



Efficiency Scale of *Salacca zalacca* var. *amboinensis* Farming and Their Determinants

I Made Tamba¹, Nyoman Yudiarini²

^{1,2}Agribusiness Study Program, Universitas Mahasaraswati Denpasar, Bali, Indonesia

ABSTRACT: *Salacca zalacca* var. *amboinensis* planting centers are spread across several districts in Bali. The expansion of *Salacca zalacca* var. *amboinensis* farming carried out by the community and/or the thinning of old plants is believed to have changed the proportion of production factor utilization. This condition will have an impact on the achievement of *Salacca zalacca* var. *amboinensis* farming efficiency. This research aims to analyze (1) the technical efficiency and (2) scale of efficiency of *Salacca zalacca* var. *amboinensis* farming. This survey research approach was carried out in *Salacca zalacca* var. *amboinensis* production centers in Bali Province. A total of 139 respondents were determined using a quota sampling technique. Data collection was carried out through interviews with respondent farmers using a questionnaire. The collected and tabulated data was analyzed using data envelopment analysis (DEA model) to determine the technical efficiency and scale of efficiency. The average technical efficiency of *Salacca zalacca* var. *amboinensis* farming was 0.93. The average efficiency scale for *Salacca zalacca* var. *amboinensis* farming was obtained at 0.87. The efficiency scale for *Salacca zalacca* var. *amboinensis* farming is highest in the planting area >50 strata. Based on the results of this research, it is recommended that *Salacca zalacca* var. *amboinensis* farmers with a planting area of <50 acres reorganize the proportion of use of production factors in accordance with the proportion of production factors used in *Salacca zalacca* var. *amboinensis* farming with a planting area of >50 acres. The technical efficiency of *Salacca zalacca* var. *amboinensis* farming is more influenced by management intensity and targeted inputs than by land expansion or quantitative increases in inputs such as fertilizers.

KEYWORDS: Scale efficiency, *Salacca zalacca* var. *amboinensis* farming, technical efficiency.

INTRODUCTION

Salacca zalacca var. *amboinensis* (Salak Bali) is a type of local fruit that has been a biological treasure for generations. The community has inherited *Salacca zalacca* var. *amboinensis* as a source of income from the agricultural sector, which must be preserved and developed sustainably. It is very urgent that the *Salacca zalacca* var. *amboinensis* cultivation pattern be internalized in the behavior of farmers so that they are able to provide adequate care for their salacca plants. In the last five years, *Salacca zalacca* var. *amboinensis* production has increased by 5.52% from the original production of 256,396 quintals in 2019 to 270,558 quintals in 2023 ¹.

Nowadays *Salacca zalacca* var. *amboinensis* planting centers have spread across several districts in Bali. Many new areas of salacca plantations have been opened by the community in an effort to expand and develop salacca as a commodity that has economic, social, and cultural value. Rai et al. ² stated that the salacca plant is one of the local Balinese fruits that, besides having economic value, also has social and cultural value. Its multiple-use value is a driving factor in the development of *Salacca zalacca* var. *amboinensis* in several new planting areas. *Salacca zalacca* var. *amboinensis* has now become one of the superior fruits of Bali Province ³. The stretch of *Salacca zalacca* var. *amboinensis* farming has developed into an agritourism area that has competitive advantages ⁴. It is not an exaggeration to say that, in the course of managing *Salacca zalacca* var. *amboinensis* farming, many farmers make various efforts, both intensification and extensification. Activities carried out include rejuvenating plants, expanding planting areas, or even reducing the number of plants and planting areas.

The expansion of *Salacca zalacca* var. *amboinensis* plantations that many people have carried out and also the thinning of old plants, of course, change the proportion of production factors used. These conditions will have an impact on the achievement of the scale of efficiency and economic scale of *Salacca zalacca* var. *amboinensis* farming. In fact, efficiency and economic scale really determine the level of profit from *Salacca zalacca* var. *amboinensis* farming. Many observers of *Salacca zalacca* var. *amboinensis* farming have published the results of their research regarding the performance of *Salacca zalacca* var. *amboinensis* farming, as a



form of contributing to the development of *Salacca zalacca var. amboinensis* farming including⁵⁻⁹. Meanwhile, studies on the efficiency and economic scale following the expansion of *Salacca zalacca var. amboinensis* plantations have not been carried out. In order to contribute innovation as a solution to the problems faced by *Salacca zalacca var. amboinensis* farmers, it is very urgent to conduct a study of the efficiency and economic scale of the *Salacca zalacca var. amboinensis* farming business. The aim of this research is to analyze (1) the technical efficiency of *Salacca zalacca var. amboinensis* farming and (2) the scale of efficiency of *Salacca zalacca var. amboinensis* farming.

METHODS

The study was conducted by survey-based research in seven districts in Bali, including Badung, Gianyar, Klungkung, Karangasem, Bangli, Tabanan, and Buleleng regencies. The determination of respondents was carried out using the quota sampling technique with a total of 139 respondents who were then positioned as the decision-making unit (DMU) of the *Salacca zalacca var. amboinensis* farming. Data collection was carried out through interviews with respondent farmers in the *Salacca zalacca var. amboinensis* farming using a structured questionnaire. The data collected through questionnaires method was organized by a tabulating process. Both raw data sets were analyzed using statistical analysis. The technical efficiency of *Salacca zalacca var. amboinensis* farming were analyzed using data envelopment analysis (DEA). The used model was DEA-CCR with constant return to scale approach and variable return to scale with input orientation.

The constant return to scale model with input orientation is used model from CCR (Charnes, Cooper, Rhodes). The specification of mathematical equation was made as follows:

Multiplier Form

$$\max z = \sum_{r=1}^s \mu_r y_{ro}$$

Refer to

$$\begin{aligned} \sum_{r=1}^s \mu_r y_{rj} - \sum_{i=1}^m V_i x_{ij} &\leq 0 \\ \sum_{i=1}^m V_i x_{io} &= 1 \\ \mu_r, V_i &\geq \varepsilon > 0 \end{aligned}$$

With

$$i = 1, 2, \dots, m;$$

Envelopment Form

$$\min \theta - \varepsilon \left(\sum_{i=1}^m s_i^- + \sum_{s=1}^s s_r^+ \right)$$

Refer to

$$\begin{aligned} \sum_{j=1}^n x_{ij} \lambda_j + s_i^- &= \theta x_{io} \\ \sum_{j=1}^n x_{rj} \lambda_j + s_r^+ &= y_{ro} \\ \lambda_j &\geq 0 \end{aligned}$$

$$r = 1, 2, \dots, s;$$

$$j = 1, 2, \dots, n;$$

Meanwhile, the equation from BCC (Banker, Charnes, Cooper) is used in the variable return to scale equation. The mathematical equation can be written as follows:

Multiplier Form

$$\max z = \sum_{r=1}^s \mu_r y_{ro} + \mu_o$$

Refer to

$$\begin{aligned} \sum_{r=1}^s \mu_r y_{rj} + \mu_o - \sum_{i=1}^m V_i x_{ij} &\leq 0 \\ \sum_{i=1}^m V_i x_{io} &= 1 \end{aligned}$$

Envelopment Form

$$\min \theta - \varepsilon \left(\sum_{i=1}^m s_i^- + \sum_{s=1}^s s_r^+ \right)$$

Refer to

$$\begin{aligned} \sum_{j=1}^n x_{ij} \lambda_j + s_i^- &= \theta x_{io} \\ \sum_{j=1}^n x_{rj} \lambda_j + s_r^+ &= y_{ro} \end{aligned}$$



$$\mu_r, V_i \geq \varepsilon > 0$$

$$\sum_j^n \lambda_j = 1, \text{ dan } \lambda_j \geq 0$$

With

$$i = 1, 2, \dots, m;$$

$$r = 1, 2, \dots, s;$$

$$j = 1, 2, \dots, n;$$

The efficiency scale is obtained by the formula ¹⁰:

$$SE = \frac{TE_{CRS}}{TE_{vRS}}$$

SE = 1 indicates full scale efficiency;

SE < 1 indicates inefficiency

Remarks:

SE = scale of economic

TE_{CRS} = Technical Efficiency constant return to scale

TE_{vRS} = Technical Efficiency variable return to scale

To analyze the determinants of technical efficiency in *Salacca zalacca var. amboinensis* farming, a beta regression model was used, which is a quantitative approach to analyzing the factors that influence technical efficiency (in the range of 0 and 1) in *Salacca zalacca var. amboinensis* farming. Beta regression is an appropriate method when the dependent variable is a proportion that lies exclusively between 0 and 1 (Ferrari & Cribari-Neto, 2004). This model considers the beta distribution as a flexible probability distribution to capture heteroscedasticity and asymmetry in proportional data. Parameter estimation is performed using maximum likelihood estimation (MLE).

In general, beta regression models the conditional mean of the response variable $y_i \in (0, 1)$ as a function of covariates through the logit link transformation:

$$\text{logit}(\mu_i) = \eta_i = \mathbf{x}_i^T \boldsymbol{\beta}$$

where:

μ_i is the mean of the beta distribution for the i^{th} observation

η_i is the linear predictor

\mathbf{x}_i is the covariate vector

$\boldsymbol{\beta}$ is the regression coefficient vector

The full distribution of y_i is defined as:

$$y_i \sim \text{Beta}(\mu_i \phi, (1 - \mu_i)\phi)$$

where ϕ is the precision parameter, which controls the dispersion of the beta distribution; the larger ϕ , the smaller the dispersion of the values y_i around μ_i .

Using this estimation method, the empirical model in this study is formulated as follows:

$$\text{logit}(\mu_i) = \beta_0 + \beta_1 \ln(\text{Land area}_i) + \beta_2 \ln(\text{quantity of salacca plant}_i) + \beta_3 \ln(\text{quantity of fertilizer}_i) + \beta_4 \ln(\text{quantity of Labor}_i)$$

where:

μ_i : technical efficiency of *Salacca zalacca var. amboinensis* farming

$\ln(\text{land area}_i)$: natural logarithm of land area (hectares)

$\ln(\text{quantity of salacca plant}_i)$: natural logarithm of the number of salacca plants (stems)



$\ln(\text{quantity of fertilizer}_i)$: natural logarithm of fertilizer use (kg)

$\ln(\text{quantity of labor}_i)$: natural logarithm of labor (work daily)

β 's coefficients are estimated using MLE, and the precision parameter values ϕ are also modeled using the following model:
 $\log(\phi_i) = \gamma_0$

The logit coefficient values indicate the direction and strength of the influence of each variable on the average technical efficiency. For example, an increase in the log of the number of salacca plants significantly increases technical efficiency, while an increase in fertilizer use actually decreases technical efficiency, indicating the potential for overuse or misallocation of these inputs.

All estimations were performed using Python software with the statsmodels library, specifically the BetaModel module for beta regression. Model diagnostics, log-likelihood values, AIC, and BIC were used to evaluate model quality. Variable descriptions are presented in Table 1.

Table 1. Variable Descriptions

No.	Variable	Definition	Unit	Type	Source
1	Technical efficiency (Y)	Producing the maximum possible output from a given set of inputs or using the minimum inputs to achieve a specific output		Discret	Data analysis
2	Land area (X1)	Total cultivated area used for the salacca	Acres	Continuous	Survey data
3	Quantity of salacca plants (X2)	Total population of salacca cultivated	Trees	Continuous	Survey data
4	Quantity of fertilizer (X3)	Total number of fertilizer used	kg	Continuous	Survey data
5	Quantity of labor (X4)	Total labor days allocated to salacca farming	(working days)	Continuous	Survey data

RESULT AND DISCUSSION

Characteristics of Salacca zalacca var. amboinensis Farming

Salacca zalacca var. amboinensis farming can operate through the collaboration of several production factors, such as: land, plants, fertilizer, and labor. The contribution of endowment factors certainly cannot be ignored, and these factors greatly determine the success of *Salacca zalacca var. amboinensis* farming. The ability to orchestrate production factors also greatly influences the achievement of farming success. The characteristics of *Salacca zalacca var. amboinensis* farming can be described as presented in **Table 1**.

Table 1. Descriptive Statistics of Salacca zalacca var. amboinensis Farming

Description	Unit	Minimum	Average	Maximum	SD
Land Area	acres	15.00	68.55	250.00	52.48
Quantity of plants	trees	305.00	1,492.23	5,050.00	112,603.00
Quantity of fertilizer	Kg	32.00	186.48	700.00	140.38
Quantity of labor	Manpower	8.00	45.21	110.00	16.75
Production	Kg	457.50	4,334.95	17,675.00	3,704.99

The area of *Salacca zalacca var. amboinensis* farming cultivated by farmers varies from 15 acres to 250 acres, with an average of 68.55 acres. The number of plants cultivated ranges from 305 trees to 5,050 trees. The average annual production is 4,334.95 kg per average farming area of 68.55 acres, or 64675.35 kg per hectare. *Salacca zalacca var. amboinensis* has two harvest seasons: the main harvest season (January to March) and the low harvest season (July to September).



Technical Efficiency and Scale Efficiency of *Salacca zalacca* var. *amboinensis* Farming

The planting area of *Salacca zalacca* var. *amboinensis* farming managed by farmers varies from 15 acres to 250 acres. To provide a more detailed description of the technical efficiency and scale of efficiency of *Salacca zalacca* var. *amboinensis* farming, the planting area is classified into three strata, namely planting area <25 acres, planting area 25 acres to 50 acres, and planting area > 50 acres. The results of the analysis of the technical efficiency of *Salacca zalacca* var. *amboinensis* farming are presented in Table 2.

Table 2. Efficiency Estimation of *Salacca zalacca* var. *amboinensis* Farming Techniques According to Planting Area Strata

Planting Area Strata	Value	Minimum	Average	Maximum	SD
Planting area < 25 acres	TE _{CRS}	0.4905	0.6392	0.8571	0.0969
	TE _{VRS}	0.7024	0.8105	1.0000	0.0763
	SE	0.4905	0.7876	0.8571	0.0969
Planting area 25 – 50 acres	TE _{CRS}	0.5714	0.7928	0.9944	0.1223
	TE _{VRS}	0.7986	0.8869	1.0000	0.0682
	SE	0.5714	0.8907	0.9944	0.0896
Planting area > 50 acres	TE _{CRS}	0.7483	0.9153	1.0000	0.0601
	TE _{VRS}	0.7687	0.9347	1.0000	0.0543
	SE	0.9399	0.9791	1.0000	0.0191

Remarks:

SE = scale of economic

TE_{CRS} = Technical Efficiency constant return to scale

TE_{VRS} = Technical Efficiency variable return to scale

The average technical efficiency of *Salacca zalacca* var. *amboinensis* farming (TE_{CRS}) for the <25 planting area strata is 0.6392, indicating a relatively low level of technical efficiency. The lowest level of technical efficiency in this planting area strata is 0.4905. This showed the low level of efficiency of a set of resources used in the production process. In such conditions, relatively high inefficiency occurs. This inefficiency factor is certain to be very detrimental to the existence of *Salacca zalacca* var. *amboinensis* farming due to the suboptimal use of resources. In fact, farmers can optimize the use of their inputs to be at the same production level. The technical efficiency of *Salacca zalacca* var. *amboinensis* farming can be increased if the level of inefficiency can be reduced in total. The results of the study showed that out of 29 respondents who were *Salacca zalacca* var. *amboinensis* farmers in this planting area strata, only 4 respondents (13.79%) provided intensive maintenance to the *Salacca zalacca* var. *amboinensis* farming, while the other 25 respondents (86.21%) stated that they only came to their farms when their salacca plants were bearing fruit.

The average technical efficiency of *Salacca zalacca* var. *amboinensis* farming (TE_{CRS}) for the stratum of planting area of 25 to 50 was obtained at 0.7928, indicating a relatively high level of technical efficiency. However, the technical efficiency of *Salacca zalacca* var. *amboinensis* farming for the stratum of planting area of 25 to 50 can still be improved if the level of inefficiency can be reduced in total (9.41%) so that the technical efficiency will increase to 0.8869 (TE_{VRS}). In this stratum of planting area, there is no *Salacca zalacca* var. *amboinensis* farming that operates optimally, so there is a relatively large potential to increase production if farmers provide adequate maintenance, especially in regulating the combination of the use of production factors.

The average technical efficiency of *Salacca zalacca* var. *amboinensis* farming (TE_{CRS}) for the stratum of planting area > 50 was 0.9153, indicating a high level of technical efficiency. In this stratum, it is indicated that most farmers have fully realized the importance of plant maintenance that is adaptive to innovation and technological developments. It is confirmed that most farmers provide intensive maintenance for *Salacca zalacca* var. *amboinensis* plants. It means innovation has a significant impact on increasing production achievements and the competitive advantages of *Salacca zalacca* var. *amboinensis*¹¹. The level of inefficiency in the strata of planting area >50 is relatively low at only 1.94%. By reducing the inefficiency that occurs, the efficiency of the *Salacca zalacca* var. *amboinensis* farming technique in the strata of planting area >50 will increase to 0.9347.



The technical efficiency of the *Salacca zalacca var. amboinensis* farming business in the <25 acres planting area strata is the lowest, while the >50 acres planting area strata has the highest technical efficiency. This fact indicates that in the wider *Salacca zalacca var. amboinensis* farming, it tends to have higher technical efficiency. The results of this study are in line with the findings of Čechura et al (2022), which state that the smallest producers lag far behind the largest producers due to the scale effect^{12,13}. This is in accordance with the sincere confession of several farmers in the <25 acres planting area strata who stated that they only come to their farms when their *Salacca zalacca var. amboinensis* plants bear fruit. Managing the *Salacca zalacca var. amboinensis* farming in the narrow planting area strata is considered less profitable. They do not carry out proper maintenance on the *Salacca zalacca var. amboinensis* plants. The activities of fertilization, irrigation, weed control, pruning, pest control, and disease control escape the attention of most farmers in this planting area. Further indications from this phenomenon are that the *Salacca zalacca var. amboinensis* plants are not due to maintenance but to the support of endowment factors. In such conditions, the *Salacca zalacca var. amboinensis* plants grow and develop naturally, so the resulting production tends to be below average. In this regard, government support and improvement of farming facilities is a solution for small-scale agriculture¹⁴.

In line with the technical efficiency conditions, the efficiency scale indicators show almost the same symptoms. The stratum of planting area <25 has the lowest efficiency scale, followed by the stratum of planting area 25 to 50 in second place, and then the highest efficiency scale is the stratum of planting area >50. This finding indicates that the *Salacca zalacca var. amboinensis* farming requires a certain planting area in order to achieve an optimal efficiency scale. Optimization of the efficiency scale is very urgent to provide maximum profit to *Salacca zalacca var. amboinensis* farmers. The components of production factors need to be arranged in a combination of their utilization in the production process so as to produce an optimal combination, which is then expected to lead to maximum profit. The combination of the utilization of production factors must take into account the dynamics of the prices of each production factor involved in the production process. In studies examining drivers of agricultural productivity, accurately identifying and estimating the factors contributing to productivity growth is critical for designing effective agricultural policies. For instance, Le Clech and Fillat-Castejón (2020) highlight the importance of detailed analysis of productivity drivers such as efficiency improvements and technological change to understand agriculture's total factor productivity and its evolution¹⁵. Additionally, empirical research on technical efficiency in agriculture shows that socio-economic and environmental factors significantly influence efficiency outcomes. According to Nowak et al. and related literature, soil quality, the age of the household head, and investment costs (surcharges) have been found to have positive effects on the technical efficiency of agricultural production, underscoring the need to include both biophysical and human capital variables in efficiency analysis^{14,15}.

The efficiency scale refers to the optimal efficiency scale (SE = 1) for the stratum of planting area <25, which is 0%. This means that all farming units have not been optimal in applying production technology to combine production factors, so that the expected production target has not been achieved. The impact at the micro level is that it is certain that all farming units have not been able to achieve profit maximization, so the development of *Salacca zalacca var. amboinensis* farming is relatively stagnant.

The same thing also happened in the *Salacca zalacca var. amboinensis* farming business in the 25- to 50-acres planting area strata where there were no *Salacca zalacca var. amboinensis* farming units operating at the optimal efficiency scale (SE = 1). This means that all *Salacca zalacca var. amboinensis* farming units in this planting area strata are in a technically inefficient condition, so that the expected production target has not been achieved. This condition has an impact on the inability of all *Salacca zalacca var. amboinensis* farming units to achieve profit maximization, so that capital fertilization for the development of *Salacca zalacca var. amboinensis* farming is hampered.

The efficiency scale refers to the optimal efficiency scale (SE = 1) for the planting area strata >50, which is 16.36%. This means that only 16.36% of farmers have achieved optimal conditions for utilizing their production factors. As many as 83.64% of farmers are not optimal or are in a technically inefficient condition, so that the expected production target has not been achieved. The impact at the micro level is that 83.64% of farming units are indicated as unable to achieve profit maximization, so that *Salacca zalacca var. amboinensis* farmers do not receive significant incentives.

The results of the t-test on the average technical efficiency between farming units in the <25 acres strata and other planting area strata farming units show that farming units in the planting area strata >50 have the highest technical efficiency significantly compared to other planting area strata farming units. This means that to produce the same level of output, *Salacca zalacca var. amboinensis* farming in the planting area strata >50 uses a relatively smaller quantity of input. The results of this study indicates



that profitable production can be achieved by increasing the scale of production by increasing the size of the land or by collaborating between two or more agricultural lands ¹⁸.

Scale Efficiency and Return to Scale of Salacca zalacca var. amboinensis Farming

The average cumulative technical efficiency (TE_{CRS}) of *Salacca zalacca var. amboinensis* farming is 0.8092, while the cumulative expected technical efficiency (TE_{VRS}) is 0.9294 (Table 3), so there is an inefficiency of 12.02%. This inefficiency factor is likely to significantly hinder the production achievements, which explains why the cumulative production level hasn't reached its maximum potential. However, the cumulative technical efficiency can still be improved if the inefficiency level of 12.02% can be reduced in total, so that the cumulative technical efficiency of *Salacca zalacca var. amboinensis* farming will increase to 0.9294. The occurrence of technical inefficiency conditions is due to the inaccuracy of the size of the farming business, and if a farming unit moves towards the optimal size, then efficiency achievement can be improved at the same level of technology application ¹⁹. Synergistic collaboration among all farmers is a sufficient requirement to develop a strategy for implementing a strong and efficient *Salacca zalacca var. amboinensis* farming.

Table 3. The Cumulative of Efficiency Scale

Score TE	Technical Efficiency		
	TE _{CRS}	TE _{VRS}	SE
Minimum	0.4906	0.7687	0.4906
Mean	0.8092	0.9294	0.8732
Maximum	1.0000	1.0000	1.0000
SD	0.1401	0.0689	0.1459
TE _{VRS} = 1	29.50%		
SE = 1	6.47%		

Remarks:

SE = scale of economic

TE_{CRS} = Technical Efficiency constant return to scale

TE_{VRS} = Technical Efficiency variable return to scale

The efficiency scale is the potential productivity achievement from the optimal size of the decision-making unit (DMU). If DMUs move towards an optimal size, then overall efficiency can be improved at the same level of technology implementation because some of the inefficiency refers to inappropriate DMU sizes. The average cumulative efficiency scale was obtained at 0.8732. This figure means that the achievement of the efficiency scale of *Salacca zalacca var. amboinensis* farming is not yet optimal, so there is still room to reorganize the use of production factors in such a way as to achieve optimal conditions. The efficiency scale refers to the optimal efficiency scale (SE = 1), which is cumulatively 6.47%. This means that only 6.47% of *Salacca zalacca var. amboinensis* farming units have reached optimal conditions for utilizing their production factors. As many as 93.53% of *Salacca zalacca var. amboinensis* farming units have not been optimal in implementing production technology to combine production factors, so that the expected production targets have not been achieved. Of the 93.53% of *Salacca zalacca var. amboinensis* farming units that are not yet technically efficient, it turns out that 61.87% are increasing returns to scale and 31.66% are decreasing returns to scale (Table 4). The *Salacca zalacca var. amboinensis* farming unit, which is in a condition of increasing returns to scale, needs to move to increase its use of inputs in such a way that it reaches an optimal size, while the *Salacca zalacca var. amboinensis* farming unit, which is in a condition of decreasing returns to scale, needs to reduce its use of inputs in such a way that it reaches an optimal size.

Table 4. Efficiency Scale and Return to Scale of *Salacca zalacca* var. *amboinensis* Farming

Type of Return to Scale	Number of <i>Salacca zalacca</i> var. <i>amboinensis</i> farming units	Percentage (%)	Efficiency Scale
Increasing return to scale	86	61.87	0.87
Constant return to scale	9	6.47	1.00
Decreasing return to scale	44	31.66	0.85
Cumulative	139	100.00	0.87

Based on the data in Table 4, which shows that the majority of *Salacca zalacca* var. *amboinensis* farming units are in a condition of increasing returns to scale, this is in line with the recognition of some farmers who relatively rarely and never even provide a touch of maintenance to *Salacca zalacca* var. *amboinensis* plants. They stated that they did not fertilize, did not prune the midribs of *Salacca zalacca* var. *amboinensis* leaves, did not do weeding, and did not control pests and diseases. *Salacca zalacca* var. *amboinensis* plants really need adequate maintenance so that they can produce optimally⁵. Systematic steps are needed to carry out detailed identification of all components involved in the production process to produce optimal synergy while increasing scale efficiency. Rearranging the production scale and also the combination of input use is an absolute requirement for achieving optimal efficiency. Each farmer is required to have special notes on each technology application so that they can be used as a basis for information in carrying out evaluations and developing continuous corrective actions. The weakness recorded by some farmers is the lack of complete farming records related to technology applications and farming management.

Determinants of Technical Efficiency in *Salacca zalacca* var. *amboinensis* Farming

Several variables are thought to influence the technical efficiency of *Salacca zalacca* var. *amboinensis*, namely land area (acre), quantity of salacca plants (trees), quantity of fertilizer (kg), and quantity of labor (working days). Beta regression analysis reveals that several variables such as land area, number of salacca plants, fertilizer, and labor have a statistically significant relationship with the technical efficiency of *Salacca zalacca* var. *amboinensis* farming (Table 6). Significant negative or positive coefficients indicate that the direction of the variable's influence on technical efficiency is systematically decreasing or increasing. Based on the coefficient values, several insights can be drawn, namely:

1. Land area has a negative effect on technical efficiency, indicating that the larger the area of land used, the lower the technical efficiency.
2. The quantity of salacca plants has a positive effect, meaning that intensification of planting (number of plants per unit of land, or plant density) increases efficiency.
3. Fertilizer shows a negative effect, meaning that more intensive fertilizer use is inversely proportional to technical efficiency.
4. Labor has a positive effect, indicating that an increase in labor in proportion to technical efficiency output increases efficiency.

In addition, the positive and significant precision-1 parameter indicates a stable model fit for beta regression, although it is not analyzed further here. The negative coefficient for land area indicates a phenomenon often found in the literature where larger agricultural land areas can reduce technical efficiency. This is consistent with many studies showing that larger scales often reduce managerial intensity, quality control, and attention per unit of land, thereby reducing efficiency. Arable land per hectare actually reduced the technical efficiency of cereal production by 44.7% (negative elasticity), while labor and fertilizer had positive contributions (labor 51.5%, fertilizer 5.7%)²⁰. Large-scale management structures often lead to a lack of micro-supervision and suboptimal use of inputs, thereby reducing efficiency.

Empirical research on agricultural productivity also shows that increases land areas without adjustments in technology and labor, input intensity per unit decreases, reducing marginal returns and output efficiency (due to imprecise management)²¹. This motivates the negative coefficient of Land Area in the model regarding area expansion without proportional increases in managerial inputs and local labor, causing technical efficiency to weaken.

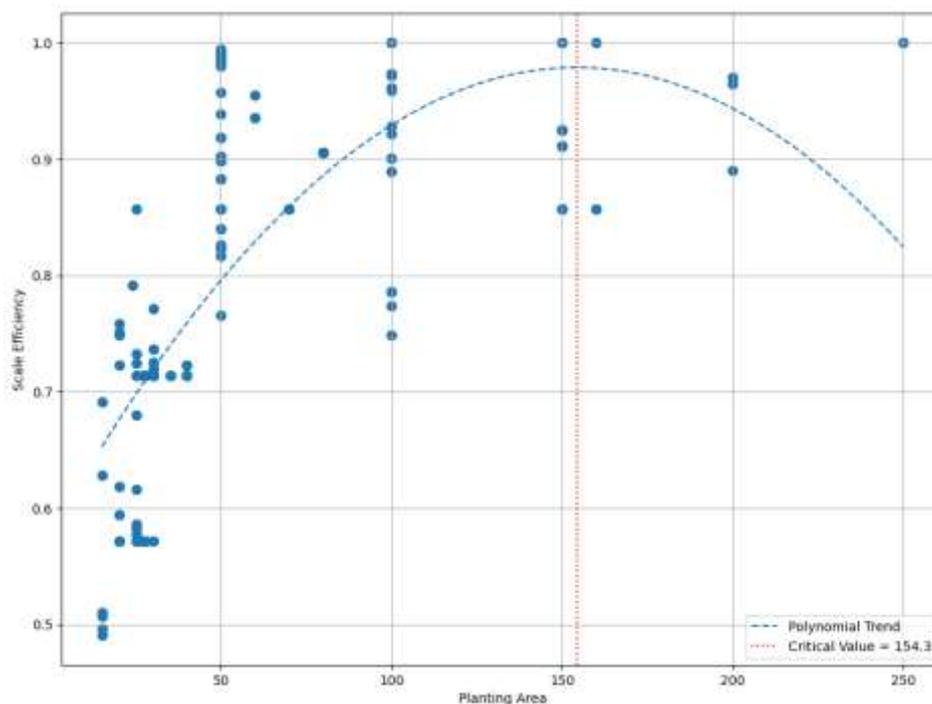


Figure 1. Relationship between Land Area and Technical Efficiency

Looking at the curve relating technical efficiency and the area of *Salacca zalacca var. amboinensis* farming, it can be interpreted that technical efficiency increases as land area increases up to around 154.26 acres (Figure 1 **Error! Reference source not found.**). At this early stage, land expansion is beneficial because it helps *economies of scale*, reduces fixed costs per unit of output, and may allow for more efficient crop rotation or space management. However, once land use exceeds this point, technical efficiency actually declines. This decline can be explained by limitations in managerial capacity, a lack of labor to manage larger areas, or a decrease in input intensity per unit area, which has a negative impact on yield and technical efficiency.

Theoretically, this phenomenon is closely related to the concept of returns to scale in production economics. When the scale of production is expanded, efficiency can increase (*increasing returns*), remain *constant* (*constant returns*), or decrease (*decreasing returns*). This graph shows a transition from increasing returns to decreasing returns after the land is expanded beyond the optimal point. This theory is also often found in empirical agricultural studies, where the relationship between land size and technical efficiency is not always linear. Research by Alvarez & Arias, (2004), for example, shows that technical efficiency often declines among farmers with excessively large land holdings if it is not accompanied by an increase in managerial inputs or adequate labor²².

From an agronomic perspective, managing excessively large areas of land can make it difficult to implement intensive cultivation practices such as pruning, precision fertilization, or detailed pest control. This is especially true if land expansion is not balanced with an increase in labor or appropriate mechanization. As a result, attention to detail in each part of the land decreases, thereby reducing technical efficiency as a comparison between input and output²³.

The findings from this graph show that for the context of *Salacca zalacca var. amboinensis* farming, the optimal land area for maximum technical efficiency is around 154.26 units of area. Above this value, the risk of inefficiency increases due to managerial and technical factors that are not proportional to the scale of the land. Therefore, policies and recommendations to farmers should consider this optimal limit, and if expansion is still carried out, it needs to be accompanied by increased management capacity, precision agricultural technology, and labor so that efficiency is maintained. This graph is quantitative evidence that in agriculture, bigger is not always better, and that the optimal production limit is not only a matter of crop yield but also the efficient use of resources.

Furthermore, the positive coefficient of the number of *Salacca* plants reflects that increasing the density of salacca planting per unit of land tends to increase technical efficiency. This is in line with the concept of planting intensification, which, when carried out with proper management, can maximize land use, reduce idle space, and produce higher output for a given input. Although there is no specific literature on salacca farming, meta-regression shows that, in general, inputs such as quality seeds or intensification often have a positive effect on technical efficiency in agriculture in many developing and developed countries²⁴. This intensification can take the form of using superior varieties, equalizing planting distances, and the like.

A contradictory situation arises again with regard to the negative impact of fertilizers. This may seem paradoxical, as fertilizers are often assumed to increase production. However, this shows that in this context, an increase in fertilizer consumption on a weighted scale results in decreased efficiency. Possible causes include *over-application* (excess fertilizer) leading to physical inefficiency or environmental degradation; or that farmers add fertilizer in response to less productive land, rather than as a means of intrinsically improving efficiency. A study in China on organic fertilizer substitution concluded that the use of more environmentally friendly fertilizers increases efficiency by about 9.5% compared to the use of conventional chemical fertilizers, because suboptimal chemical use actually reduces farmers' technical efficiency²⁵. This means that more fertilizer is not necessarily more efficient if it is not accompanied by optimal application techniques and land compatibility.

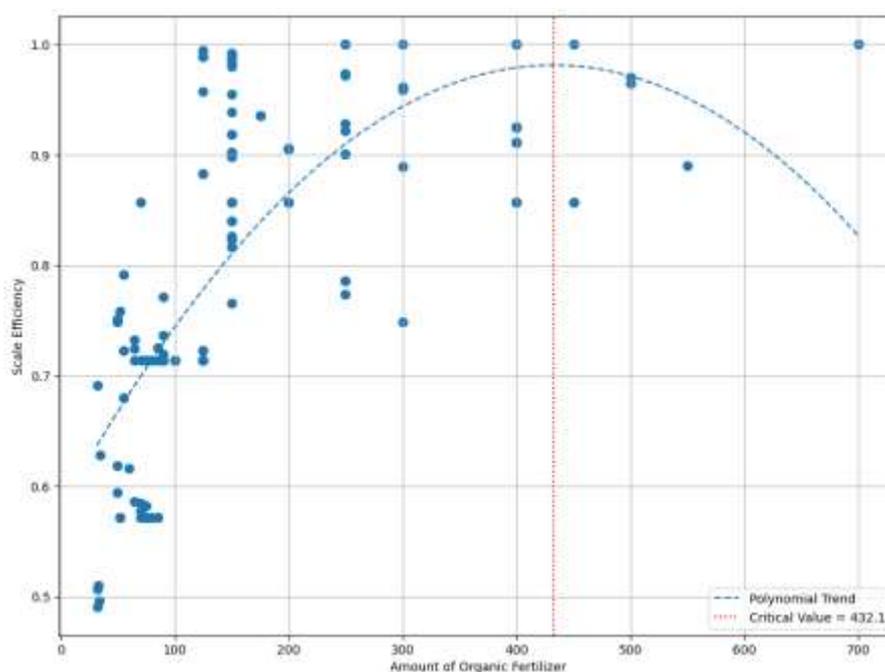


Figure 2. Relationship between Fertilizer Intensity and Technical Efficiency

Delving deeper into the relational connection, the graph shows the relationship between the amount of fertilizer used and the technical efficiency of *Salacca zalacca* var. *amboinensis* farming (Figure 2). Based on the second-order polynomial trend curve added to the scatter plot, it is clear that the relationship between the two forms a downward-curving nonlinear pattern (*inverted U-shape*). At the beginning of the curve, an increase in the amount of fertilizer correlates positively with an increase in technical efficiency, which means that at this stage, each additional fertilizer is still able to efficiently drive an increase in productivity per unit of input. However, after passing the peak point of the curve, which is empirically located at 432.07 kg, the direction of the relationship changes: the addition of fertilizer actually causes a decrease in technical efficiency. This point becomes the optimal limit for fertilizer use, indicating the maximum amount of input that can still contribute positively to technical efficiency.

This phenomenon is very much in line with the classical production economics principle known as *the law of diminishing returns*. In the context of agriculture, this law states that if one input is continuously added while other inputs remain



constant (such as land and labor), the additional output produced will be smaller and at a certain point may even be negative. In this case, fertilizer, which functions as an initial production input, initially contributes significantly to technical efficiency. However, when the amount exceeds the needs of the plants, its effectiveness decreases. In addition, agronomic aspects also play a role, where over-fertilization or excessive fertilizer application can cause negative effects on plants and the environment, such as nutrient toxicity, increased soil salinity, disruption of microorganisms, and reduced nutrient uptake by plant roots²⁶. These factors not only reduce efficiency but can also have a long-term impact on crop yields and soil quality.

Previous studies have confirmed similar findings, fertilizer use above the optimal limit reduces the technical efficiency of rice farmers due to input waste and environmental damage. The study emphasizes that input optimization, rather than maximization, is the key to productive and sustainable agriculture. Therefore, the critical point of 432.07 shown in this graph can be used as an important guideline in formulating fertilization policies for salacca farmers. Fertilizer amounts below this figure allow for maximum technical efficiency, while use above this figure risks reducing efficiency due to excess inputs.

In practice, this information can be used to develop more precise fertilizer dosage recommendations based on agroecological zones. This data-driven approach is far more effective than uniform general recommendations, as it considers saturation points and the specific response of plants to inputs. Farmers who are able to adjust fertilizer doses to soil characteristics, salacca variety types, and plant growth stages will be better able to maintain technical efficiency and the sustainability of their agricultural systems. Therefore, these findings have important implications, not only in an academic context, but also for modern agricultural practices that prioritize resource efficiency and environmental sustainability.

In the last variable, the positive coefficient of Labor Input indicates that an increase in labor (per unit of output) in logarithmic terms actually increases technical efficiency. This is show that the contribution of labor to increasing technical efficiency is very large, around 51.5%, and is very sensitive to changes in climate productivity²⁰. Furthermore, Chinese panel literature shows that labor and capital inputs such as fertilizers directly affect positive agricultural output technical efficiency, provided they are managed properly. The important role of labor in manually caring for crops, controlling pest attacks, and harvesting on time is a strong reason for the positive coefficient.

Policy Recommendations

The pattern of coefficients in this model reflects the dynamics between scale, intensification, and input management:

- Land expansion without increased intensive management or plant density maintenance actually reduces efficiency.
- Intensification of salacca cultivation (more plants per unit) helps maximize output per input, increasing technical efficiency.
- Using more fertilizer without efficient application techniques or adjustments to soil type can lead to inefficiency and even ecosystem imbalance.
- Adequate and appropriate labor strengthens intensive management, maintenance, and technical adaptation in salacca Bali, thereby boosting efficiency.

Regarding scale and input settings, several studies suggest relevant policy directions and practices:

- Optimal land size: Meta-regression studies show that there is an optimum scale at which technical efficiency is maximized—after which it may decline again (U-shaped relationship between farm size and TE). Therefore, it is recommended that salacca farmers maintain a land scale that can be intensively controlled²⁷.
- Increased intensification with appropriate technology: The use of effective intensification methods such as optimal planting distances, regular irrigation, and superior varieties can increase output per unit of input and raise efficiency without expanding land area.
- Application of fertilizers based on land needs: Fertilizers should be applied based on soil analysis and plant nutrient requirements, not simply by increasing the amount. A Chinese study on the use of organic versus chemical fertilizers emphasizes the importance of substitution that significantly improves technical efficiency²⁸.



- Strengthening the role of human labor: Since labor positively contributes to efficiency, agricultural management training, improving labor quality, and supporting mechanization (rather than replacing the critical role of humans in technical decisions) will be useful.

CONCLUSION

The average technical efficiency of *Salacca zalacca var. amboinensis* farming was 0.93, with the highest technical efficiency achieved in the >50-acre planting area stratum and the lowest in the <25-acre planting area stratum. Furthermore, the average scale efficiency of *Salacca zalacca var. amboinensis* farming was 0.87, with the highest scale efficiency achieved in the >50-acre planting area stratum and the lowest scale efficiency in the <25-acre planting area stratum. Only 6.47% of *Salacca zalacca var. amboinensis* farming units operated efficiently (optimal), while most (61.87%) operated under increasing returns to scale, and 31.66% operated under decreasing returns to scale. From the beta regression results, it can be concluded that the technical efficiency of *Salacca zalacca var. amboinensis* farming is more influenced by management intensity and targeted inputs than by land expansion or quantitative increases in inputs such as fertilizers.

REFERENCES

1. Statistik, BPBali Province in Figures. BPS - Stat. Bali Prov. 2024;48:
2. Rai, IN, Wijana, G, Sudana, IP, Wiraatmaja, IW, Semarangjaya, CGA, Alit Astiari, NKIdentifikasi dan Telaah Pemanfaatan Sumber Daya Genetik Buah-buahan Lokal untuk Meningkatkan Integrasi Pertanian dan Pariwisata di Bali. *J. Hortik. Indones.* 2016;7(1):31–39.
3. Tamba, IMKajian Buah-Buahan Lokal Unggulan Provinsi Bali dan Potensi Dinamisnya. *JIA (Jurnal Ilm. Agribisnis) J. Agribisnis dan Ilmu Sos. Ekon. Pertan.* 2024;9(2):126–132.
4. Sucandrawati, NLKAS, Murdani, NKPeran Competitive Advantage Dalam Pengembangan Agrowisata Abian Salak Di Kabupaten Karangasem. *J. Ilm. Satyagraha.* 2020;3(1):24–36.
5. I. M. Sukewijaya, INR and MSMDevelopment of salak bali as an organic fruit. *Asian J. Food Agro-Industry.* 2012;5(01):71–78.
6. Adijaya, IN, Jl, B, Rai, PDBPNPengaruh Pupuk Organik dan Penjarangan Buah terhadap Produktivitas Salak Gula Pasir. 2015;:
7. Sumantra, I. K, Labek, IN, Pura, SPembuahan Salak Gulapasier Di Luar Musim Berkualitas Standar Salak Indonesia. *J. Bakti Sar.* 2015;04(01):64–72.
8. Rai, IN, Sudana, LP, Wiraatmaja, W, Sukewijaya, MPenataan Kebun Dan Pembuatan Kuliner Dari Buah Dan Rebung Salak Untuk Mendukung Pengembangan Desa Sibetan Sebagai Desa Sentra Agrowisata Berbasis Salak. *Bul. Udayana Mengabd.* 2018;17(2):57.
9. Putri, DDA, Susrusa, KB, Arisenna, GMKMarketing System of “Gula Pasir” Snake Fruit in Bebandem District, Karangasem Regency. *AGRISOCIONOMICS J. Sos. Ekon. dan Kebijakan. Pertan.* 2020;4(2):255–265.
10. Lawalata, Dwidjono Hadi Darwanto, dan Slamet Hartono, MEfisiensi Relatif Usahatani Bawang Merah di Kabupaten Bantul dengan Pendekatan Data Envelopment Analysis (DEA). *Ilmu Pertan. (Agricultural Sci.* 2015;18(1):1.
11. Tamba, IMThe Competitive Advantages of Salacca Zalacca Var. Amboinensis and Their Determinants. *AgBioForum.* 2023;25(3):20–29.
12. Čechura, L, Žáková Kroupová, Z, Lekešová, MProductivity and efficiency in Czech agriculture: Does farm size matter? *Agric. Econ. (Czech Republic).* 2022;68(1):1–10.
13. Cheruiyot, JK, Sang, NInfluence of Scale of Operation and Farmers’ Risk Aversion on Sugarcane Productivity in Nandi County, Kenya. *Asian J. Agric. Extension, Econ. Sociol.* 2020;:14–26.
14. Ferreira, A, Kunh, SS, Fagnani, KC, Souza, TA De, Tonezer, C, Santos, GR Dos, et al.Economic overview of the use and production of photovoltaic solar energy in brazil. *Renew. Sustain. Energy Rev.* 2018;81(April 2016):181–191.
15. Clech, NA Le, Fillat-Castejón, CNew estimates of total factor productivity, technical and efficiency changes for the global agricultural economy. *Spanish J. Agric. Res.* 2020;18(2):1–14.
16. Nowak, A, Kijek, T, Domańska, KTechnical efficiency and its determinants in the European Union agriculture. *Agric. Econ.*



(Czech Republic). 2015;61(6):275–283.

17. Laz, J, Laz, Z, Tak, Isustainability Technical Efficiency in the Agricultural Business — The Case of Slovakia. 2019;:1–17.
18. Tampio, E, Winquist, E, Luostarinen, S, Rinne, MA farm-scale grass biorefinery concept for combined pig feed and biogas production. *Water Sci. Technol.* 2019;80(6):1042–1052.
19. Nassiri, SM, Singh, S Study on energy use efficiency for paddy crop using data envelopment analysis (DEA) technique. 2009
20. Alemu, FM, Mengistu, YA, Wassie, AG Factor productivity impacts of climate change and estimating the technical efficiency of cereal crop yields: Evidence from sub-Saharan African countries. *PLoS One.* 2024;19(11):e0310989.
21. Chiarella, C, Meyfroidt, P, Abeygunawardane, D, Conforti, P Balancing the trade-offs between land productivity, labor productivity and labor intensity. *Ambio.* 2023;52(10):1618–1634.
22. Alvarez, A, Arias, C Technical efficiency and farm size: a conditional analysis. *Agric. Econ.* 2004;30(3):241–250.
23. Zhang, W The impact of agricultural farmland scale management on land yield: a perspective based on the adoption of agricultural machinery in different production links. *Front. Environ. Sci.* 2025;13:1573394.
24. Bravo-Ureta, B, Solis, D, López, VM, Maripani, J, Thiam, A, Rivas, T Technical efficiency in farming: a meta-regression analysis. *J. Product. Anal.* 2007;27(1):57–72.
25. Sun, Z, Li, X Technical efficiency of chemical fertilizer use and its influencing factors in China's rice production. *Sustainability.* 2021;13(3):1155.
26. Song, Q, Fu, H, Shi, Q, Shan, X, Wang, Z, Sun, Z, et al. Overfertilization reduces tomato yield under long-term continuous cropping system via regulation of soil microbial community composition. *Front. Microbiol.* 2022;13:952021.
27. Fan, Y, Guoyong, W, Riaz, N, Radlinska, K Technical efficiency and farm size in the context of sustainable agriculture. *Agric. Econ.* 2024;70(9):446–456.
28. Zhang, L, Meng, T, Zhang, Z, Mu, Y Effects of Organic Fertilizer Substitution on the Technical Efficiency among Farmers: Evidence from Bohai Rim Region in China. *Agronomy.* 2023;13(3)

Cite this Article: Tamba, I.M., Yudiarini, N. (2025). Efficiency Scale of Salacca zalacca var. amboinensis Farming and Their Determinants. International Journal of Current Science Research and Review, 8(12), pp. 6572-6584. DOI: <https://doi.org/10.47191/ijcsrr/V8-i12-67>