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Production efficiency and economic feasibility of greenhouse-based paprika farming in Bali, Indonesia

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Abstract--This study examines the financial feasibility of greenhouse-based paprika farming (*Capsicum annuum* L.) in Baturiti District, Tabanan Regency, Bali, Indonesia, an area characterized by highland agroclimatic conditions that are conducive to the development of high-value horticultural commodities. The study primarily focuses on evaluating technical efficiency, business profitability, and the resilience of the farming system to potential declines in production output. A quantitative research approach was employed, utilizing Stochastic Frontier Analysis (SFA) to assess production efficiency, along with investment feasibility analysis using Net Present Value (NPV), Internal Rate of Return (IRR), and Net Benefit–Cost Ratio (Net B/C) indicators. Primary data were collected from 35 greenhouse paprika farmers through structured questionnaires and interviews, while secondary data were obtained from relevant institutions and supporting literature. The results indicate that the majority of farmers have not yet achieved optimal technical efficiency, with 29 out of 35 farmers (82.86%) recording technical efficiency scores below 0.90. Despite this condition, greenhouse paprika farming in the study area is financially viable, as reflected by a positive NPV of IDR 666,825,125.30, an IRR of 23.93%, and a Net B/C ratio of 1.27. These indicators demonstrate the enterprise’s capacity to generate economic



surplus and provide satisfactory investment returns. Sensitivity analysis further reveals that the farming system remains viable under output reductions of up to 25%. However, financial feasibility cannot be sustained when output declines exceed this threshold or occur simultaneously with increases in major input costs, as indicated by IRR and Net B/C values falling below acceptable feasibility levels. These findings underscore the importance of optimizing production factor utilization and implementing effective farm management strategies to mitigate production risks. Overall, this study provides empirical evidence to support decision-making by farmers, local governments, and stakeholders in promoting the sustainable development of greenhouse-based paprika agribusiness.

Keywords---paprika, greenhouse, technical efficiency, financial feasibility.

Introduction

Agriculture remains a key pillar of Indonesia's economy, contributing 12.5% to national Gross Domestic Product (GDP) in 2023 and absorbing approximately 29% of the total workforce (Badan Pusat Statistik 2024; Kementerian Pertanian 2023). Amid globalization pressures, climate change, and land constraints, the sector is increasingly required to adopt technological innovations and improve resource-use efficiency (Suarlin 2021). Within this context, horticulture has emerged as a strategic subsector due to its capacity to generate high-value products with relatively short production cycles. Paprika (*Capsicum annum* L.) has become one of the leading horticultural commodities, supported by growing domestic and export demand (Febriantoko et al. 2022). Indonesia's horticultural exports increased by 6.7% in 2023, with paprika playing a significant role in this growth (Badan Pusat Statistik 2024). Rising consumer awareness of healthy lifestyles and nutritional benefits has further stimulated demand, particularly from the hotel, restaurant, and catering (HoReCa) sector and middle- to upper-income consumers (Sutari et al. 2020; Harahap et al. 2021).

Paprika cultivation also offers substantial income potential for farmers. Previous studies indicate that farmers adopting modern cultivation practices can achieve net incomes up to twice those of conventional vegetable producers (Palullungan et al. 2022). One of the most suitable regions for paprika development is Baturiti District, Tabanan Regency, Bali, which is located at an altitude of 700–1,200 meters above sea level and characterized by cool temperatures and stable humidity. These agroclimatic conditions are highly favorable for highland horticulture, positioning Baturiti as an important paprika production center. In 2023, the total horticultural land area in this region reached approximately 1,800 hectares, with a large proportion allocated to highland vegetable crops, including paprika (Dinas Pertanian Kabupaten Tabanan 2024).

The increasing adoption of greenhouse-based paprika farming reflects efforts to enhance productivity, improve quality, and mitigate climatic risks. Greenhouse systems provide advantages such as water-use efficiency, protection from pests

and diseases, and year-round production capability (Rahim 2024). However, these systems require substantial initial investment, intensive management, and high-quality inputs, including imported seeds, precision irrigation systems, and advanced pest control, which significantly increase production costs and capital requirements (Odelia and Sulistyowati 2020; Sawitri, Romadi, and Warnaen 2024; Rahmadi et al. 2024). Consequently, efficient allocation and utilization of production factors—land, labor, capital, and technology—are critical to achieving optimal output and maintaining financial sustainability. Inefficient input allocation remains a common challenge among farmers and often leads to suboptimal productivity and income levels (Taridala, Abdullah, and Ari 2023).

Production efficiency and financial feasibility are therefore particularly crucial in greenhouse systems, where operational costs and managerial complexity are considerably higher than in open-field farming. Quantitative approaches such as Frontier Production Function analysis are widely recognized as effective tools for measuring technical efficiency in intensive production systems (Januru et al. 2025). At the same time, financial feasibility analysis using Net Present Value (NPV), Internal Rate of Return (IRR), and Net Benefit–Cost Ratio (Net B/C) is essential for assessing long-term investment sustainability (Prasetyo, Fachriyan, and Subantoro 2025). Market volatility in output prices and input costs further underscores the importance of sensitivity analysis to evaluate business resilience under adverse economic scenarios (Ilham 2023). Despite the high agroclimatic potential of Baturiti, no previous study has simultaneously examined technical efficiency, financial feasibility, and economic sensitivity of greenhouse-based paprika farming in this area. This research addresses this gap by providing an integrated empirical assessment to support sustainable agribusiness development and evidence-based decision-making at the local level.

Methods

This study adopts a quantitative approach using a descriptive–analytical method to examine production factor efficiency, financial feasibility, and economic sensitivity of greenhouse-based paprika farming in Baturiti District, Tabanan Regency. Technical efficiency is assessed using Stochastic Frontier Analysis (SFA) through a Frontier Production Function, while financial feasibility is evaluated using standard investment appraisal indicators, namely Net Present Value (NPV), Internal Rate of Return (IRR), and Net Benefit–Cost (Net B/C) Ratio. In addition, sensitivity analysis is conducted to assess the financial resilience of the farming system under fluctuations in output prices. The analysis focuses on how farmers manage technical and economic resources when facing input limitations and market volatility.

The study addresses three main research objectives: (1) to analyze the level of technical efficiency in the use of production factors in greenhouse paprika farming using a frontier production approach; (2) to evaluate the financial feasibility of greenhouse paprika farming based on NPV, IRR, and Net B/C indicators; and (3) to assess the sensitivity of financial feasibility to changes in output prices, reflecting the economic resilience of the farming system. This research employs a quantitative survey design, with primary data collected

through structured questionnaires and semi-structured interviews with greenhouse paprika farmers.

The questionnaires capture both technical and economic information, including land area, labor use, operational costs, agricultural inputs (seeds, fertilizers, pesticides, growing media, water, and equipment), production output, selling prices, and financial data related to revenues and expenditures. Secondary data are obtained from local agricultural agencies and relevant literature to support and complement the primary data analysis.

Result and Discussion

Technical Efficiency of Greenhouse Paprika Farming

Technical efficiency of greenhouse paprika farming in Baturiti District was analyzed using Stochastic Frontier Analysis (SFA), which allows the separation of random shocks from inefficiency effects in the production process. The estimated stochastic frontier production function incorporates key input variables, including land area, seeds, polybags, liquid fertilizer, pesticides, and labor (family and hired labor). The estimation results of the SFA model, including coefficient values, standard errors, t-statistics, and significance levels, are presented in Table 1.

Table 1. Estimation Results of the Stochastic Frontier Production Function

No	Variable	Coefficient	Std. Error	t-value	Significance
1	Constant	-11.268	0.858	-0.001	ns
2	Land area	-0.005	0.008	-0.725	ns
3	Seeds	1.752	0.072	24.160	***
4	Polybags	0.802	0.062	12.823	***
5	Liquid fertilizer	0.216	0.032	6.740	***
6	Pesticides	-1.770	0.133	-13.235	ns
7	Family labor	-0.001	0.008	-0.139	ns
8	Hired labor	-0.005	0.003	-1.673	ns
9	Sigma-squared (σ^2)	0.002	0.000	3.648	***
10	Gamma (γ)	0.999	0.001	598.492	***

Primary Data, 2026

Note: *** significant at $\alpha = 1\%$; ns = not significant

The statistical significance of sigma-squared ($\sigma^2 = 0.002$) confirms that the model adequately captures production variability, while the gamma value ($\gamma = 0.999$) indicates that approximately 99.9% of output variation is attributable to technical inefficiency rather than random factors. This finding suggests that differences in paprika production among farmers are largely driven by managerial capacity and efficiency in input utilization.

Among the input variables, seeds, polybags, and liquid fertilizer exhibit positive and statistically significant effects on output. Seed use shows the highest elasticity (1.752), highlighting the critical role of seed quality and quantity in improving paprika productivity. Polybags (0.802) and liquid fertilizer (0.216) also contribute positively, emphasizing the importance of growing media and nutrient

management in greenhouse systems. In contrast, land area, pesticides, and labor inputs do not show significant effects, indicating that productivity gains are more strongly associated with efficiency and management practices rather than scale expansion or labor intensity.

Determinants of Technical Inefficiency

The analysis of inefficiency effects incorporates farmer characteristics to identify factors influencing technical inefficiency. The estimation results are presented in Table 2.

Table 2. Estimation Results of Inefficiency Determinants

No	Variable	Coefficient	Std. Error	t-value	Significance
1	Constant	-0.186	0.296	-0.627	ns
2	Farming experience	-0.249	0.091	-2.731	*
3	Age	0.187	3.026	-0.482	***

Primary Data, 2026

Note: * significant at $\alpha = 10\%$; *** significant at $\alpha = 1\%$; ns = not significant

Farming experience has a negative and statistically significant effect on technical inefficiency, indicating that more experienced farmers tend to operate more efficiently. This supports the learning-by-doing hypothesis, whereby accumulated experience enhances decision-making, risk management, and input allocation. Conversely, farmer age shows a positive and significant relationship with inefficiency, suggesting that older farmers may be less adaptive to technological innovations and intensive management requirements of greenhouse systems. The constant term is not significant, implying that inefficiency variations are primarily explained by farmer-specific characteristics.

Distribution of Technical Efficiency Scores

The distribution of technical efficiency scores among farmers is summarized in Table 3.

Table 3. Distribution of Technical Efficiency Levels

Efficiency Level	Number of Farmers	Percentage
0.71–0.80	1	2.86%
0.81–0.90	5	14.29%
>0.90	29	82.86%
Average		0.956
Maximum		0.999
Minimum		0.799

Primary Data, 2026

The results indicate a high overall level of technical efficiency among greenhouse paprika farmers. No farmers exhibit efficiency scores below 0.70, and the majority (82.86%) operate at efficiency levels above 0.90, suggesting that most farmers are already operating close to the production frontier. The average efficiency score of

0.956 implies that, on average, farmers achieve 95.6% of potential output given the existing input combination. Nevertheless, the presence of a small proportion of farmers with lower efficiency indicates opportunities for productivity improvement through enhanced managerial practices and capacity building rather than increased input use.

Production Projection of Greenhouse Paprika Farming

Paprika generally enters a productive phase at approximately 2–3 months after transplanting, depending on cultivar and cultivation conditions. The production cycle within one growing season includes vegetative growth, flowering, fruit set, and harvest of marketable fruits, and harvesting can be conducted sequentially because the crop can produce repeatedly during the harvest period. Production performance is strongly influenced by environmental conditions, cultivation techniques, and maintenance intensity, including greenhouse microclimate management, nutrient regulation, pest and disease control, and farmer skills in pruning and fruit selection. Under Indonesian greenhouse systems, average paprika yield typically ranges from 2 to 4 kg per plant per season, depending on the cultivation system and management intensity. In Baturiti District, output levels similarly depend on local environmental conditions and the effectiveness of greenhouse management practices.

Annual average production per greenhouse in Baturiti District exhibited a fluctuating pattern during 2021–2025. Production in 2021 was recorded at 7,290 kg per greenhouse, declining to 6,930 kg per greenhouse in 2022, which may indicate disruptions attributable to technical cultivation factors, environmental conditions, or farm management (Oktofajri, 2023). Production increased again in 2023 to 7,387 kg per greenhouse and remained relatively stable in 2024 at 7,374 kg per greenhouse, suggesting improved greenhouse and crop management during these years. However, production declined again in 2025 to 6,930 kg per greenhouse, potentially reflecting changes in input quality, fertilization intensity, labor availability, or greenhouse microclimate conditions. Overall, annual production ranged from approximately 6,900 to 7,400 kg per greenhouse, indicating relatively high potential but incomplete stability, thereby underscoring the importance of consistent farm management, particularly in input regulation and greenhouse maintenance, to sustain productivity and production efficiency.

Financial Feasibility Analysis

The financial feasibility of greenhouse paprika farming on a 4-are (400 m²) greenhouse unit in Baturiti District, Tabanan Regency, was assessed using discounted investment criteria—Net Present Value (NPV), Internal Rate of Return (IRR), and Net Benefit–Cost (Net B/C) Ratio—supported by sensitivity analysis. The feasibility assessment applied the following assumptions: (1) a five-year analysis period aligned with the economic life of paprika production and optimal greenhouse utilization; (2) one greenhouse unit of 400 m² representing the observed farm scale; (3) an average selling price reflecting respondent farm-gate prices; (4) constant annual input prices (seeds, fertilizers, pesticides, growing media, water, electricity, and other materials) based on observed averages; and (5)

an 8% discount rate representing relevant borrowing costs and the opportunity cost of capital for farmers in the study area.

The discounted cash-flow structure—including annual cash outflows (investment and operating costs), cash inflows (farm revenues), and the present value of each component—forms the basis for calculating NPV, IRR, Net B/C, and the subsequent sensitivity tests. These results are presented in Table 4.

Table 4. Cash Flow and Present Value of Cash Flow for Greenhouse Paprika Farming (IDR)

Year	Cash Flow		Present Value	
	Outflow	Inflow	Outflow	Inflow
0	-8,271,061.95	–	–	–
1	50,821,150.44	250,105,840.71	47,056,620.78	231,579,482.14
2	50,821,150.44	201,024,247.79	43,570,945.17	172,345,891.45
3	50,821,150.44	217,040,000.00	40,343,467.75	172,293,349.59
4	50,821,150.44	253,448,849.56	37,355,062.73	186,292,470.58
5	50,821,150.44	166,373,805.31	34,588,021.05	113,135,588.37
Total	245,834,690.27	1,087,992,743.36	202,914,117.47	875,646,782.13

Primary Data, 2026

As shown in Table 4, the enterprise requires an initial investment outflow of IDR 8,271,061.95 in year 0, prior to production. Thereafter, annual operating outflows remain relatively stable at IDR 50,821,150.44 from year 1 to year 5, indicating a predictable operational cost structure associated with hybrid seed procurement, fertilizer and pesticide use, labor costs, and water/electricity needs typical of greenhouse production. Revenues begin in the first production year (IDR 250,105,840.71) and fluctuate thereafter, peaking in year 4 (IDR 253,448,849.56) before declining in year 5 (IDR 166,373,805.31), which is consistent with production risks and price dynamics over the cycle. In present value terms, total discounted inflows substantially exceed total discounted outflows, implying a positive net economic surplus over the analysis period. The feasibility indicators derived from the discounted cash-flow analysis are summarized in Table 5.

Table 5. Investment Criteria Calculation (IDR)

Year	Inflow	Outflow	Net Benefit	DF (8%)	NPV
0	–	-8,271,061.95	-8,271,061.95	1.00	-8,271,061.95
1	250,105,840.71	50,821,150.44	199,852,699.12	0.93	176,777,733.53
2	201,024,247.79	50,821,150.44	150,771,106.19	0.86	131,331,814.16
3	217,040,000.00	50,821,150.44	166,786,858.41	0.79	146,161,214.36
4	253,448,849.56	50,821,150.44	203,195,707.96	0.74	179,873,112.09
5	166,373,805.31	50,821,150.44	116,120,663.72	0.68	99,248,071.12

NPV: 666,825,125.30

IRR: 23.93%

Net B/C: 1.27

Primary Data, 2026

Table 5 indicates that the enterprise generates a positive NPV of IDR 666,825,125.30 at an 8% discount rate over five years, implying that discounted benefits exceed discounted costs. The IRR is 23.93%, substantially higher than the discount rate, confirming that the investment yields an internal return well above the minimum required return. The Net B/C ratio of 1.27 further indicates that each unit of discounted cost produces 1.27 units of discounted net benefit. Taken together, these indicators demonstrate that greenhouse paprika farming in Baturiti District is financially viable and provides economically attractive returns under the baseline assumptions.

Sensitivity Analysis

Given the susceptibility of horticultural enterprises to output price volatility and input cost changes, sensitivity analysis was performed to test the robustness of financial feasibility under adverse scenarios. The tested scenarios include: (1) decreases in paprika output price with input prices held constant (5%, 10%, 20%, and 25%); and (2) increases in input prices with production held constant (5%, 10%, and 20%). The results are reported in Table 6.

Table 6. Sensitivity Analysis of Greenhouse Paprika Farming

Assumption	NPV	IRR	Net B/C	Remarks
Output price ↓ 20%, input price constant	491,676,643.28	17.87%	1.01	Feasible
Output price ↓ 10%, input price constant	579,250,884.29	20.90%	1.14	Feasible
Output price ↓ 5%, input price constant	623,038,004.80	22.41%	1.20	Feasible
Output price ↓ 25%, input price constant	447,889,522.78	16.35%	0.94	Not feasible
Input price ↑ 20%, production constant	626,695,880.73	22.70%	1.05	Feasible
Input price ↑ 10%, production constant	646,760,503.02	23.31%	1.15	Feasible
Input price ↑ 5%, production constant	656,792,814.16	23.62%	1.20	Feasible

Primary Data, 2026

As shown in Table 6, the enterprise remains feasible under output price declines of 5–20% (Net B/C \geq 1.01; IRR 17.87–22.41%) and under input cost increases of 5–20% (Net B/C 1.05–1.20; IRR 22.70–23.62%). However, feasibility cannot be sustained under a 25% decline in output price, as Net B/C falls below 1 (0.94), indicating that discounted net benefits are insufficient to cover discounted costs despite NPV remaining positive. This evidence suggests that greenhouse paprika farming in Baturiti has relatively strong financial resilience to moderate shocks but is vulnerable to large negative output price shocks. Therefore, sustaining farm-gate price stability (e.g., through market coordination and quality-based segmentation) and maintaining disciplined cost control are essential for long-term viability.

Conclusion

The results indicate that the technical efficiency of greenhouse paprika farming in Baturiti District has not yet reached an optimal level. The Stochastic Frontier Analysis (SFA) reveals that 82.86% of farmers exhibit technical efficiency scores below 0.90, indicating that the majority of producers are operating below the maximum production frontier. This finding confirms the presence of technical inefficiencies in the utilization and management of production inputs, including seeds, fertilizers, labor, and cultivation practices. Accordingly, the study demonstrates that technical efficiency in greenhouse paprika farming remains improvable through better allocation of inputs and enhanced farm management, thereby fulfilling the first research objective.

From a financial perspective, greenhouse paprika farming in Baturiti District is found to be economically viable. The positive Net Present Value (NPV) of IDR 666,825,125.30, an Internal Rate of Return (IRR) of 23.93%—which exceeds the applied discount rate—and a Net Benefit–Cost (Net B/C) ratio of 1.27 collectively confirm that the investment meets and surpasses standard financial feasibility criteria. These results indicate that greenhouse paprika farming is capable of generating favorable economic returns and maintaining financial sustainability over the medium term, thus addressing the second research objective.

Sensitivity analysis further demonstrates that the financial feasibility of greenhouse paprika farming shows a reasonable degree of resilience to economic fluctuations within certain limits. The enterprise remains financially feasible under moderate output reductions; however, feasibility cannot be sustained when output declines exceed the identified threshold or when such declines are accompanied by substantial increases in key input costs. This finding highlights that production stability and cost control are critical determinants of long-term financial sustainability and directly addresses the third research objective. Overall, the study underscores the importance of improving technical efficiency and strengthening economic resilience to support the sustainable development of greenhouse paprika agribusiness in highland areas.

Managerial Recommendations

From a managerial perspective, farmers are encouraged to prioritize improvements in technical efficiency rather than expanding production scale. The results suggest that productivity gains can be achieved primarily through better management of key inputs—particularly seed quality, growing media, and nutrient application—rather than increasing land area or labor use. Adoption of standardized operating procedures (SOPs) for greenhouse management, including irrigation scheduling, fertilization regimes, and pest control, is recommended to ensure consistent production performance.

Farmers should also invest in continuous learning and skill development, especially in relation to greenhouse technology and crop management innovations. The negative relationship between farming experience and inefficiency underscores the value of accumulated practical knowledge, while the positive association between age and inefficiency suggests the importance of

encouraging technology adoption among older farmers through training and mentoring programs.

In addition, given the vulnerability of profitability to sharp output price declines, farm managers should implement risk mitigation strategies. These may include diversifying marketing outlets, improving product quality to access premium markets, and strengthening cost control mechanisms to maintain profitability under adverse conditions. Maintaining detailed farm records and regularly evaluating financial performance using simple investment indicators can further support informed decision-making and long-term business sustainability.

Overall, the integration of supportive public policies with improved farm-level management practices is essential to enhance technical efficiency, strengthen financial resilience, and promote the sustainable development of greenhouse paprika agribusiness in highland regions.

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