data shows a significant decline in the number of young farmers in Indonesia from 2020 to 2023, threatening the sustainability of the agricultural sector. In 2020, only 8% of farmers were under 35 years old, and this number is projected to continue to decline. Urbanization, lack of interest among the younger generation, and limited access to modern agricultural technology are the main causes.

Without interventions such as education and training for young farmers and government policy support, agricultural productivity, including bitter melon cultivation, risks declining. Technical efficiency is important to increase production by minimizing input use without reducing output. Factors such as education, farming expertise, number of family members, and age of farmers affect technical efficiency. The right combination of production input use and farmers' socioeconomic factors are essential to achieve efficiency in bitter melon cultivation (Primary Data Processed, 2024).Technical efficiency in bitter melon plants using Data Envelopment Analysis (DEA) models is a crucial aspect of agricultural productivity assessment. DEA is a method that allows for the evaluation of the relative efficiency of decision-making units, such as bitter melon farms, by comparing their input and output levels. By applying DEA, researchers can identify the most efficient farms and provide insights into best practices for improving productivity [1].

Efficiency in agricultural production is a multifaceted concept that encompasses various factors such as technical efficiency, output growth, and productivity. Studies like the one conducted on small-scale rice farmers in Eastern India have shown that technical efficiency plays a significant role in production growth. When technical efficiency decreases, technical change becomes the primary driver of production growth. This highlights the importance of assessing technical efficiency in bitter melon plants to understand the factors influencing their output [1].

Moreover, the use of models like the super-efficiency Slack-based measure-Data Envelopment Analysis (SBM-DEA) can provide a comprehensive analysis of agricultural eco-efficiency. By examining spatiotemporal differentiation characteristics in agricultural ecological efficiency, as done in Chongqing, researchers can gain valuable insights into the efficiency levels across different districts. Applying similar models to bitter melon cultivation in Tanah Laut District can reveal patterns of efficiency and guide interventions for improvement [2]. In the context of sustainable urban development, studies have explored the relationship between urban form, agricultural eco-efficiency, and economic outcomes. Assessing the environmental costs and economic benefits of agricultural eco-efficiency in various districts, as seen in the research conducted in Huancayo Province, Peru, can offer a holistic view of the sustainability of agricultural practices. This approach can be adapted to evaluate the eco-efficiency of bitter melon cultivation in Tanah Laut District, contributing to environmentally conscious agricultural practices [3].Efficiency evaluations, such as those conducted using two-stage DEA models in Serbian districts, provide a structured framework for assessing agricultural productivity. By examining the relative technical efficiency of different districts, researchers can pinpoint areas for improvement and optimize resource allocation.

Applying similar methodologies to analyze bitter melon production in Tanah Laut District can lead to targeted interventions to enhance efficiency and overall productivity [4]. Furthermore, studies focusing on the analysis of scale effects and temporal stability of groundwater in irrigation districts underscore the importance of efficient resource utilization. By identifying stability sites and controlling factors affecting groundwater quality, researchers can ensure sustainable agricultural practices. This approach can be valuable when assessing water usage efficiency in bitter melon cultivation, especially in regions like Tanah Laut District where water resources may be limited [5]. In evaluating agricultural sustainability based on the water-energy-food nexus, researchers have highlighted the significance of water-use efficiency and crop yield per unit area. These metrics serve as indicators of agricultural sustainability and can guide decision-making processes. Assessing these parameters in the context of bitter melon cultivation in the Chenmengquan Irrigation District of China sheds light on the interplay between resource utilization and productivity, offering insights applicable to similar agricultural settings like Tanah Laut District [6].

II. METHODS

This research was conducted in Tanah Laut Regency, South Kalimantan Province from February to June 2024 starting from the preparation stage, searching for journals, discussions with supervisors, making proposals, collecting data to the report preparation stage. Primary data was collected through direct interviews with bitter melon farmers using a list of questions or questionnaires that had been prepared previously. And for secondary data collected from various agencies and institutions related to this research, such as the Central Bureau of Statistics, Food Security Office, Agriculture and Fisheries Office and some literature such as books, journals and theses related to this research.

The method in this study was carried out in several stages, starting from:

1. The first stage, the determination of sub-districts bypurposive means, namely Takisung and Tambang Ulang sub-districts with the consideration after being surveyed that these two sub-districts are the sub-districts with the most farmers in bitter melon farming and are considered to represent areas that are categorized as having the most bitter melon farmers compared to other sub-districts in Tanah Laut Regency;
2. The second stage, sampling was conducted using census sampling with a total of 50 respondents in Takisung and Tambang Ulang sub-districts. Sampling with a tolerable error rate in regression analysis of 5% (0.05).

To achieve the research objectives, two types of analysis methods were used, namely the analysis of technical efficiency of farming with DEA and the analysis of factors affecting the technical efficiency of bitter melon farming with logit regression. DEA is a tool that can be used to evaluate the performance of an activity that uses one or more types of inputs and produces one or more types of outputs. The measurement of the ratio of inputs to outputs expressed partially. Each unit to be evaluated in DEA is a Decision Making Unit (DMU) that will give various results, due to the different combination of inputs used to produce different outputs. The efficiency score can be obtained from the comparison between inputs and outputs in each UPK. The result of this technical efficiency is one of them, if the result is less than one which will show that the technical efficiency of the farm is relatively technically inefficient. In DEA, the measurement of technical efficiency with the assumption of Constant Return to Scale (CRS) is called Overall Technical Efficiency (OTE) which describes the efficiency of managerial impact and scale [7]. This CRS assumption is only appropriate if all UPKs operate at optimal scale. If UPKs are not operating at optimal scale, then Variable Return to Scale/VRS applies. OTE theory can be decomposed into Technical Efficiency (ET) and Scale Efficiency (SE). The TE measurement indicates the type of managerial efficiency, i.e. management's ability to convert inputs into outputs, while SE measures the indication of whether or not the UPK in question is operating at an optimal scale. The mathematical program formula with CRS inputs and assumptions is described as follows:

$\text{Min } \theta\lambda\ \theta,$

$\text{St: } -q + Q\lambda \geq 0,$

$: \theta xi - X\lambda \geq 0,$

$: \lambda \geq 0$

Description:

θ = Tennis efficiency value

λ = Weight

$-q$ = Output of i-th UPK

Q = Total output multiplied by weight

X = Total input multiplied by weight

Furthermore, to answer the first objective, namely analyzing the technical efficiency of bitter melon farming, using a non-parametric Data Envelopment Analysis (DEA) approach. This approach is used to evaluate the performance of an activity that uses one or more kinds of inputs and produces one or more outputs. Each UPK will obtain a diversity of results, due to differences in the combination of inputs used so as to produce different outputs. The efficiency score is obtained from the comparison between inputs and outputs in the UPK. The value of technical efficiency in this study is one, if it is less than one then the farm is said to be technically inefficient. This research uses the DEA Variable Return to Scale (VRS) model approach. The calculation of technical efficiency with the VRS input orientation model is mathematically written as follows [7]:

$\text{Max}\varphi\lambda\ \Phi,$

$\text{St: } - \varphi\ yi + Y\ \lambda \geq 0,$

$: xi - X\ \lambda \geq 0.$

$: N1'\ \lambda = 1$

$: \lambda \geq 0$

Description:

$- \varphi$ = Output of i-th UPK

x = Tennis efficiency value

Y = Total output multiplied by weight

X = Total input multiplied by weight

λ = Weight

The explanation is 1 ≤ φ < □ and φ-1 is the proportional increase in output that can be achieved by the UPK with the quantity of inputs available. The next calculation that needs to be done is to find the value of the efficiency scale obtained by doing the following calculation:

$$SE = \frac{\text{TE CRS}}{\text{TE VRS}}$$

Description:
SE = Efficiency Scale
TE CRS = Technical Efficiency Constant Return to Scale
TE VRS = Technical Efficiency Variable Return to Scale

The SE value in the equation above is the scale efficiency value of the existing UPK. The above calculation is obtained if VRS has been obtained, the value of scale efficiency (SE) is the value of comparison between UPKs carried out at each UPK to determine the condition of its production scale. This means that each UPK can be efficient, but not necessarily in accordance with the scale of production, if the scale of production is too small, there will be increasing returns to scale and if it is too high, there will be decreasing returns to scale. The solution is to adjust the production scale of the UPK that is at the highest efficiency level of the CRS.

This analysis is used to determine the factors that influence the decision of sharecroppers in farming. This analysis can be done using the logit regression method which can be formulated as follows:

$$y(x) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6$$

Description:
$y(x)$ = binary logit function (1 = efficient; 0 = inefficient)
$\beta 0$ = intercept or constant
X_1 = Age of tenant farmers (1 = productive; 0 = nonproductive)
X_2 = Education level (1 > 9 years; 0 < 9 years)
X_3 = Bitter melon farming experience (1 ≥ 10 years; 0 < 10 years)
X_4 = Number of family members (1 ≤ 3 people; 0 > 3 people)
X_5 = Land ownership status (1 = privately owned; 0 = other, rented/loaned)
X_6 = Income outside bitter melon farming (1 = available; 0 = not available)

III. RESULT AND DISCUSSION

Result

1. Characteristics of Respondent Farmers

Differences in farmer characteristics will affect farmers in farming and production input-oriented technical efficiency. Differences in farmer characteristics in this study include farmer age, education level, bitter melon cultivation experience, number of family members, land ownership and off-farm income.

2. Farmer Age

The age of farmers based on data from respondents in this study, the largest percentage is in the productive age group of 31-64 years old as many as 47 people with a percentage of 94%, the non-productive group is > 65 years old as many as 3 people with a percentage of 6%. The average age of respondent farmers is 47 years with the youngest age of 35 years and the oldest age is 66 years. This productive age grouping is based on the age classification according to the Central Bureau of Statistics (BPS), where ages 16-64 years are included in the adult/productive age group, while those aged > 65 years are included in the non-productive age group. The level of work productivity and the level of understanding of technology in agriculture are related to the age of the farmer. Generally, young farmers will more easily understand technology and be able to make decisions on the application of technology in their farms.

3. Education

The level of education referred to here is the length of time a farmer has attended formal education. Respondents who did not finish school amounted to 3 people (6%), who completed elementary school amounted to 9 people (18%), and junior high school amounted to 18 people (36%) which indicates a lack of awareness of the importance of formal education. The remaining 20 people (40%) graduated from senior high school. The lack of awareness of formal education is partly due to the need for family labor to carry out farming activities, as well as factors such as the poor economy and the long distance to formal education. Some farmers who have higher education will find it easier to understand and accept any information, especially with additional informal education such as counseling and training that can provide direct learning of farming success.

4. Farming Experience

Farming experience is one indicator that indirectly shows experience in farming. Most respondents with 11-20 years of farming experience were 30 people (60%). Farmers with more experience are able to solve farming problems longer than new farmers. This explains that growing bitter melon commodities generates profits and is the main livelihood for farmers, in addition to other income outside farming.

5. Family Dependents

The number of family members indicates the size of the family's living expenses and can also be a source of family labor if they are of productive age. However, if there are family members who are not of productive age, it will increase the cost of living for the family. The average number of family members of respondent farmers in the two sub-districts amounted to 3.26 ≈ 3 people, with the most being 7 people and the least being only 1 member.

6. Land Ownership Status

The land ownership status of farmers in Tanah Laut District is divided into owned, borrowed and rented land. Farmers' land ownership status determines their income. Land ownership status is mostly self-owned land as many as 39 people (78%). In addition, some farmers have borrowed land without paying rent, 6 farmers (12%). This is very profitable for respondents because the benefits obtained are greater than a farmer who must set aside his income to pay land rent.

7. Off-Farm Income

Non-farm income is income earned by farmers apart from their farming activities which can be offered from several sources including trading, construction labor, livestock breeding and others. Some farmer respondents in Tanah Laut District had non-farm income as many as 17 people (34%) and 33 people (66%) had no income outside of farming. Farmer respondents who have no other income outside farming are better at managing their farming business, because it is their only source of income. Another case for farmers who have other income outside farming. The efforts made will shorten the time in running their farms and cause non-optimal farm management.

8. Input Use Level of Bitter melon Farmers in Tanah Laut Regency

Production factors used in bitter melon farming in Tanah Laut Regency are land area, bitter melon seeds, organic fertilizer, inorganic fertilizer, liquid pesticides, solid pesticides and labor.

9. Land area

The area of land planted with bitter melon, whether the land is owned, rented or borrowed. Based on data from respondent farmers, the largest cultivated land area is 0.81-1.00 hectares which represents 6 farmers (12%) of the total respondents. While farmers with a land area of 0.20 - 0.40 hectares is the smallest land with the most farmers totaling 28 people (56%).

10. Seed Use

Bitter melon seeds used in Tanah Laut district ranged from 0-150 grams/ha used by 28 farmers. Bitter melon seeds used ranged from 150-300 grams/ha by 17 farmers. Respondent farmers who used > 350 grams/ha of seed amounted to 5 farmers. The average use of bitter melon seeds amounted to 166 grams/ha where the least use of seeds was 80 grams/ha and the most was 350 grams/ha.

11. Fertilizer Use

Fertilizers used by respondent farmers in Tanah Laut District are divided into two types, namely organic fertilizers and inorganic (chemical) fertilizers. Farmers use organic fertilizer from chicken manure mixed with husks, in one hectare farmers use organic fertilizer with an average of 2,659 kg/ha. The use of organic fertilizer ranges from 1,280-5,600 kg/ha. Farmers use inorganic fertilizer at an average of 208 kg/ha with a range of use between 100 and 438 kg/ha.

12. Pesticide Use

The use of pesticides is very important in crop maintenance, because plants are very vulnerable to pests and diseases. The use of pesticides varies depending on the needs of the plant and what pests attack the plant. The average use of liquid pesticides was 7.08 liters/ha with the lowest use being 4 liters/ha and the highest being 13 kg/ha. While for solid pesticides the average is 7.24 kg/ha with the lowest use being 4 lt/ha and the highest being 14 kg/ha.

13. Labor

The use of labor is needed in farming activities ranging from land cultivation to harvesting. Labor that carries out bitter melon farming activities comes from within and outside the family. The labor used by farmers varies, because it is harmonized based on the area of land used by farmers and the number of adult family members they have. Generally, respondent farmers only use labor within the family in their farming business, as much as 65%, while labor outside the family amounts to 35%. The average use of labor is 339 HKSP with the highest use being 654 HKSP and the lowest being 134 HKSP.

Discussion

Technical Efficiency Using Data Envelopment Analysis (DEA)

Data processing results of bitter melon farming in Tanah Laut Regency with input orientation showed an average technical efficiency of 80.8% for the CRS model, 89.9% for the VRS model, and 89.8% for the SE model. The percentage ratio showed 16 farmers (32%) at the IRS scale, 13 farmers (26%) at the CRS scale, and 21 farmers (42%) at the DRS scale. These technical efficiency values indicate variations in the use of production inputs per unit area of land. Farmers are categorized as efficient if they have a technical efficiency value above 90% [8]. In this study, only 13 farmers (26%) in the CRS model were technically efficient, while in the VRS model 22 farmers (44%) were technically efficient, and 13 farmers (26%) were in SE.The DEA CRS and VRS models were used to determine whether the trend of respondent bitter melon farmers in the research location was Increasing Return to Scale (IRS) or Decreasing Return to Scale (DRS). If the CRS technical efficiency value is lower than the VRS, then farmers must produce in a way that decreases the return to scale. Data from both sub-districts show that all VRS technical efficiencies are greater than CRS, so it can be concluded that farmer respondents in the research locations are DRS members.The measurement of Scale Efficiency (SE) aims to determine the excess input caused by variable scale of return. The majority of inefficient bitter melon farmers are in a position to reduce inputs (decreasing returns to scale), with 21 farmers (42%) where the increase in inputs is greater than the increase in output.

Input slack indicates the inputs that farmers can reduce due to excess use of inputs to produce the same level of output. Input slack occurs for farmers who are inefficient compared to their efficient counterparts. Reduction of excess inputs is necessary to improve the efficiency of farmers compared to other farmers. Input slack in inefficient farmers varies and is spread across all input factors. Land use area has an average slack of 0.012 hectares. A total of 21 farmers (42%) were able to reduce land use by an average of 0.012 hectares without reducing bitter melon production, indicating that efficient farmers (efficiency level = 1,000) peers 32% of farmers on land input use.In the use of seeds, there were 21 farmers (42%) who were inefficient with an average of 96.791 grams of seeds. In the use of organic fertilizer, there were 15 farmers (30%) who were inefficient with an average of 6.774 kg of organic fertilizer saved. In the use of inorganic fertilizer, 28 farmers (20%) were inefficient with an average of 8.827 kg of inorganic fertilizer saved. The same thing happened with the use of liquid pesticides, with the average use of pesticides that could be saved by 6,871 ml without reducing the output of bitter melon production was 24 farmers (48%). The use of solid pesticides that can be saved is 6,667 kg to achieve the same production target as its peers. Labor has an average slack value of 6.460, indicating that 21 farmers (42%) can still reduce the use of labor by an average of 16.350 HKSP to get the same inputs as their peers.

Factors Affecting Technical Efficiency (Using Logit Regression)

Factors influencing the technical efficiency of bitter melon plants in the Tanah Laut District can be examined through various factors, including age, education, farming experience, family size, land ownership status, and non-farm income. These elements are crucial in determining the productivity and effectiveness of bitter melon cultivation in the region. The potential of chitosan–selenium nanoparticle foliar spray in alleviating salt stress in bitter melon plants, demonstrating how innovative agricultural practices can enhance plant resilience and potentially improve technical efficiency [9]. Intercropping patterns of bitter melon and tomato illustrates the significance of planting arrangements in maximizing efficiency, with specific patterns showing notably higher efficiency levels [10]. This finding emphasizes the importance of agricultural practices and crop combinations in influencing technical efficiency outcomes. The role of bitter melon rootstock in enhancing heat tolerance in cucumber plants through the regulation of photosynthetic and antioxidant defense pathways [11]. This suggests that grafting techniques and plant interactions can impact the overall efficiency and productivity of bitter melon cultivation. Moreover, the effectiveness of pollination, the contribution of stingless bees to bitter melon plants, highlights the importance of biodiversity and ecological factors in agricultural settings [12].

The presence of pollinators can significantly influence crop yield and quality, thereby affecting technical efficiency. Additionally, the medicinal properties of bitter melon, the multifaceted benefits of this plant beyond its nutritional value, potentially impacting the overall health and vigor of bitter melon crops [13], [14]. The nutraceutical potential of Momordica charantia L. in addressing inflammatory-related diseases, pointing towards the broader health implications of bitter melon consumption [15]. Understanding the health benefits associated with bitter melon can provide insights into consumer demand and market dynamics, which can indirectly influence the technical efficiency of bitter melon cultivation. The insecticidal potential of ethanol extracts from Melia azedarach Linn. against Bactrocera cucurbitae highlights the role of pest management strategies in optimizing crop production and efficiency [16]. The potential biomarkers of fatigue in athletes using Momordica charantia, suggest the performance-enhancing properties of bitter melon, which can have implications for agricultural practices aimed at improving crop vitality and productivity [17]. Understanding the physiological effects of bitter melon on fatigue and energy metabolism can inform cultivation techniques that promote plant health and vigor, ultimately impacting technical efficiency. Additionally, the metabolic effects of Momordica charantia, as studied by , highlight the plant's beneficial properties in addressing metabolic syndrome parameters, which can have implications for crop management practices and overall plant health [18].

Based on logit regression analysis, it was found that age, formal education level, and farming experience had a significant effect on the technical efficiency level of bitter melon farming in Tanah Laut District. In contrast, the number of family members, land ownership status, and non-farm income had no significant effect.

1. Influence of Age

Farmers' age affects their performance, where technical efficiency tends to decrease with age. Research by [19], [20] also show that age has a negative effect on technical efficiency. Younger farmers are more efficient than older farmers [21]. In this study, the majority of respondents were at productive age, which supports the finding that younger age correlates with higher efficiency.

2. Effect of Education

Formal education level has a positive and significant influence on technical efficiency. Farmers with higher education have better access to information and technology, which makes it easier for them to manage their farms. Research by [22], [23] also show that education level has a positive and significant influence on technical efficiency. They also have a better ability to process knowledge and apply efficient cultivation techniques. This suggests that education plays an important role in improving farmers' technical efficiency.

3. Effect of Farming Experience

Farming experience also has a positive and significant effect on technical efficiency. More experienced farmers tend to make better decisions and avoid mistakes in cultivation activities. Manganga (2012) and Hussain et al. (2014) also stated that farming experience has a positive influence on technical efficiency. Experience helps farmers in making better decisions as they have learned from previous failures.

4. Effect of Number of Family Members

The number of family members of farmers has a positive effect on technical efficiency, although it is not significant. The average family burden in the study location is about 3 people. [24], [25] revealed that a large number of family members can help overcome labor constraints, especially in rural areas that rely more on family members as labor than hiring others.

5. Effect of Land Ownership Status

Land ownership status has a negative and insignificant effect on technical efficiency. Farmers who own their own land tend not to show a decrease in the value of technical efficiency in their farming activities. As many as 60% of respondents own their own land. Research by [26], [27] also stated that land ownership status had a negative effect on technical efficiency. That farmers who own their own land tend to be more negligent in managing their farms [28].

6. Effect of Non-Farm Income

Off-farm income has a negative and insignificant effect on technical efficiency. Although additional income can provide extra funds, if not managed properly, these funds will not have a significant effect. Farmers who have non-farm income may not focus on managing their farms, which can reduce technical efficiency. Research by [29]–[31] also stated that the higher the off-farm income, the lower the farm efficiency due to the lack of focus on agricultural activities.

IV. CONCLUSION

Technical efficiency analysis using Data Envelopment Analysis (DEA) reveals that bitter melon farmers in Tanah Laut Regency are technically inefficient, with average efficiencies of 80.8% for the CRS-DEA model, 89.9% for the VRS-DEA model, and 89.8% for the SE-DEA model, leaving a 10.2% opportunity for efficiency improvement. The efficiency scale distribution shows that 32% of farmers operate under increasing returns to scale (IRS), 26% under constant returns to scale (CRS), and 42% under decreasing returns to scale (DRS). Significant factors influencing technical efficiency include the level of education, farming experience, and the number of family members, while the age of farmers, land ownership status, and off-farm income do not have a significant impact.

Bitter melon farmers in Tanah Laut Regency can enhance the technical efficiency of their farms by reducing excessive input use, particularly in organic fertilizers, inorganic fertilizers, and pesticides, which exhibit significant input slack. Government socialization through agricultural extension workers is crucial to educate farmers on the importance of using appropriate inputs and to improve their understanding of effective cultivation techniques. Sustainable training programs are also essential to enhance farmers' cultivation skills. Additionally, there is a pressing need to engage the younger generation, especially agricultural graduates, in the agricultural sector to ensure the sustainability of agriculture in Indonesia. Further studies and research on technical efficiency in bitter melon farming and the factors influencing it are necessary to achieve more comprehensive and effective results.

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