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Existence of Technical Efficiency Level of Melon Farming with the *Greenhouse* System in East Java, Indonesia

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Abstract. Land conversion poses a major challenge to increasing melon productivity, making greenhouse technology a promising alternative. This study assesses the technical efficiency of melon farming using a greenhouse system in East Java, based on a sample of 60 farmers. The analysis employs the Stochastic Frontier Translog approach, chosen for its ability to generate varied and accurate elasticity estimates, thereby strengthening the relationship between input and output. The results demonstrate that labor, seeds, and organic fertilizers have a positive and significant effect on melon production, whereas land area, inorganic fertilizers, pesticides, and additional nutrients show no significant impact. While most farmers use production inputs efficiently, 26.67% still fail to apply them optimally. Technical efficiency achieved by melon farmers who adopt greenhouse technology is determined by the number of family dependents, extension intensity, farmer group participation, and partnership relationships. Conversely, farmers who rely solely on farming as their primary occupation tend to exhibit lower efficiency. Recommendations include promoting farmer regeneration, providing organic fertilizer subsidies, and conducting further studies on profitability, ecology, and the externalities of greenhouse technology.

Keywords: greenhouse; productivity; stochastic frontier translog; technical efficiency

INTRODUCTION

The existence of Indonesia's melon commodity production as a commodity with high consumption interest in the horticultural subsector has had a negative trend over the last five years. This is indicated by a significant decline in melon production from 2020 to 2021 of 6.54% (Direktorat Jenderal Hortikultura, 2022). In line with this, the contribution of the horticulture subsector also shows a very small contribution of 11.8% to the agricultural sector, smaller than other agricultural subsectors (Kementrian Pertanian, 2020). The fundamental thing that triggers the low level of melon production in Indonesia is the escalation of land conversion in other sectors, which occurs very massively, such as in other agricultural and development sectors. According to the Direktorat Jenderal Hortikultura (2022), productive land for productive melon farming in Indonesia amounted to 8,211 ha. However, this cannot be used as a cause for increasing melon productivity through the intensification of productive land with the adoption of renewable planting technology. The adoption of planting technology is an effective solution for increasing farm productivity, as well as increasing the income received by farmers (Felices *et al.*, 2023; Anang *et al.*, 2020; Lanamana & Fatima, 2022; Abdulai *et al.*, 2018; Tamirat & Tadele, 2023; Mulugeta & Heshmati, 2023; Puppala *et al.*, 2023)

East Java is a potential area and national melon production center with a production level of 68,527 tons.ha^{-1} and a total productive land area of 3,354 ha (Direktorat Jenderal Hortikultura, 2022). This production level does not show the existence of high melon productivity; in fact, the East Java region, in the use of productive land, cannot produce maximum melon production. Empirical evidence, when compared with other potential areas, such as Yogyakarta, has a higher productivity of 21.22% than the achievement of melon productivity in East Java of 20.43% (Direktorat Jenderal Hortikultura, 2022). The low productivity of melon farming in East Java is indicated by the disproportionate and inefficient use of

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production inputs. According to DeLay *et al.* (2022); Rhezandy *et al.* (2023); Islam *et al.* (2023); Workneh & Kumar (2023) ; Khatri-Chhetri *et al.* (2023), the efficient use of production inputs can be achieved through the effective use of appropriate technology. However, this statement is still paradoxical because, of course, the use of technology must be adapted to the geographical conditions in Indonesia in general, the use of land by farmers in Indonesia is relatively very small and certainly different from land conditions in other countries with the adoption of technology at a very broad level of land tenure. Geographical conditions of land use in Indonesia According to Kubitza *et al.* (2018) land tenure and very small land ownership by every farmer in Indonesia still dominate. The linearity of land intensification with the use of appropriate technology is a must for policymakers to have an impact on determining accurate and appropriate regulations (Geffersa *et al.*, 2019).

One alternative technology for land intensification is Greenhouse cultivation, a renewable technology-based farming method. The effectiveness of this approach has been demonstrated in enhancing crop productivity, even on limited land areas. Furthermore, this technology has proven efficient in optimizing production inputs (Mamoun *et al*., 2019; Maraveas *et al*., 2023; Felices *et al*., 2023; Nicola *et al*., 2020; Sajid *et al*., 2023; Ihoume *et al*., 2023). However, its implementation requires risk mitigation strategies, particularly in pest control, as greenhouse systems are highly susceptible to large-scale pest infestations (Felices *et al*., 2023).

Existing literature on technical efficiency in melon farming primarily focuses on traditional planting methods. Studies examining the technical efficiency of open-field or traditional melon farming yield varying results. For example, Ebukiba *et al.* (2022) found that melon farming in Nigeria's capital is technically inefficient, whereas Yekti et al (2017) concluded that melon farming in Kulon Progo Regency, Indonesia, has achieved high technical efficiency on aggregate. Although these studies were conducted in different geographical regions, the contrasting findings suggest that the technical efficiency of open-field melon farming is heavily influenced by geographical conditions and management practices. Greenhouse technology presents a more effective alternative due to its reduced dependence on weather conditions, thereby improving both production and input-use efficiency. This is supported by Irawan *et al.* (2023) and Susanto *et al.* (2023), who reported that greenhouse adoption in melon farming has positively impacted productivity.

This study contributes to the literature in two key aspects. First, it addresses a research gap by shifting focus from input efficiency in open-field melon farming, the primary emphasis of previous studies, to Greenhouse-based cultivation, which remains underexplored. Second, it employs the *Stochastic Frontier Translog* estimation method to analyze technical efficiency, offering a more flexible and robust assessment of the relationship between output and production inputs. Unlike prior studies by Ebukiba *et al.* (2022) and Yekti et al (2017), which employed the *Cobb-Douglas Stochastic Frontier* approach that does not explicitly reveal the elasticity of each input. Assessing technical efficiency in greenhouse systems is critical for evaluating the effectiveness of production inputs in melon farming. As noted by Ghimire *et al.* (2023) ; Kitole *et al.* (2024) ; Kurnia *et al.* (2024), technical efficiency measurements serve as a benchmark for innovation and policy formulation, enabling more targeted agricultural interventions. Accordingly, this study aims to estimate the technical efficiency of Greenhouse-based melon farming in East Java, Indonesia.

METHODS

This study was conducted in East Java Province, selected through a multistage sampling approach due to its status as

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Indonesia's highest melon-producing region, with a total output of 68,527 tons.ha^{-1} (Direktorat Jenderal Hortikultura, 2022). Given the limited availability of detailed data on harvested area, production volume, and the population of greenhouse melon farms, the district-level selection was guided by Cahyani *et al.* (2024), who identified Blitar Regency as the primary hub for greenhouse melon cultivation in East Java. In the final stage, Wates Subdistrict was selected as the research site, as it recorded the highest melon production in Blitar Regency 14,322 quintals in 2023 (BPS, 2024). Given the limited data on the population of greenhouse melon farmers, the sample size was determined using Cochran's formula Sugiyono (2019), with a sampling error tolerance of 12.6%. Consequently, the study comprised a total sample of 60 respondents, selected through purposive sampling based on the criterion that farmers must employ greenhouse technology for melon cultivation. Data collection was conducted from November 2023 to March 2024 via direct field observations and structured interviews, utilizing a questionnaire designed to capture socioeconomic characteristics, melon production outputs, and input utilization.

The data described to formulate the production function used in this study are Greenhouse melon production (Kg) in one harvest season, labor (HOK), Building land area (m^2), seeds (Pack), Organic fertilizer (Kg), inorganic fertilizer (Kg), Pestidisa (liter), and Nutrition (liter). This study uses the *Stochastic Frontier Translog* analysis method to determine the production factors that affect greenhouse melon production and the level of technical efficiency, as well as to estimate the factors that affect the occurrence of technical inefficiency. The technical inefficiency variable ($Vi - Ui$) is a socio-economic variable of Greenhouse melon farmers, including age (years), number of dependents (∑people), experience (years), formal education (years), *dummy* intensity of extension (1 = there is an extension, 0 = there is no extension), *Dummy* Internet access ownership (1= have, 0 = do not have), *Dummy* farmer group participation (1= follow, 0 = do not follow), *Dummy* partnership relationship with private institutions (1 = have, 0 = do not have), and *Dummy* Main occupation (1= farmer, 0 = other).

The measurement of the estimated level of technical efficiency is based on the production function used (Debertin, 1986). Most researchers who estimate the efficiency level of farming use the *Cobb-Douglas* production function approach. However, through the *Cobb-Douglas* approach, the efficiency level is homogeneous and does not vary, with a value almost equal to zero (Moss, 2022). One of the areas for improvement of this production function tends to be in input exponents that are easy to calibrate with the basic assumption that the production factors used can substitute perfectly (Corbo & Meller, 1979). This study uses the *Transcendental Logarithm (Translog)* production function approach because there is no limitation in the value of elasticity which tends to vary and the value of the estimated coefficient is relatively greater than the *Cobb-Douglas* assumption (Boisvert, 1982; Corbo & Meller, 1979; Moss, 2022; Nicola *et al.*, 2020; Forgione & Migliardo, 2023). So the *translog* production function approach has a strong level of accuracy of economic theory values and allows a very strong relationship between the output and production input relationships. The *translog* production function in Cano-Leiva *et al.* (2023) research was formed using the *Natural Logarithm (Ln)* and can be written in Equation 1.

$$Ln\,Y = Ln\alpha_0 + \sum_{i=1}^{n} \alpha_i\, Ln\, X_i + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln X_i \ln X_j \ldots\ldots\ldots \quad (1)$$

Meanwhile, the calculation of the production elasticity value can be written in Equation 2.

$$e_i = \frac{\partial ln_y}{\partial Lnx_i} = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln X_j \ldots\ldots\ldots \quad (2)$$

The production function will then be developed by combining the production

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inefficiency function due to risk and technical inefficiency, known as the *Stochastic Frontier* function (Coelli *et al.*, 2005). The *Stochastic Frontier* production function can generally be written in Equation 3.

$$Y = \exp(\beta 0 + \beta 1\ LnXi + Vi - Ui) \quad (3)$$

The form of *Stochastic Frontier Translog* modeling in this study can be written in Equation 4.

$$lnProd = \beta_0.lnC + \beta_1 lnTk + \beta_2 lnLl + \beta_3 lnBn + \beta_4 lnPo + \beta_5 lnPano + \beta_6 lnPes + \beta_7 lnNut + \beta_8.0.5.lnTk^2 + \beta_9.0.5.lnLl^2 + \beta_{10}.0.5.lnBn^2 + \beta_{11}.0.5.lnPo^2 + \beta_{12}.0.5.lnPano^2 + \beta_{13}.0.5.lnPes^2 + \beta_{14}.0.5.lnNut^2 + \beta_{15} lnTklnLl + \beta_{16} lnTklnBn + \beta_{17} lnTklnPo + \beta_{18} lnTklnPano + \beta_{19} lnTklnPes + \beta_{20} lnTklnNut + \beta_{21} lnLllnBn + \beta_{22} lnLllnPo + \beta_{23} lnLllnPano + \beta_{24} lnLllnPes + \beta_{25} lnLllnNut + \beta_{26} lnBnlnPo + \beta_{27} lnBnlnPano + \beta_{28} lnBnlnPes + \beta_{29} lnBnlnNut + \beta_{30} lnPolnPano + \beta_{31} lnPolnPes + \beta_{32} lnPolnNut + \beta_{33} lnPanolnPes + \beta_{34} lnPanolnNut + \beta_{35} lnPeslnNut + \ln(Vi - Ui) \quad (4)$$

Description: lnC (Constant), lnTk (Labor), lnLl (Building land area), lnBn (Seed), lnPo (Organic fertilizer), lnPano (Anorganic fertilizer), lnPes (Pesticide), lnNut (Nutrient).

Then to calculate the degree of sensitivity of changes in output due to changes in production inputs or estimate the level of elasticity of each production input of Greenhouse melon can be written in Equation 5 (example case of labor elasticity).

$$ep = \frac{lnProd}{lnTk} = \beta_1 + \beta_8 lnTk + \beta_{15} lnLl + \beta_{16} lnBn + \beta_{17} lnPo + \beta_{18} lnPano + \beta_{19} lnPes + \beta_{20} lnNut \ldots\ldots\ldots\ldots \quad (5)$$

The analytical tool to estimate the technical efficiency and measurement level of the *Translog* production function uses *Frontier 4.1* Software with *Maximum Likelihood Estimated* (MLE) estimation values. The test of the log-likelihood production function modeling uses the likelihood ratio test (LR test), which estimates the unrestricted (Lu) and restricted (Lr) likelihood values. The estimate will describe good production function modeling when the LR Test value > X^2 (Palm code value). The form of the equation in estimating the LR Test value, according to Coelli *et al.* (2005) can be written in Equation 6.

$$LR = -2[\text{Ln}\ L_r - \text{Ln}\ L_u] \sim X^2 \ldots\ldots\ldots\ldots \quad (6)$$

The form of production function modeling that has been statistically accepted will then be used to formulate the equation function in estimating the level of technical efficiency. The equation function for measuring technical efficiency in this study refers to the technical efficiency function developed by O'Donnell (2018) can be written in Equation 7:

$$ETi = \frac{y}{y_i} = E[\exp(-Ui)] \ldots\ldots\ldots\ldots \quad (7)$$

As for estimating the influence of technical inefficiency factors $(Vi - Ui)$ This can be written in Equation 8.

$$Vi - Ui = \delta + \delta_1 Us + \delta_2 Tang + \delta_3 Peng + \delta_4 Pend + \delta_5 IP + \delta_6 AI + \delta_7 Kkt + \delta_8 Hk + \delta_9 Pu \ldots\ldots\ldots\ldots \quad (8)$$

Description: Us (age), Tang (number of dependents), Peng (experience), Pend (education), IP (extension intensity), AI (internet access), Kkt (farmer group participation), Hk (partnership relationship), and Pu (Main occupation). The result of technical efficiency analysis ranges from 0-1 or 0<ET<1. The category of efficiency analysis results refers to the expression of Coelli *et al.* (2005) and the study of technical efficiency analysis conducted by Harianto & Keraru (2022) that farmers can be said to be efficient if they have an efficiency value ≥ 70% (0.7).

RESULTS AND DISCUSSION

Descriptive Statistic

Characteristics of melon farmers with Greenhouse system planting can be seen in **Table 1**. Both from sociodemography and the results of using inputs and outputs produced. The average age of farmers is around 47 years, implying that the age of farmers who adopt Greenhouse technology is in the productive age category. The number of family dependents is still small, and the

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average farming experience is adequate at 14 years. The education of melon farmers who adopt Greenhouse technology is 11 years or are upper secondary education graduates. However, field findings also show that 13.3% of farmers are higher education graduates. The intensity of counseling is two times in one planting, implying that extension activities still need to be more productive in providing non-formal education to melon farmers.

Table 1. Descriptive Statistics of Research Variables

Socio-Economic Variable			Production Input Variable		
Variable	**Mean**	**std error**	**Variable**	**Mean**	**Std. error**
Age	46.76667	1.55363	Production	7081	926.0225
Number of dependent	2.183333	0.135488	Labor	42.86667	3.346257
Experience	14.16667	1.772541	Land area	906.5333	110.4718
Education	10.95	0.358453	Seed	10.16667	1.065951
Extension intensity	1.7	0.301877	Organic fertilizer	1884.108	210.5992
Internet access	0.966667	0.02337	Inorganic fertilizer	46.335	7.733641
Farmer group participation	0.75	0.056374	Pesticide	1.143067	0.276382
Partnership relationship	0.4	0.063779	Nutrient	1.7932	0.770688
Main occupation	0.583333	0.064184			

Greenhouse melon farmers can access the internet on average. 75% of melon farmers actively participate in farmer group activities, and 40% partner with the private sector. Farmers utilize partnership relationships in terms of input provision and institutional relationships in melon farming marketing. The main occupation of 41.7% of melon farmers is not in the agricultural sector. This implies that melon farming with the adoption of Greenhouse technology is used as an additional income. The average production of Greenhouse melon farming is 7.08 tons with minimal labor use and land area < 1000 m^2. According to Kaleel & Ali (2024), adopting technology can minimize labor use and land resources. Greenhouse farmer behavior also showed that organic fertilizers dominated over Inorganic fertilizers during production activities. The use of pesticides is smaller than the use of nutrients, implying that the use of Greenhouse technology is done to minimize the possibility of farm failure due to plant pest attacks, as well as plant growth needs that can be properly fulfilled (Felices *et al*., 2023).

Estimation of *Stochastic Frontier Translog* Production Function

The results of the analysis of the estimation of the *Stochastic Frontier Translog* production function are shown in **Table 2**. with Maximum Likelihood Estimated (MLE) parameters and the TE Effect Model approach to determine the magnitude of the influence of production factors used on the production of Greenhouse melons and see the magnitude of the influence of socio-economic variables on the existence of their influence on increasing or decreasing technical efficiency (technical inefficiency). The analysis results show that the value of Generalized Likelihood (LR test) as a basic requirement in this analysis obtained a value of 37.97. the value is consistent and higher than the significance level obtained from the table David A Kodde And Franz C Palm 1%, 5%, and 10%. The estimation results show that the variables of labor, seedlings, and organic fertilizer have a significant influence on the yields.

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Table 2. Estimation of Stochastic Production Translog

Variable	*Maximum Likelihood Estimate*		
	Coefficient	**Std error**	**T-Ratio**
Constanta	3.1434	1.1024	2.8515***
LnTk	4.6651	0.9187	5.0780***
LnLLg	1.0871	0.7725	1.4073
LnBn	-2.1529	0.8750	-2.4605**
LnPOr	-1.7301	0.7258	-2.3836**
LnPAnor	-0.1478	0.5194	-0.2845
LnPes	-0.2035	0.4902	-0.4152
LnNut	-0.2275	0.1599	-1.4226
0.5(*LnTk*^2)	0.0525	0.4779	0.1099
0.5(*Ln*LLg^2)	-1.5493	0.2849	-5.4383***
0.5(*Ln*Bn^2)	-0.2347	0.2806	-0.8364
0.5(*Ln*POr^2)	0.1270	0.1111	1.1433
0.5(*Ln*PAnor^2)	-0.2546	0.0578	-4.4071***
0.5(*Ln*Pes^2)	0.0264	0.0131	2.0122**
0.5(*Ln*Nut^2)	-0.0261	0.0116	-2.2426**
LnTk*LnLLg	0.4580	0.2332	1.9636*
LnTk*LnBn	0.0472	0.2799	0.1686
LnTk*LnPOr	-1.0924	0.1889	-5.7838***
LnTk*LnPAnor	0.2699	0.1594	1.6940*
LnTk*LnPes	0.3483	0.0970	3.5918***
LnTk*LnNut	-0.0436	0.0303	-1.4387
LnLLg*LnBn	0.7451	0.1784	4.1764***
LnLLg*LnPOr	0.7548	0.1098	6.8731***
LnLLg*LnPAnor	0.2041	0.1055	1.9333*
LnLLg*LnPes	-0.1018	0.1007	-1.0108
LnLLg*LnNut	0.0240	0.0268	0.8941
LnBn*LnPOr	-0.0548	0.1134	-0.4836
LnBn*LnPAnor	-0.4952	0.1095	-4.5224***
LnBn*LnPes	-0.0174	0.1189	-0.1467
LnBn*LnNut	0.0378	0.0263	1.4349
LnPOr*LnPAnor	-0.0433	0.0660	-0.6563
LnPOr*LnPes	-0.0379	0.0517	-0.7319
LnPOr*LnNut	0.0001	0.0194	0.0042
LnPAnor*LnPes	-0.0284	0.0312	-0.9106
LnPAnor*LnNut	0.0205	0.0072	2.8509***
LnPes*LnNut	-0.0177	0.0101	-1.7582*
Sigma – squared	0.1330	0.0192	6.9337***
Gamma	0.9994	0.0040	247.0524***
Log-likelihood function	27.9989		
LR Test	37.9792***		
Labor elasticity	0.783125		
Seeds elasticity	0.251009		
Organic fertilizer elasticity	0.244861		

Note: ***) Significant at 1% level, **) Significant at 5% level, *) Significant at 10% level.

The labor variable has a positive influence with an elasticity value of 0.783125, which means that a 1% increase in labor expenditure can increase melon production by 0.783125%. Field findings indicate Greenhouse technology that utilizes automation during melon farming activities to replace human labor. These results prove that the use of labor in Greenhouse melon farming is very effective. According to Kaleel & Ali (2024), adopting technology can minimize labor use and land resources. Objectively, the results of field conditions during Greenhouse melon farming activities only amounted to 39% of the use of outside family labor, while the remaining 61% of Greenhouse melon farming activities could be carried out by labor within the family. The

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average use of labor during farming activities is 43 HOK. These findings underscore the importance of optimizing family labor utilization through targeted agricultural training programs. Such initiatives should prioritize capacity-building for farming families, equipping them with the necessary skills to autonomously manage greenhouse systems. This approach would enhance operational self-sufficiency while reducing reliance on external labor.

The use of melon seeds consistently shows a positive correlation relationship to melon production. This means that the increase in the number of plant seeds in Greenhouse technology by 1% affects increasing melon production by 0.251009%. Consistency with this study agrees with the results of studies Abdulai *et al.* (2018); Ebukiba *et al.* (2022); Geffersa *et al.* (2019) ; Syafrial *et al.* (2021), which assumes the production capacity of plants is determined by the number of seeds used. Field findings objectively illustrate using an average seed quantity of 10 packs with linearity in the environmental condition of the amount of land input < 1000 m^2. These results indicate that there is still room for increased production through an increase in the number of seeds under these land conditions. However, although increasing the number of seeds has a positive correlation with the escalation of melon production, rationality and adjustment to the conditions of the melon-growing environment are very important. Agricultural extension programs should emphasize training on optimal seed density management in relation to environmental carrying capacity. This educational intervention would shift farmer focus from input maximization to sustainable input optimization, thereby mitigating production losses associated with seed overuse. To a certain extent, excessive seed use in a limited growing medium will decrease plant development. The need to balance the number of plants cultivated and environmental conditions is an important factor in plant growth stimulation (Hilty *et al*., 2021).

Organic fertilizer shows its ability to increase the melon production capacity. The positive and significant influence with an elasticity value of 1.16 proves this. An additional change in the quantity of organic fertilizer by 1%, gives a positive response to the escalation of melon production in the Greenhouse plant system by 1.16. Scientifically explained by Sukendah *et al.*, (2023), the provision of organic materials will trigger a very fast plant growth rate. This study's results align with the argumentation of Shaker & Rasool (2022) regarding the positive correlation between the use of organic fertilizers and plant production. Organic fertilizer treatment in Greenhouse melon plants is essential during production activities. There was a significant difference of 90% in organic fertilizers over using inorganic fertilizers during Greenhouse melon production activities. This form of treatment is also a positive thing for the sustainability of land fertility (Sáenz *et al.*, 2024). These findings further underscore the critical role of integrating greenhouse cultivation systems with organic waste recycling from household, agricultural, and livestock sources. Such integration ensures a sustainable organic fertilizer supply while simultaneously enhancing production efficiency and maintaining soil health.

The analysis revealed that in greenhouse-based melon production systems, several conventional agricultural inputs, including land area, inorganic fertilizers, pesticides, and nutrients, demonstrated no statistically significant impact on melon production. This finding can be attributed to the fundamental operational paradigm of greenhouse technology, where technological mechanization supersedes land conditions as the primary growth determinant. Unlike traditional system or open-field cultivation where soil quality critically influences plant development (Workneh & Kumar, 2023; Huang *et al*., 2023). Greenhouse systems decouple production from inherent land

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characteristics. Similarly, the application of inorganic fertilizers, pesticides, and nutrients showed limited efficacy in greenhouse environments. Producers consciously minimize dependence on these chemical inputs due to their potential to trigger pest outbreaks while offering marginal productivity benefits. This stands in contrast to findings by Syafrial *et al.* (2021), who documented greater production sensitivity to chemical fertilizers in conventional systems. While synthetic inputs may accelerate vegetative growth, their application requires careful optimization to prevent evaporative losses that could ultimately depress yields (Asadu et al., 2024).

Examination of Technical Efficiency of Melon Farming through Greenhouse System

The analysis test on the TE Effect Model approach on the *Stochastic Frontier* Production function obtained the estimated value of the technical efficiency level of the Greenhouse system melon farming in East Java in **Figure 1**. The results showed that the use of production inputs in melon farming was technically efficient, with an average estimated value of 0.8076, higher than the estimated indicator value of 0.7. This means that using production inputs in the Greenhouse system can achieve the maximum quantity level of melon production. The review of actual conditions that refer to the average value of the technical efficiency level indicates that melon farming has a feasible production level and potential to be developed from the productivity scale. In line with this expression, it is supported by research Sajid *et al.* (2023); Mamoun *et al.* (2019); Maraveas *et al.* (2023), which confirmed that Greenhouse technology is the most careful solution in increasing the efficiency of input use. This result confirms that the occurrence of production input efficiency and escalation of productivity changes is determined by the realization of the use of technology in farming activities (Hanani *et al.*, 2023).

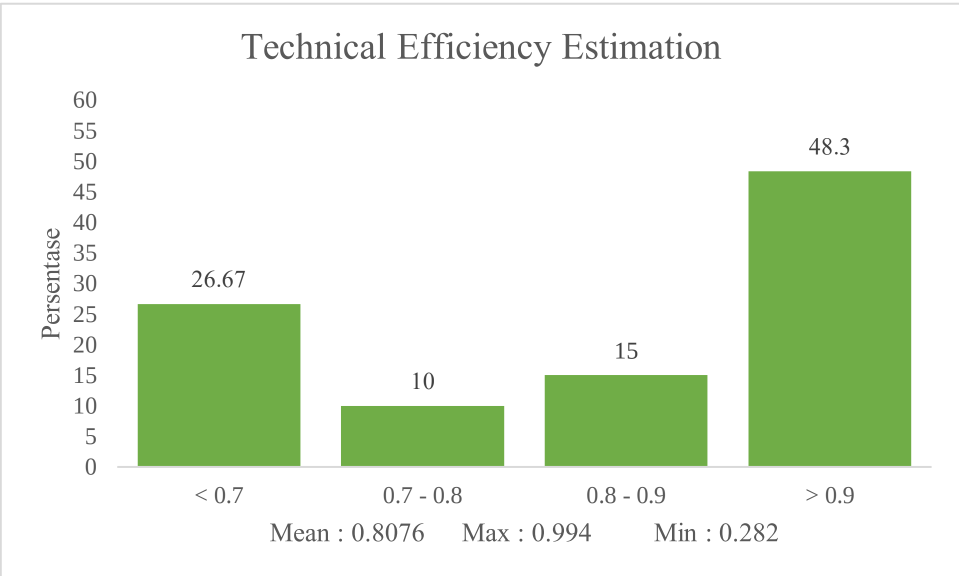

Figure 1. Estimation of Technical Efficiency Level of Greenhouse Melon Farming

Referring to the technical efficiency results obtained, the actual output by 73.3% melon farmers who have achieved technical efficiency has the opportunity to maximize the potential output value of melon production that can be achieved by 18.7% (1-(0.8076/0.994)), while the least technically efficient farmers have the potential output opportunities that can be achieved through the use of existing production factors by 71.6% (1-(0.282/0.994)). This potential output opportunity can be achieved through

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mechanization of production factors with more appropriate use (Suprapti *et al.*, 2016). 26.67% of Greenhouse melon farmers need to be more efficient. Field findings show that the rationalization of input calculations is always based on melon farmers' assumptions. Of course, this assumption will be paradoxical because the farmer's projection method uses an interpretation method based on personal perceptions and experiences, and there is no mathematical calculation system for the needs required. This condition can be justified by the research of Suprapti *et al.* (2016), which pointed out that one of the characteristics of farmers is often unable to adjust input needs to the agricultural location used. Many studies explain the low technical efficiency among farmers due to external factors such as socioeconomic (education, experience, etc.) farmers are still relatively low (Ebukiba *et al.*, 2022; Geffersa *et al.*, 2019; Ariyanto *et al.*, 2020). This study also examines the factors that cause the inefficiency of melon farmers (technical inefficiency) in applying greenhouse technology, as shown in **Table 3**. The factors causing technical inefficiency are significantly influenced by the number of family dependents, extension intensity, partnership relationship, and main occupation. Socioeconomic variables in this study, such as age, experience, education, and internet access did not have a significant effect.

The number of family dependents has a negative correlation with technical inefficiency. This means that an increase in the number of family members will impact increasing technical efficiency by 0.402%. The relationship with the increase in productivity of melon farming is that the allocation of labor in the family will be maximized in implementing Greenhouse melon farming. The previous discussion also mentioned that labor in the family is higher than labor outside the family, which means that the use of labor in the family is more intensive and productive in Greenhouse melon farming. This result can be justified based on the research of Geffersa *et al.* (2019) regarding the importance of the number of family members who play an important role in increasing farm productivity.

Table 3. Estimation of Technical Inefficiency Level of Greenhouse Melon Farming

Variable	***Maximum Likelihood Estimate***		
	Coefficient	**Std error**	**T Ratio**
Konstanta	0.4778	0.6871	0.6954
Age	0.0157	0.0107	1.4675
Number of dependent	-0.4020	0.0998	-4.0280 ***
Experience	-0.0048	0.0089	-0.5410
Education	0.0013	0.0458	0.0284
Extension intensity	-0.0702	0.0341	-2.0621**
Internet access	-0.6886	0.6027	-1.1426
Farmer group participation	-0.9355	0.2552	-3.6664***
Partnership relationship	-0.7895	0.2526	-3.1255***
Main occupation	1.1687	0.2887	4.0485***

Notes: ***) Significant at 1% level, **) Significant at 5% level, *) Significant at 10% level

Extension intensity also consistently has a negative relationship to technical inefficiency. Increasing the intensity of extension, in this case, will impact reducing inefficiency by 0.0702%. Based on information from greenhouse melon farmers, the average farmer gets a form of supervision >2 times in one planting, which implies that

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extension activities are relatively productive in providing non-formal education to greenhouse melon farmers. Extension institutions have a central role in improving the technical capabilities of farmers in the management of melon farming (Salam & Islam, 2023; Wu *et al*., 2024; Sanogo *et al*., 2023). In line with the improvement of agricultural technology, the existence of extension plays a central role in providing education to farmers, which will form an innovation based on solving farmers' problems in farming activities.

The existence of farmer groups is a positive support for farmers; in this case, showing their existence can reduce the risk of technical inefficiency with a coefficient of -0.9355. This result implies that the participation of farmer groups can support the increase in technical efficiency of Greenhouse melon farming carried out by each farmer. As many as 75% of the total sample of farmers are actively involved in farmer group activities, which are used as a forum for exchanging information and knowledge between farmers. Farmer groups will be a source of access to information and support the adoption of technology that can support the success of farming (Ghimire *et al*., 2023). Farmers with adequate farming experience will be a good source of information in the technical implementation of melon farming, as well as young farmers with a more dominant character in the knowledge of agricultural technology development (Islam *et al*., 2023). The effectiveness of farmer groups is limited to access to information and effective access to resources such as the availability of input resources obtained from government assistance or private institutions. Through the results of this study, it is necessary to strengthen the consolidation of farmer groups that become the support system for farmers in carrying out farming activities that can support the increase in productivity of melon farming.

The partnership relationship in this study had a positive impact on increasing technical efficiency by 0.7895%. The connotation of partnership relationships is often considered to have a negative correlation, as conveyed by Sudaryana & Pramesti (2018), which suggests that the dominance of private institutions that penetrate the capital aspect of farming activities has an impact on the disparity between the price of production inputs at the farm level and the general market price. The results of this study can refute this statement, which is that the process of increasing melon productivity through the adoption of greenhouse technology requires higher investment costs. As many as 40% of Greenhouse melon farmers are involved in partnerships with the private sector. Farmers utilize partnership relationships in terms of input provision and institutional relationships in melon farming marketing, in this case, the burden on farmers in the implementation of farming can be reduced.

Likewise, the main occupation of melon farmers has a negative relationship with technical inefficiency, with a coefficient of 1.1687%. The main occupation of Greenhouse melon farmers, 41.7%, is not in the agricultural sector. This implies that melon farming with the adoption of Greenhouse technology is used as an additional income. Off-farm income will make a major contribution to the capital aspect of farming activities so that the implementation of farming can be maximized due to the availability of adequate capital (Syafrial *et al*., 2021).

CONCLUSION

The estimation of the *Stochastic Frontier Translog* production function indicates that greenhouse technology in melon farming in East Java is utilized optimally. Factors such as labor, seeds, and organic fertilizers have a positive and significant effect on melon production. Melon farmers tend to optimize the use of family labor and are able to rationalize seed usage. Additionally, land extensification is not a priority for melon farmers; instead, they maximize existing land through greenhouse mechanization, which

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explains why land area does not have a significant impact on melon production in this study. The use of production inputs containing chemicals, such as inorganic fertilizers, pesticides, and nutrients, also shows no significant effect on melon production. This reflects farmers' positive behavior in supporting land sustainability and minimizing production risks. Overall, the use of production inputs in greenhouse melon farming in East Java is carried out efficiently. Approximately 73.3% of farmers fall into the category of efficient input use, with a potential production increase margin of 18.7%. Meanwhile, 26.67% of melon farmers are categorized as inefficient, with a potential output gap of 71.6%. Technical efficiency increases with the number of family dependents, which drives higher work intensity. Participation in extension programs and active involvement in farmer groups serve as important sources of information supporting the adoption of greenhouse technology, thereby enhancing technical efficiency. The partnership factor with the private sector shows a negative coefficient, while having farming as the main occupation is positively associated with technical inefficiency. This indicates that reliance on agriculture as the primary source of income has not been sufficient to offset the high costs of greenhouse technology. However, these constraints can be minimized through partnerships with the private sector.

First, it is important for extension agencies to focus on farmer regeneration by providing opportunities for young farmers to actively participate in farmer groups, who are more likely to be capable of advancing agricultural technology and innovation. Second, promotional activities in the form of organic fertilizer subsidies are highly beneficial for increasing melon production and fostering a positive attitude among farmers toward long-term environmental sustainability. Third, the authors acknowledge that this study focuses exclusively on productivity improvement. Future research should expand the scope to examine profitability, ecological impacts, social dynamics, and potential externalities associated with greenhouse technology adoption to generate more comprehensive policy and practical implications.

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