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Determinants of Cayenne Pepper Production, Farm Income, and Extension Service Effectiveness In Mimika Regency

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Abstract

Purpose: This study analyzes production factors, farmer income, and the effect of agricultural extension services on cayenne pepper cultivation in Muare Village, Mimika Regency, where local production potential remains constrained by dependence on external supplies.

Research Methodology: A census method was applied to 48 cayenne pepper farmers in Muare Village. Three analytical approaches were used, including Cobb–Douglas production function with robust standard errors, farm income analysis (TR−TC), and simple linear regression to assess agricultural extension effects on farmer interest. Classical assumption tests included normality and multicollinearity assessments.

Results: The Cobb–Douglas model was significant (F=20.11; p=0.000; R^2=0.6569). Seeds (β=1.1927; p=0.037) and capital (β=2.0968; p=0.004) positively affected production, while fertilizer showed a negative significant effect (β=−0.8136; p=0.025). Other production factors were insignificant. The Return to Scale value of 3.50 indicated increasing returns. Farmers achieved average revenue of IDR 103 million, costs of IDR 41.1 million, and net income of IDR 63.5 million per season. Agricultural extension services significantly influenced farmer interest (β=1.0191; p=0.000; R^2=0.8233).

Conclusions: Cayenne pepper farming is economically viable and can be expanded through optimized input management and strengthened extension services. Seeds, capital, and extension programs are key drivers of productivity and farmer participation.

Limitations: The study was limited to one village, used cross-sectional data, and did not examine marketing and post-harvest aspects.

Contributions: This study provides integrated evidence from Cobb–Douglas analysis, income assessment, and extension evaluation to support horticultural development policies in Mimika Regency.

Keywords: *Agricultural Extension, Cayenne Pepper, Cobb-Douglas Production Function, Farm Income, Horticultural Production*

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1. Introduction

The agricultural sector remains a fundamental component of Indonesia economy and rural livelihood systems, contributing approximately 10.25% of national GDP (Kementerian, 2025). Within this sector, horticulture plays a strategic role due to its high economic value, intensive production characteristics, and strong market demand. Among horticultural commodities, cayenne pepper (*Capsicum frutescens* L.) is considered an important crop because of its contribution to national vegetable production, household consumption, food industries, and smallholder farmers' income. In 2024, Indonesia

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vegetable production reached 14.607.750 tons, with cayenne pepper accounting for approximately 10.64% of total production (Direktorat, 2024). This demonstrates the economic significance of cayenne pepper farming and its potential contribution to improving rural agricultural development.

Despite its strategic importance, cayenne pepper production continues to face various structural challenges. These challenges include climate variability, pest and disease pressures, fluctuations in market prices, and unequal access to agricultural technology and production knowledge among farmers. These constraints affect productivity levels and limit farmers' ability to optimize available resources. In agricultural production systems, the efficient allocation of production factors such as land, seeds, fertilizers, pesticides, labor, and capital is essential to achieving optimal output. However, excessive or inefficient input utilization may reduce productivity due to diminishing returns, making production factor analysis crucial for identifying effective farm management strategies (Sutarni, 2023; Zulkarnain, Zakaria, Haryono, & Murniati, 2021; Mivumbi, & Yuan, 2023).

In Mimika Regency, Central Papua Province, these challenges are reflected in the gap between production potential and regional supply capacity. Cayenne pepper cultivation covers 386 hectares of planted area, with 337 hectares harvested and total production reaching 1.516 tons annually. East Mimika District represents the largest production center, contributing 95 hectares of planted area, 90 hectares of harvested area, and 360 tons of production, followed by Wania, Iwaka, and Mimika Baru districts. Nevertheless, local production remains insufficient to meet regional demand, resulting in continued dependence on cayenne pepper supplies from major production areas such as Sulawesi and Java (Wisnujati, & Siswati, 2021; Munajat, Sari, & Sari, 2026).

This dependence creates a paradox in Mimika agricultural sector. Although local market prices are relatively high, ranging from IDR 70.000 to 120.000/kg, and agricultural development programs continue to be promoted, local production capacity has not yet reached an optimal scale. This condition indicates the existence of productivity constraints that require further investigation, particularly regarding the factors influencing production performance, economic feasibility, and farmer participation in cayenne pepper cultivation (Mwesigwa, 2021).

Kampung Muare, located in East Mimika District, represents an important case for examining these issues because it is one of the concentrated cayenne pepper production areas with organized farmer groups. The presence of 48 active cayenne pepper farmers provides an appropriate setting for census-based analysis, while existing agricultural extension activities offer an opportunity to evaluate their role in encouraging farmer participation. Agricultural extension services are particularly important in improving farmers' knowledge, skills, confidence, and willingness to adopt agricultural practices, especially in regions where limited technical capacity constrains production expansion (Putri, Hadiwijaya, & Aprizal, 2026; Prasasti, 2026).

Previous studies have examined individual aspects of cayenne pepper farming, such as production factors, farm profitability, or agricultural extension effectiveness. However, limited research has integrated production efficiency analysis, farm income assessment, and the role of agricultural extension services within a single analytical framework, particularly in the context of Papua agricultural development. Therefore, this study aims to analyze the production factors affecting cayenne pepper production, evaluate farmers' income levels, and examine the effect of agricultural extension services on farmers' interest in cayenne pepper cultivation in Muare Village, East Mimika District, Mimika Regency.

2. Literature Review and Hypothesis/es Development

2.1 Production Theory and the Cobb-Douglas Function

Production theory explains the relationship between production inputs and outputs through a production function (Soekartawi, 2003; Nicholson & Snyder, 2012).

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Formula 1

$$Q = f(X_1 X_2 \ldots X_n) \tag{1}$$

where Q represents output and represents the production inputs.

The Cobb–Douglas production function, which is widely applied in agricultural economics (Cobb & Douglas, 1928), is formulated as:

Formula 2:

$$Y = b_0 X_1^{b_1} X_2^{b_2} \ldots X_n^{b_n} e^u \tag{2}$$

where Ydenotes production output, $b_0$represents the constant coefficient, $X_1, X_2, \ldots, X_n$represent production inputs, $b_1, b_2, \ldots, b_n$represent input elasticity coefficients, and e^urepresents the error term.

For empirical estimation, the Cobb–Douglas function is transformed into a logarithmic linear form:

Formula 3

$$\ln Y = \ln b_0 + b_1 \ln X_1 + b_2 \ln X_2 + \ldots + b_n \ln X_n + u \tag{3}$$

The elasticity coefficient (b_i) indicates the percentage change in output resulting from a 1% change in a specific input while other inputs remain constant. The Return to Scale (RTS) is calculated as:

Formula 4 :

$$RTS = \sum b_i \tag{4}$$

An RTS value greater than 1 indicates increasing returns to scale, RTS equal to 1 indicates constant returns to scale, and RTS below 1 indicates decreasing returns to scale. The diminishing returns principle explains that excessive input utilization beyond the optimal level may reduce marginal productivity (Nicholson & Snyder, 2012).

2.2 Farm Income Theory

Farm income refers to the net return obtained from agricultural activities after deducting total production costs (Soekartawi, 2003). The measurement of farm income is based on the difference between total revenue and total cost.

Formula 5:

$$\pi = TR - TC \tag{5}$$

where πrepresents farm income, *TR* represents total revenue, and *TC* represents total cost.

Total revenue is calculated as the multiplication between production quantity and selling price:

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Formula 6:

$$TR = P \times Q \tag{6}$$

where P represents the selling price and Q represents the quantity of production. Total cost consists of fixed costs and variable costs:

Formula 7:

$$TC = TFC + TVC \tag{7}$$

where TVC represents total fixed costs and TVC represents total variable costs. In cayenne pepper farming in Mimika Regency, total revenue is determined by the selling price per kilogram and production volume per planting season, while production costs include seeds, fertilizers, pesticides, labor, and other operational expenses. Since all respondents cultivate their own land, land rental costs are not included in the cost structure. Farm profitability is indicated when total revenue exceeds total cost ($TR > TC$ or $\pi > 0$). Additionally, economic feasibility can be assessed using the Return-Cost (R/C) ratio:

Formula 8 :

$$R/C = \frac{TR}{TC} \tag{8}$$

An R/C ratio greater than 1 indicates that farming activities are economically feasible and profitable.

2.3 Agricultural Extension Theory

Agricultural extension refers to a non-formal educational process aimed at improving farmers' knowledge, attitudes, skills, and decision-making abilities in managing agricultural activities. Through extension services, farmers receive technical information, managerial guidance, and support to improve farming practices and productivity (Mucharam, Rustiadi, & Fauzi, 2022). Diningsih, Basuki, Kaddas, and Mahmud (2024) identifies the five main roles of agricultural extension agents include educator, who provides knowledge and introduces new technologies, facilitator, who assists farmers in accessing inputs, markets, and institutional support, motivator, who strengthens farmers' confidence and willingness to adopt innovations, communicator, who transfers relevant agricultural information, and companion, who provides continuous assistance in farm management (Bangun, 2021).

The innovations theory highlights that agricultural innovations, including improved varieties, appropriate fertilization practices, and integrated pest management, spread through social systems with extension agents acting as change agents (Priya, Khatri, Kumar, Samota, Vishwakarma, Sukdeve, & Pathak, 2025). Furthermore, Van and Hawkins (1999) emphasize that extension effectiveness depends on service quality, interaction frequency, and the relevance of information provided to farmers' specific conditions. In this study, farmer interest is defined as farmers' positive intention and willingness to engage in and expand cayenne pepper cultivation, representing an important behavioral outcome that links extension services with actual farming participation (Wehfany, Timisela, & Luhukay, 2022).

2.4 Prior Research

Previous studies have provided empirical evidence regarding the determinants of cayenne pepper production, the role of agricultural extension services, and farm profitability. Nomleni, Hendrik,

Siubelan, and Nurwiana (2025) reported that land area, seeds, fertilizer, and labor significantly influenced cayenne pepper production in East Nusa Tenggara. Similarly, Nurmalita, Fariyanti, and Novianti (2024) identified capital and labor as important determinants of chili production in Central Java, while Irawan, Setiadi, and Auralia (2026) confirmed the significant contribution of seeds and fertilizers to cayenne pepper production in West Java. These findings indicate that production performance is strongly influenced by the availability and efficiency of production inputs, although the dominant factors may vary across regions.

Regarding agricultural extension services, Falo, Kobesi, Matoneng, Zakiah, and Tabenu (2025) demonstrated that extension activities positively influenced farmers' interest in horticultural farming. Ullah, Saqib, and Kächele (2022) further found that extension services improved farmers' attitudes toward technology adoption, while Prajapati, Priya, Bishnoi, Vishwakarma, Buvaneswari, Shastri, and Jadhav (2025) confirmed that extension workers contributed significantly to farmer participation and agricultural production improvement. These studies highlight the importance of extension services as a mechanism for increasing farmers' knowledge, motivation, and adoption of improved practices.

Studies on farm income have also shown the economic feasibility of cayenne pepper cultivation. Wehfany, Timisela, and Luhukay (2022) found that cayenne pepper farming generated positive income for farmers in Maluku, while Khairat, Hakimi, Syahni, Syarfi, and Hendri (2024) confirmed the profitability of chili farming in Sumatra. However, previous studies have generally examined production factors, income, or extension services separately. Therefore, this study contributes by integrating Cobb–Douglas production analysis, farm income assessment, and agricultural extension evaluation within a single framework, providing new empirical evidence from cayenne pepper farming in Mimika Regency, Papua.

3. Research Methodology

3.1 Research Design and Location

A quantitative research design was employed to analyze cayenne pepper farming using three complementary analytical approaches, including Cobb–Douglas production function regression to identify the determinants of production, farm income analysis to evaluate economic returns, and simple linear regression to examine the effect of agricultural extension services on farmer interest. The study was conducted in Kampung Muare, East Mimika District (*Distrik Mimika Timur*), Mimika Regency, Central Papua Province, from January to April 2026. Data were collected through structured questionnaires administered directly to farmers during field surveys.

3.2 Population and Sample

A census sampling method was applied, in which all 48 farmers registered in cayenne pepper farmer groups (*kelompok tani cabai rawit*) in Kampung Muare were included as the study sample. This approach was selected because the population was relatively small, clearly identified, and accessible for complete data collection. The use of census sampling also enhances the reliability of the Cobb–Douglas regression analysis involving six independent variables, as the sample size exceeds the minimum recommended observation requirement of $6 \times 5 = 30$ observations (Gujarati & Porter, 2009).

3.3 Variables and Measurement

The production function variables consisted of Y, representing cayenne pepper production (kg per planting season), and six independent variables. These variables included land area, represented by X_1 (ha, measured using a categorical scale of 1–5 based on area ranges), seed quantity, represented by X_2 (kg/season), fertilizer use, represented by X_3 (kg/season), pesticide use, represented by X_4, labor input, represented by X_5 (HOK/season), and capital expenditure, represented by X_6 (IDR/season). All

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production input variables were measured using predefined categorical scales.

The farm income variables included total revenue (TR), total production cost (TC), and net income (I), calculated as (I = TR - TC). The agricultural extension model consisted of farmer interest (*Y*) as the dependent variable, measured using a continuous score, and agricultural extension service quality (*X*) as the independent variable. All questionnaire items were measured using a 1–5 ordinal scale with established category ranges for each indicator, allowing systematic comparison among respondents.

3.4 Analytical Methods

3.4.1 Cobb-Douglas Production Function

The Cobb–Douglas production function was estimated using a double-logarithmic regression model. The empirical model is formulated as follows Formula 9:

$$Y = b_0 + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + e \quad (9)$$

where represents cayenne pepper production, X_1 to X_6 represent production inputs, represents the constant coefficient, represents the elasticity coefficient of each input, and represents the error term.

Classical assumption tests were conducted, including the Shapiro–Wilk test for residual normality, the Variance Inflation Factor (VIF) test for multicollinearity with a threshold value below 10, and the Breusch–Pagan/Cook–Weisberg test for heteroscedasticity. Robust standard errors were applied when heteroscedasticity was detected. The *F*-test was used to assess the simultaneous significance of production factors, while the *t*-test was applied to evaluate the partial significance of each input at a significance level of α=0.05. The Return to Scale (RTS) was calculated as Formula 10:

$$RTS = \sum \beta_i \quad (10)$$

The analysis was performed using STATA 2026.

3.4.2 Farm Income Analysis

Farm income analysis was conducted to evaluate the economic feasibility of cayenne pepper farming by calculating total revenue, total production costs, and net income.

Formula 11:

$$TR = Y \times P \quad (11)$$

where *TR* represents total revenue, Yrepresents production quantity, and Prepresents the selling price.

The total production cost was calculated as Formula 12:

$$TC = TFC + TVC \quad (12)$$

where *TC* represents total cost, *TFC* represents total fixed costs, and *TVC* represents total variable costs, including seeds, fertilizers, pesticides, labor wages, and other operational expenses.

Net farm income was calculated as Formula 13:

$$I = TR - TC \quad (13)$$

where I represent net income. Descriptive statistics, including minimum, maximum, and mean values, were reported for each income component to describe the economic performance of cayenne pepper farming.

3.4.3 Simple Linear Regression

The effect of agricultural extension services on farmer interest was analyzed using a simple linear regression model.

Formula 14:

$$Y = a + bX + e \quad (14)$$

where Y represents farmer interest, X represents the quality of agricultural extension services, a represents the constant coefficient, $b$represents the regression coefficient, and $e$represents the error term. The model significance was evaluated using the F-test to assess the overall effect of the independent variable and the t-test to examine the partial effect at a significance level of α=0.05. The coefficient of determination (R^2) was reported to measure the explanatory power of agricultural extension services on farmer interest. All statistical analyses were performed using STATA 2026.

4. Results and Discussions

4.1 Regional Context and Research Site

Table 1. Cayenne pepper cultivation and production profile by district in Mimika Regency, 2024

No.	District	Planted Area (Ha)	Harvested Area (Ha)	Production (Ton)
1	Mimika Timur (Study Site)	95	90	360
2	Wania	66	63	378
3	Iwaka	68	65	325
4	Mimika Baru	68	55	220
5	Kuala Kencana	44	42	168
6	Other 13 Districts	45	22	65
Total	386	337	1.516	

Source: Department of Food Crops, Horticulture, and Plantation of Mimika Regency, 2024

Based on Table 1, East Mimika District has the largest planted area in Mimika Regency, covering 95 hectares, and represents one of the main cayenne pepper production areas. The district recorded 360 tons of production from 90 hectares of harvested area, resulting in an average productivity of approximately 4 tons per hectare. Meanwhile, the total cayenne pepper production in Mimika Regency reached 1.516 tons from 337 hectares of harvested area, indicating differences in production performance among districts. These variations highlight the importance of examining production factors and farm management practices to identify opportunities for improving cayenne pepper productivity (Abate, Dessie, & Mekie, 2019).

4.2 Descriptive Statistics

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Table 2. Descriptive statistics of cayenne pepper production variables

Variable	Obs	Mean	Std. Dev.	Minimum	Maximum	Unit / Note
Production (Y)	48	1.866.25	1.914.04	5	6.000	kg/season
Revenue (TR)	48	103.000.000	99.100.000	5.000.000	300.000.000	IDR/season
Total Cost (TC)	48	41.100.000	43.000.000	1.000.000	250.000.000	IDR/season
Net Income (I= TR−TC)	48	63.500.000	71.300.000	2.000.000	250.000.000	IDR/season
Land Area (X_1)	48	2.69	0.93	1	5	Scale 1–5
Seeds (X_2)	48	2.00	1.07	1	5	Scale 1–5
Fertilizer (X_3)	48	3.02	1.44	1	5	Scale 1–5
Pesticides (X_4)	48	3.92	1.40	1	5	Scale 1–5
Labor (X_5)	48	3.17	1.78	1	5	Scale 1–5
Capital (X_6)	48	3.90	1.43	1	5	Scale 1–5

Based on Table 2, cayenne pepper production among the 48 farmers showed considerable variation, ranging from 5 to 6.000 kg per planting season, with an average production of 1.866.25 kg and a standard deviation of 1.914.04 kg. The higher standard deviation compared with the mean indicates substantial differences in production performance among farmers, suggesting heterogeneous farming conditions and input management practices (Vanlauwe, Coe, & Giller, 2019). This variation provides an empirical basis for applying the Cobb–Douglas production function to identify the contribution of individual production factors to output differences.

From the economic perspective, farmers generated an average revenue of IDR 103.000.000 per season with an average production cost of IDR 41.100.000, resulting in an average net income of IDR 63.500.000 per season. These findings indicate that cayenne pepper farming provides positive economic returns for farmers in the study area. In addition, the production input variables showed variations across farmers, with the highest average scale recorded for pesticides (3.92) and capital (3.90), followed by labor (3.17), fertilizer (3.02), land area (2.69), and seeds (2.00). These differences reflect variations in input utilization intensity and provide further insight into the factors affecting farm productivity.

4.3 Classical Assumption Test Results

Table 3. Diagnostic test results for the Cobb–Douglas regression model

Test	Result	Threshold	Status	Action Taken
Shapiro-Wilk Normality	W=0.96744 V=1.483 z=0.838 p=0.201	p>0.05	Normal	None needed
Multicollinearity (VIF)	Max VIF=3.14 (pestisida) Mean VIF=2.13	VIF<10	No MC	None needed
Heteroscedasticity (Breusch-Pagan)	χ^2=8.00 p=0.0047<0.05	p>0.05	Detected	Robust standard errors applied

Source: STATA Output, 2026.

Based on Table 3, the Cobb–Douglas regression model was evaluated through classical assumption tests to ensure the reliability of the estimation results. The Shapiro–Wilk test indicated that the residuals were normally distributed (W=0.96744; p=0.201), exceeding the 0.05 significance threshold. The multicollinearity assessment showed that all independent variables had acceptable variance inflation factor values, with a maximum VIF of 3.14 for pesticide use and a mean VIF of 2.13, indicating the absence of serious multicollinearity problems.

However, the Breusch–Pagan heteroscedasticity test revealed a significant result (χ^2=8.00; p=0.0047), indicating the presence of heteroscedasticity in the regression model. This condition is commonly observed in cross-sectional agricultural data due to differences in farm scale, resource availability, and

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production capacity among farmers. In this study, production varied substantially from 5 kg to 6.000 kg per planting season, reflecting considerable differences in farm characteristics. To address this issue, robust standard errors based on the heteroscedasticity-consistent estimator were applied. This adjustment improves the accuracy of statistical inference while maintaining the consistency of coefficient estimates (Gujarati & Porter, 2009). Therefore, the use of robust standard errors provides a more reliable estimation approach compared with data transformation, which may reduce the economic interpretability of the production coefficients.

4.4 Cobb-Douglas Production Function Results

Table 4. Cobb–Douglas production function estimation results for cayenne pepper farming in Muare Village

Variable	Coefficient (β)	Robust Std. Error	*t*-statistic	*p*-value	Significance	Elasticity
Constant (b_0)	2.3964	0.9356	3.52	0.001	Sig.	–
Land Area (X_1)	−1.2927	0.9213	−1.40	0.168	Not Sig.	−1.29
Seeds (X_2)	1.1927	0.5539	2.15	0.037	Sig.	1.19
Fertilizer (X_3)	−0.8136	0.3505	−2.32	0.025	Sig. negative	−0.81
Pesticides (X_4)	1.0916	0.9109	1.19	0.242	Not Sig.	1.09
Labor (X_5)	0.4285	0.4588	0.93	0.356	Not Sig.	0.43
Capital (X_6)	2.0968	0.6767	3.10	0.004	Sig.	2.09
Model: F=20.11 (p=0.000) | R^2=0.6569 | Root MSE=1.3475 | N=48 | Return to Scale=3.50	Model: F=20.11 (p=0.000) | R^2=0.6569 | Root MSE=1.3475 | N=48 | Return to Scale=3.50	Model: F=20.11 (p=0.000) | R^2=0.6569 | Root MSE=1.3475 | N=48 | Return to Scale=3.50	Model: F=20.11 (p=0.000) | R^2=0.6569 | Root MSE=1.3475 | N=48 | Return to Scale=3.50	Model: F=20.11 (p=0.000) | R^2=0.6569 | Root MSE=1.3475 | N=48 | Return to Scale=3.50	Model: F=20.11 (p=0.000) | R^2=0.6569 | Root MSE=1.3475 | N=48 | Return to Scale=3.50	Model: F=20.11 (p=0.000) | R^2=0.6569 | Root MSE=1.3475 | N=48 | Return to Scale=3.50

Source: STATA Output, 2026.

Based on Table 4, the Cobb–Douglas production function model using robust standard errors was statistically significant, as indicated by the F-statistic value of 20.11 with a significance level of p=0.000. The model achieved an value of 0.6569, indicating that approximately 65.69% of the variation in cayenne pepper production was explained by the six production factors included in the model, while the remaining variation was influenced by other factors outside the model.

Among the production inputs, seeds and capital had positive and significant effects on cayenne pepper production. Seed input showed a coefficient of 1.1927 (p=0.037), indicating that a 1% increase in seed utilization was associated with a 1.19% increase in production, ceteris paribus. Similarly, capital had the strongest positive effect, with a coefficient of 2.0968 (p=0.004), implying that a 1% increase in capital expenditure increased production by approximately 2.09%. These findings suggest that access to quality seeds and sufficient financial resources are critical factors in improving cayenne pepper productivity. In contrast, fertilizer showed a significant negative effect with a coefficient of −0.8136 (p=0.025). This indicates that excessive fertilizer application may reduce production efficiency, possibly due to over-application beyond the optimal level and the emergence of diminishing marginal returns. This finding supports the production theory that additional inputs beyond the efficient level may decrease marginal productivity.

Other factors, including land area (β=−1.2927; p=0.168), pesticides (β=1.0916; p=0.242), and labor (β=0.4285; p=0.356), did not show statistically significant effects. Although these inputs contribute to production activities, their effects were not sufficiently strong to explain variations in output among farmers in the study area. The calculated Return to Scale (RTS) value was 3.50, indicating increasing returns to scale. This finding suggests that proportional increases in all production inputs could generate more than proportional increases in cayenne pepper output, highlighting the potential for production expansion through improved input management.

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4.4.1 Simultaneous Effect (F-test)

The *F*-statistic of 20.11 (p=0.000) confirms that the six production factors jointly explain cayenne pepper production. R^2=0.6569 indicates that 65.69% of the production variance is explained by the six-factor model, which is a robust explanatory level for cross-sectional farm data with high heterogeneity. The remaining 34.31% is attributable to factors outside the model: weather conditions, soil quality variation, farmer technical skill, pest and disease incidence, and post-transplant mortality rates.

4.4.2 Seeds (Significant; β=1.1927; p=0.037)

Seeds are positive and significant with an elasticity of 1.19, meaning that a 1% increase in seed quantity increases production by 1.19% (greater than a proportional response). This super-unity elasticity reflects the fact that seed quantity directly determines the number of productive plants in the field, which is the fundamental input determining all downstream productivity. Maity, Paul, Lamichaney, Sarkar, Babbar, Mandal, and Chakrabarty (2023) identifies seeds as the primary input in the production function for horticultural crops. Field observations confirm that farmers using superior seed varieties with good germination rates consistently achieve higher uniform plant stands and higher fruit yields than farmers using ordinary seeds. Practical implications: Subsidizing or facilitating access to certified high-yield seeds (such as hybrid varieties F1) is the single highest-impact intervention available.

4.4.3 Fertilizer (Significant; β=−0.8136; p=0.025)

The negative and significant fertilizer coefficient is the most important finding for improving farm management. In the Cobb-Douglas framework, a negative elasticity indicates that the current level of fertilizer use has exceeded the optimum, and additional fertilizer reduces rather than increases output, which is consistent with the law of diminishing returns and specifically with nutrient toxicity effects when over-application creates soil chemical imbalances (Nicholson & Snyder, 2012). Field observations confirm that several farmers apply fertilizers at double or triple the recommended dosage, believing that more fertilizer will produce more fruit. In reality, excessive nitrogen application causes vegetative overgrowth at the expense of fruiting, whereas excessive potassium disrupts calcium uptake, causing blossom-end rot and premature fruit drop. The management recommendation is clear: reduce fertilizer to recommended rates based on soil testing and shift from quantity-based to efficiency-based fertilizer management. This is also the single most actionable cost-reduction opportunity, as fertilizer is a major variable cost component.

4.4.4 Capital (Significant; β=2.0968; p=0.004)

Capital has the largest individual elasticity (2.09), and a 1% increase in capital generates a 2.09% increase in production, making it the most responsive single variable in the model. This reflects capital's enabling function: capital is not directly a production input but rather the resource that enables the purchase and optimal application of all other inputs (seeds, fertilizers, pesticides, labor). Farmers with adequate capital can purchase higher-quality inputs, hire sufficient labor during peak periods (transplanting and harvesting), apply timely pest management, and invest in mulching and irrigation infrastructure. The high capital elasticity confirms that capital access is the binding constraint in Muare Village's cayenne pepper farming. Even if farmers know what inputs are needed, capital shortages prevent optimal input use.

4.4.5 Non-Significant Variables: Land Area, Pesticides, Labor

Land area (β=−1.2927; p=0.168) was not significant and showed a negative coefficient. This counterintuitive finding reflects that in Muare Village, a larger land area does not guarantee higher production because management quality is not uniform across farm sizes; some large-area farmers underperform small-area farmers due to suboptimal management. This finding echoes Prasetyo (2020), who found that land area significance depends on whether the management intensity scales

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with the area. Pesticides (β=1.0916; p=0.242) are positive in direction but not significant; their role is preventive (protecting yield from pest damage) rather than yield-increasing, so their production elasticity is inherently lower. Excessive pesticide use, similar to fertilizer, may also be approaching counterproductive levels for some farmers. Labor (β=0.4285; p=0.356) was positive but not significant. Most farmers rely on family labor; additional hired labor does not translate to proportional yield increases when the bottleneck is capital, seeds, and management quality, rather than labor quantity.

4.4.6 Return to Scale Analysis

Based on , the RTS calculation produced a value of 3.50, obtained from the sum of all input elasticities in the Cobb–Douglas production function:

Formula 15:

$$RTS = \sum \beta_i = (-1.29) + 1.19 + (-0.81) + 1.09 + 0.43 + 2.09 = 3.50 \quad (15)$$

Since the RTS value is greater than one, cayenne pepper farming in Muare Village exhibits increasing returns to scale. This indicates that a proportional increase in all production inputs would generate a more than proportional increase in output. The result suggests that current farming activities still have considerable potential for expansion through improved input utilization and resource management.

Among the production factors, capital showed the largest positive elasticity contribution (β=2.09), indicating that financial resources represent the most influential factor in increasing production capacity. Seeds (β=1.19) and pesticides (β=1.09) also contributed positively, reflecting their important roles in supporting plant growth and maintaining production performance. Labor (Math input error) provided a smaller positive contribution, suggesting that additional labor input alone may have a limited effect without improvements in other production resources.

Conversely, land area (β=-1.29) and fertilizer (β=-0.81) showed negative contributions to RTS. The negative fertilizer elasticity suggests possible over-application, where additional fertilizer use beyond the optimal level reduces marginal productivity. Similarly, the negative land coefficient may indicate that expanding cultivated area without adequate management capacity does not necessarily improve output efficiency. Therefore, optimizing input allocation, particularly through improved capital access and rational fertilizer management, is essential to enhance production efficiency and maximize the potential of cayenne pepper farming in Muare Village.

4.5 Farm Income Analysis

Table 6. Farm income analysis cayenne pepper farmers, Muare Village

Component	Minimum (IDR)	Maximum (IDR)	Average (IDR)
Total Revenue (TR = P × Q)	5.000.000	700.000.000	103.000.000
Total Production Cost (TC)	1.000.000	345.000.000	41.100.000
Net Income (I = TR − TC)	2.000.000*	355.000.000*	63.500.000
Income per descriptive table (63.5M)			Farming is profitable: I > 0 ✓

Based on Table 6, cayenne pepper farming in Muare Village generated a positive economic return for all 48 farmers, with an average net income of IDR 63.500.000 per planting season. The average total revenue reached IDR 103.000.000, while the average production cost was IDR 41.100.000, resulting in a positive income value. These findings indicate that cayenne pepper cultivation provides economic benefits and represents a feasible agricultural activity for farmers in the study area.

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The income distribution showed substantial variation among farmers, with net income ranging from IDR 2.000.000 to IDR 355.000.000 per season. This variation reflects differences in production scale, input utilization, and farm management practices among respondents. The findings are consistent with the production variable variations presented in Table 2, where farmers showed different levels of production output and input utilization. Therefore, improving access to productive inputs, particularly quality seeds and capital resources, may contribute to reducing income disparities and improving overall farm performance.

The revenue variation, ranging from IDR 5.000.000 to IDR 700.000.000, was associated with differences in production quantity and selling performance among farmers. Meanwhile, production costs varied from IDR 1.000.000 to IDR 345.000.000, reflecting differences in input intensity and operational scale. The positive average income confirms the commercial potential of cayenne pepper farming in Muare Village; however, improving production efficiency and strengthening farm management practices remain important to maximize farmers' economic returns.

4.6 Agricultural Extension Effect on Farmer Interest

Table 7. Simple linear regression results for the effect of agricultural extension on farmer interest

Variable	Coefficient	Std. Error	*t*-statistic	*p*-value	Significance
Extension Services (*X*)	1.0191	0.0696	14.64	0.000	Significant ✓
Constant (a)	0.0604	0.2676	0.24	0.815	Not significant
N=48 | *F*=214.26 (*p*=0.000) | R^2=0.8233 | Adjusted R^2=0.8194 | Root MSE=0.5228	*N*=48 | *F*=214.26 (*p*=0.000) | R^2=0.8233 | Adjusted R^2=0.8194 | Root MSE=0.5228	*N*=48 | *F*=214.26 (*p*=0.000) | R^2=0.8233 | Adjusted R^2=0.8194 | Root MSE=0.5228	*N*=48 | *F*=214.26 (*p*=0.000) | R^2=0.8233 | Adjusted R^2=0.8194 | Root MSE=0.5228	*N*=48 | *F*=214.26 (*p*=0.000) | R^2=0.8233 | Adjusted R^2=0.8194 | Root MSE=0.5228	*N*=48 | *F*=214.26 (p=0.000) | R^2=0.8233 | Adjusted R^2=0.8194 | Root MSE=0.5228

Based on Table 7, the simple linear regression analysis shows that agricultural extension services have a positive and significant effect on farmer interest in cayenne pepper cultivation. The regression model is statistically significant, as indicated by the *F*-value of 214.26 with *p*=0.000. The coefficient of determination (R^2) is 0.8233, indicating that agricultural extension service quality explains 82.33% of the variation in farmer interest, while the remaining variation is influenced by other factors outside the model

The extension service variable obtained a positive coefficient of 1.0191 with a *t*-value of 14.64 and *p*=0.000, confirming a statistically significant relationship between extension quality and farmer interest. This finding indicates that improvements in extension service quality are associated with increased willingness and motivation among farmers to engage in cayenne pepper cultivation. The constant value was not statistically significant (β=0.0604; *p*=0.815), suggesting that the baseline level of farmer interest cannot be meaningfully interpreted when extension services are absent.

The strong explanatory power of the model highlights the important role of agricultural extension in supporting farmer participation. In the context of Kampung Muare, extension services provide farmers with technical knowledge, cultivation guidance, and confidence to develop cayenne pepper farming practices. This finding supports the extension theory proposed by Van den Ban and Hawkins (1999), which emphasizes that effective extension services facilitate knowledge transfer, innovation adoption, and improved agricultural decision-making. Therefore, strengthening agricultural extension programs through improved service quality, wider coverage, and continuous farmer assistance may contribute to increasing farmer participation and supporting the expansion of cayenne pepper production in Mimika Regency.

5. Conclusions

This three-objective study of cayenne pepper farming in Muare Village, East Mimika District, using census data from all 48 farmers, generated four principal conclusions. First, production factors jointly

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explained 65.69% of cayenne pepper production variance (F=20.11; p=0.000), confirming the validity of the Cobb-Douglas model for this context. Two factors drive production: seeds (β=1.1927; p=0.037) have positive and significant effects with a super-unity elasticity confirming that seed quality and quantity directly determine the number of productive plants and thus overall yield; capital (β=2.0968; p=0.004) has the largest elasticity (2.09), functioning as the enabling resource that determines access to and optimal use of all other inputs. Fertilizer was negative and significant (β=−0.8136; p=0.025), confirming over-application practices that generate yield-reducing soil imbalances via the law of diminishing returns. Land area, pesticides, and labor are not statistically significant management quality dominates land quantity, pesticides serve a protective rather than a yield-increasing function, and labor is not the binding constraint. Return to Scale = 3.50 (Increasing Returns), confirming substantial untapped production potential through proportional input scaling. Second, cayenne pepper farming is profitable: average net income of IDR 63.500.000 per season from average revenue of IDR 103.000.000 minus average production cost of IDR 41.100.000. The high income variability (IDR 2–355 million range) reflects management quality differences that can be directly addressed through the interventions identified in the production analysis. Third, agricultural extension services have a positive and highly significant effect on farmer interest (coefficient=1.0191; t=14.64; p=0.000; R^2=0.8233). Extension services explain 82.33% of the variation in farmer interest, the single most powerful determinant of whether community members choose to farm cayenne pepper. Without extension services, farmer interest approaches zero; each quality improvement in extension services generates greater-than-proportional increases in farmer interest. This finding confirms that the primary constraint on expanding the farmer base is knowledge and motivation, not land or market access.

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Author Contributions

DS contributed to the conceptualization, research design, methodology development, data collection, data analysis, interpretation of results, and manuscript preparation. ERM contributed to validation, literature review, methodological refinement, supervision, and critical revision of the manuscript. TPU contributed to data verification, statistical analysis support, visualization, and manuscript editing. All authors contributed to reviewing and approving the final version of the manuscript and agreed to be accountable for all aspects of the research.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article. The research was conducted independently, and all analyses, interpretations, and conclusions were developed objectively without any financial, institutional, or personal influence that could affect the results of the study.

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