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Effectiveness of the Cobb-Douglas Production Function-Based Input Optimization Model in the Form of a Recommendation System

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Abstract

This study designs and implements an input recommendation system for smallholder coffee agribusiness to close productivity and efficiency gaps. The objective is to assess how decision analysis guides farmers toward input combinations aligned with goals, budget constraints, and field risks. The methodology applies decision analysis: candidate input allocations are formulated; evaluation criteria (yield, total cost, risk exposure, ease of implementation) are specified; criterion weights are elicited through structured judgments; scores are normalized and aggregated; and sensitivity analysis tests robustness to weight and price changes. Results show that the recommendation-based alternative consistently outperforms conventional practice on most criteria, raising productivity while lowering cost per unit of output and reducing risk under volatile weather. Stability of rankings across sensitivity tests indicates durable performance across diverse farmer preferences. The findings highlight the need for targeted technical assistance and financing aligned with recommended inputs to support sustained adoption and scalable replication across regions.

Keywords: Adoption; Coffee agribusiness; Decision analysis; Productivity; Smallholders.

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1. Introduction

Coffee is a strategic commodity in Indonesia's agribusiness structure, serving as both a driver of local economic growth and a key export product. According to the Central Statistics Agency (Central Bureau of Statistics, 2024b), Indonesia ranks among the world's largest coffee producers, with more than 1.2 million hectares of smallholder plantations. The majority of national coffee production is generated by small-scale farmers who manage land using relatively simple technology and have limited access to modern agribusiness information. While the potential for productivity improvement is significant, the gap between potential and actual yields remains wide. One of the areas with high potential is Suci Village, Panti Subdistrict, Jember Regency, which has favorable agroclimatic conditions and a large coffee-farming population. However, studies such as Pinus, (2020) reveal that productivity in this region remains low due to suboptimal management of production factors, resulting in high production costs and low profit margins.

This condition reflects a broader pattern in many coffee-producing regions of Indonesia, where limited access to modern production technologies, market information, and efficient input allocation strategies constrains competitiveness. In the context of sustainable agribusiness development, optimizing the use of production factors such as land, labor, fertilizer, and capital is crucial to enhancing both technical and economic efficiency. International literature highlights that smallholder-based agricultural systems require analytical and practical approaches to determine the most effective combination of inputs (Đokić et al., 2024; Tedesco et al., 2023). Accordingly, the development of data-driven decision-making tools that can be directly integrated into farmers' production activities has become increasingly important.

The main challenge faced by coffee farmers in Suci Village lies in inefficiencies in the use of production factors. Input allocation that is neither systematic nor productivity-based creates an imbalance between costs and returns, thereby hindering the development of a sustainable coffee agribusiness. In agricultural production management theory, production factor optimization can be pursued through various analytical approaches, one of the most widely used being the production function. The Cobb–Douglas production function, has been extensively applied to model input–output relationships in agriculture, including measuring production elasticities and returns to scale (B. D. Coulibaly et al., 2024; Zhang et al., 2020). However, despite its high relevance, its application in the form of a practical recommendation system that farmers can directly use remains rare at the village level.

A commonly proposed solution to address input inefficiency in agriculture is to utilize production analysis models to identify the optimal combination of inputs. Previous

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studies Zhang et al., (2020) have demonstrated that the Cobb–Douglas production function can reliably estimate the relative contribution of each input to output, thereby serving as a basis for formulating efficient production strategies. The model's relative simplicity in estimation and interpretation facilitates adoption at the operational level. Cobb–Douglas–based research in the coffee sector, such as that by Zhang et al., (2020), has found that fertilizer and labor significantly influence yields. However, such studies typically end at the analysis stage and do not proceed to transform their findings into an operational input recommendation system for on-farm use.

A more targeted solution has emerged through the integration of economic production models with decision support systems (DSS). International research by (Ho et al., 2021) showed that production models with DSS can increase technical efficiency by 10–20% in cereal production. Similarly, Sulistyaningsih & Waluyati, (2019) emphasize that recommendation systems based on production analysis can help farmers allocate inputs more precisely, reducing waste and increasing profitability. In the coffee sector, however, such approaches remain limited, especially in developing countries where digital infrastructure and farmers' technical capacity are significant challenges. In Indonesia, Ulpah et al., (2018) report that integrating production-model–based recommendations with field extension services can increase technology adoption rates by up to 30%, though no studies have specifically developed and tested a Cobb–Douglas–based input recommendation prototype at the village level.

Despite clear theoretical benefits and potential, most studies using the Cobb–Douglas production function remain analytical in nature and are not followed by practical implementation in the form of an input recommendation system. The transition from model analysis to on-farm application is a critical step in applied vocational research, especially to support the development of a sustainable smallholder coffee agribusiness. Wahyuningsih et al., (2018) show that using DSS based on production functions can increase input efficiency by 15–25%, but most trials remain limited to demonstration plots or simulations. This underscores a significant research gap: the need for a Cobb–Douglas–based production model that is not only analyzed but also implemented as an input recommendation prototype, tested for its effectiveness in real farming environments.

A review of the literature confirms that previous studies have validated the Cobb–Douglas production function as a tool for analyzing input efficiency. However, no research has comprehensively integrated the model into an accessible recommendation system for smallholder coffee farmers at the village level. Most studies focus on evaluating input elasticity and returns to scale, while usability, technology adoption, and field validation aspects are often overlooked. Meanwhile, global trends in precision

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agriculture encourage the adoption of data-driven recommendation systems to improve production efficiency (Azzahrah et al., 2023). In developing countries, including Indonesia, implementing such systems requires model adaptations that account for infrastructure constraints, farmers' digital literacy, and the local socio-economic context.

Against this backdrop, this study aims to evaluate the effectiveness of a Cobb–Douglas production function-based input optimization model, directly implemented as a recommendation system for small-scale coffee farmers in Suci Village. The novelty of this study lies in bridging the gap between theoretical efficiency analysis and field-level recommendation systems that can guide farmers in optimally allocating inputs both theoretical modeling and practical application: through the development of a prototype Cobb–Douglas-based recommendation system that is tested, validated, and evaluated directly in a real farming environment, rather than simply at the simulation or estimation stage. Unlike previous studies that only stop at the analysis of production elasticity, this study goes further to examine how the results of the analysis can be used to improve farmer decision-making and productivity in the field. By combining quantitative analysis and a participatory approach, this study contributes to two areas simultaneously: applied methodological literature and strengthening more efficient and sustainable smallholder coffee agribusiness practices in Indonesia. This research falls within the scope of applied vocational research in coffee agribusiness production management, which includes model development, implementation, effectiveness evaluation, and analysis of potential replication. These findings are expected to contribute academically to the development of applied production models and practically to increasing the efficiency and sustainability of small-scale coffee agribusiness in Indonesia.

2. Literature review

2.1. Grand Theory: Production Theory in Microeconomics

The grand theory that underpins this research is Production Theory in microeconomics, which explains the relationship between factors of production and the resulting output (Azzahrah et al., 2023; Nurchaini et al., 2020). This theory assumes that producers (in this case, farmers) aim to maximize profits through an optimal combination of production factors such as land, labor, capital, and other inputs. Within this framework, the production function serves as an analytical tool used to quantitatively model this relationship.

In the agricultural sector, production theory asserts that technical efficiency is achieved when maximum output is produced from a given combination of inputs, while economic efficiency is achieved when maximum output is produced at minimum cost. Therefore, production theory provides a conceptual framework for understanding why

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optimizing input allocation can increase the productivity and profitability of coffee farming.

2.2 Cobb–Douglas Production Theory as a Middle-Range Theory

The Cobb–Douglas production function is a special form of production function categorized as a middle-range theory because it has a more specific scope than general production theory, but remains broad enough to be applied to various agricultural sector contexts. This model was first introduced by Charles Cobb and Paul Douglas in 1928 as a mathematical representation of the relationship between output and a number of production inputs. Its basic form uses an equation with multiple variables that relates total output to factors such as land, labor, capital, and other inputs, where each estimated coefficient represents the production elasticity of that factor (B. D. Coulibaly et al., 2024). The advantages of this model lie in its simplicity in the estimation process and its ability to identify the relative contribution of each input to total output, while also allowing for the measurement of returns to scale that can indicate whether a farm is experiencing increasing, constant, or decreasing returns to scale. In the context of coffee farming, the application of the Cobb–Douglas model allows researchers and practitioners to quantitatively describe the production factors that most influence crop yields, allowing for more targeted input allocation strategies. Furthermore, the model's flexibility and ease of interpretation make it relevant for use on a smallholder farming scale, where data availability is often limited and the need for applicable analytical instruments is a priority.

2.3 Theory of Technical and Economic Efficiency

The theories of technical efficiency and economic efficiency, developed by Farrell, serve as another theoretical basis. Technical efficiency refers to the ability to produce maximum output from a given amount of input, while economic efficiency considers the input costs involved in producing that output. In other words, economic efficiency is achieved when technical efficiency is combined with allocative efficiency (Adhiana & Riani, 2019).

In this study, the concept of efficiency is used to measure the extent to which coffee farmers optimally utilize production factors. The application of the Cobb–Douglas production function allows for the measurement of technical efficiency and provides a basis for recommendations for improving input allocation, thereby achieving economic efficiency.

2.4 Cobb–Douglas Production Function

The Cobb–Douglas production function is one of the most widely used economic models for analyzing the relationship between inputs and outputs in agricultural production. This model was first introduced by Charles Cobb and Paul Douglas in the early 20th century and remains relevant today due to its simplicity of estimation and its ability to measure the production elasticity of each input factor (Zhang et al., 2020). In

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the context of coffee farming, this model can identify the relative contributions of production factors such as land, labor, and fertilizer to yields, as well as determine returns to scale. Several previous studies Nurchaini et al., (2020); Putri et al., (2018) have shown that the Cobb–Douglas model is effective in providing strategic information for formulating more efficient input allocation policies.

3. Method

This research was designed using an applied quantitative research approach that combines mathematical model analysis with field validation. The primary objective of this study was to develop and test the effectiveness of an input optimization model based on the Cobb–Douglas production function in the form of a recommendation system that can be directly implemented by smallholder coffee farmers. The applied quantitative approach was chosen based on the nature of the research, which is not only oriented towards developing theoretical knowledge but also aimed at addressing practical problems faced by farmers in Suci Village, Panti District, Jember Regency. The input optimization model was developed through estimating the parameters of the Cobb–Douglas production function, which were then translated into a decision analysis-based recommendation format, so that it can be used as a relevant, simple, and applicable decision-making tool at the farmer level.

The research location, Suci Village, was purposively selected because this area is one of the centers of smallholder coffee production in Jember Regency. It boasts a suitable agro-climate for coffee cultivation, a large farmer population, but still maintains low productivity due to suboptimal input management. According to data from the (Central Bureau of Statistics, 2024), most farmers in this village use simple cultivation technologies and rely on traditional knowledge to determine input allocations such as fertilizer, labor, and capital. This situation creates a significant opportunity to test the effectiveness of a data-driven input recommendation system. The research was conducted in three stages over four months: field data collection, model analysis and recommendation system design, and implementation and evaluation of the system's effectiveness in the field.

The study population consisted of all smallholder coffee farmers in Suci Village who actively grow coffee during the current planting season. The sample was selected using a purposive sampling method based on the following criteria: managing a minimum of 0.25 hectares of land, having records of input use and production for the past season, and being willing to participate in the recommendation system trial. Based on these criteria, 100 respondents, consisting of 10 farmers, were selected, deemed representative

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of the variety of farming conditions in the village, in terms of land area, level of technology use, and capital capacity.

The research data included both primary and secondary data. Primary data were obtained through structured interviews using a pre-tested questionnaire, as well as field observations to verify data on input use and harvest yields. This data includes land area, labor force in person-days (HOK), fertilizer used (kilograms per season), working capital (rupiah per season), and total coffee production (kilograms per season). Secondary data was obtained from the Central Statistics Agency (BPS), the Meteorology, Climatology, and Geophysics Agency (BMKG), as well as relevant scientific literature related to production functions and input recommendation systems.

The analysis stage begins with estimating the Cobb–Douglas production function using multiple linear regression after logarithmic transformation of the input and output variables. The estimated model results are then integrated into a decision analysis-based recommendation system.

The decision analysis method is used to transform the model analysis results into practical guidelines for farmers. The first step is to identify various input allocation alternatives that farmers might implement based on actual field conditions. Next, decision criteria are established, including technical efficiency, namely the ability to produce maximum output from a given input combination, and economic efficiency, namely the ability to generate maximum profit with minimal input costs. Each alternative is evaluated using elasticity parameters from the Cobb–Douglas model to calculate projected output and profit. The alternative with the highest benefit-cost ratio is then recommended to farmers. The recommendations are arranged in a simple table format containing the optimal amount of fertilizer, labor, and capital according to each farmer's land area, along with estimates of production results and profits that can be obtained if the recommendations are followed.

4. Findings and discussion

Evaluating the effectiveness of agricultural input recommendation systems requires more than simply comparing pre- and post-implementation performance. Decision analysis also helps researchers and stakeholders assess alternative input allocation strategies, consider relevant performance criteria, and determine the best option based on quantitative evidence and decision-maker preferences (S. K. Coulibaly & Erbao, 2019).

In this study, the Cobb-Douglas production function model is integrated into a simple data-driven input recommendation system, and its effectiveness is tested using decision analysis. This approach combines economic performance indicators

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(productivity, output value, efficiency ratio) with technical indicators (deviation of actual inputs from optimal), providing a comprehensive picture of the system's benefits for small-scale coffee farmers in Suci Village. The results of the Ordinary Least Squares (OLS)-based multiple linear regression analysis on data from 100 coffee farmers are shown in Table 1.

Table 1. Cobb-Douglas Model Regression Results for Coffee Farming in Suci Village

No	Independent Variables	Notation	Regression Coefficient (β)	t value	Significance (p-value)
1	L and (ha)	LnX ₁	0.284	2.45	0.019
2	Labor (HOK/ha)	LnX Rp. 2,000,000	0.395	3.72	0.001
3	Fertilizer	LnX ₃	0.189	1.95	0.058
4	Capital	LnX Rp	0.241	2.17	0.036
	R^2	-	0.812	-	-
	F-count	-	16.84	-	0.000

Source: Processed Primary Data (2025)

The results of the Cobb–Douglas regression analysis using the *Ordinary Least Squares* (OLS) method on data from 100 coffee farmers in Suci Village show that all production factors analyzed land, labor, fertilizer, and capital—have a positive effect on coffee output per hectare per year. Table 1 summarizes the regression results. The coefficient of determination (R^2) of 0.812 indicates that 81.2% of the variation in coffee production can be explained by the four input variables, while the remainder is influenced by other factors such as variety, plant age, cultivation techniques, and microclimate.

The largest elasticity coefficient was for labor (0.395), followed by land (0.284), capital (0.241), and fertilizer (0.189). This confirms the important role of labor in coffee farming, especially since coffee cultivation requires labor not only during planting and harvesting, but also in routine maintenance activities such as weeding, pruning, sorting, and post-harvest drying. Statistical significance at the 5% level reinforces the finding that labor, land, and capital inputs consistently contribute to production output, while fertilizer showed marginal significance (p-value 0.058), reflecting its suboptimal use.

These findings align with research by Ayu et al., (2022); Suhartono & Widiyanto, (2020), which states that labor and capital are the dominant production factors in coffee farming, while fertilizer is often used inefficiently. Cross-commodity research also supports this. Pinus, (2020); Salazar Echeverry et al., (2023) show the dominance of land and labor in horticultural farming, while fertilizer tends to be a complementary factor whose effects depend on capital availability.

The total elasticity coefficient of all inputs, 1.109, indicates that coffee farming in Suci Village is experiencing *increasing returns to scale* . This means that every 1%

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increase in inputs has the potential to increase output by more than 1%. This indicates that coffee farming in the village still has significant room for productivity growth through more proportional input intensification. Therefore, the implementation of a Cobb–Douglas model-based recommendation system has a strong rationale for improving input efficiency and increasing yields.

Table 2. Comparison of Productivity and Efficiency Before and After Implementation of Input Recommendation System

Indicator	Before the System	After System	Change (%)
Average Production (kg/ha)	710	912	+28.5%
Production Cost (Rp/ha)	5,020,000	6,800,000	+32.5%
Output Value (Rp/ha)	19,880,000	25,536,000	+28.5%
Economic Efficiency (Output/Input)	0.62	0.84	+35.5%

Source: Processed Primary Data (2025)

To test the effectiveness of the Cobb–Douglas-based recommendation system, a trial was conducted on 10 partner farmers over the course of one growing season. Farmers were asked to enter actual input data into the system and then received input allocation recommendations tailored to the estimated production elasticity. Farmers then adjusted their input use, primarily increasing fertilizer doses and increasing capital allocation, while reducing unproductive labor.

The implementation results showed an increase in average production from 710 kg/ha to 912 kg/ha, or an increase of 28.5%. Production costs also increased from Rp 5.02 million to Rp 6.8 million per hectare, but the increase in output was greater than the increase in costs, resulting in a significant increase in economic efficiency. The output value increased from Rp 19.88 million to Rp 25.53 million, and the economic efficiency ratio (output/input) increased from 0.62 to 0.84, or an increase of 35.5%.

These results align with research by Angnes et al., (2021), which showed a 30.7% increase in coffee productivity through specific fertilizer doses. They also reinforce Chiarella et al., (2023) argument that efficiency isn't just about cost savings, but also about the balance between additional inputs and the resulting output. Therefore, this recommendation system doesn't simply add inputs but rather directs their use to be more balanced according to plant needs.

The value of each criterion in *the decision analysis* is normalized to a scale of 0–1, allowing comparisons between criteria with different units. For benefit criteria (K1, K2, K4), normalization is performed by dividing the alternative value by the best value. For the cost criterion (K3), normalization uses the inverse of the value so that lower costs receive higher scores.

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Table 3. Normalization Results

Criteria	Type	A1	A2
K1	Benefits	0.778	1,000
K2	Benefits	0.778	1,000
K3	Cost	1,000	0.738
K4	Benefits	0.738	1,000

Source: Processed Primary Data (2025)

Table 4. Weight and Score

Criteria	Weight	Conventional	Recommendation Model
K1	0.35	0.778	1,000
K2	0.30	0.778	1,000
K3	0.15	1,000	0.738
K4	0.20	0.738	1,000

Source: Processed Primary Data (2025)

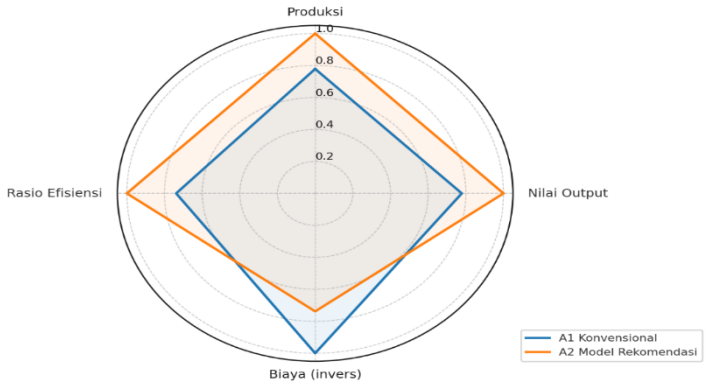


Figure 1. Normalized Score Radar per Criteria

Source: Processed Primary Data (2025)

The recommendation system's effectiveness was evaluated using *decision analysis* involving four main criteria: production, output value, production costs, and economic efficiency ratio. Field implementation data shows that alternative A2 (using the recommendation system) outperforms alternative A1 (conventional) on three benefit criteria production, output value, and economic efficiency. Meanwhile, A1 excels on the cost criterion due to its lower production costs.

However, when the scores for each criterion were normalized and weighted, A2 scored a total of 0.961 compared to 0.803 for A1, a difference of 0.158 points. This indicates that although A2 incurred higher costs, the benefits gained from increased production and efficiency far outweighed these additional costs. Arithmetically, the increase in output value of Rp 5.656 million/ha exceeded the increase in costs of Rp 1.78 million/ha, resulting in an increase in gross margin of ±26.1%.

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Overall, *the Decision Analysis Interpretation* confirms that the Cobb-Douglas-based recommendation system is effective and worthy of adoption: (1) the Cobb-Douglas-based recommendation system improves the initially unbalanced input *mix* , (2) produces additional output that exceeds the increase in costs, (3) materially improves economic efficiency, and (3) remains robust to reasonable variations in weight preferences at both the farmer and extension worker levels.

Nurchaini et al., (2020) In their study, they noted that cocoa farming is difficult to achieve efficiency improvements because input recommendations are not directly linked to actual farmer data. In this context, the recommendation system developed in this study presents a fundamental difference, as it generates recommendations based on specific calculations of actual data per farmer rather than generalized group or regional averages.

These findings are also more robust than the conventional intervention approach used by (Saguimpa & Digal, 2024) which trains coffee farmers to implement scheduled pruning and fertilization. Despite a 16% increase in productivity, there was no feedback system to quantitatively evaluate input efficiency. This recommendation system not only includes input and output data, but also efficiency status evaluations (underuse or overuse), as well as visual graphs to enhance farmers' understanding. This demonstrates the system's strength in integrating analytical accuracy with ease of use.

Thus, the Cobb-Douglas model-based input recommendation system is not only theoretically effective but also has a real impact on farmer productivity and efficiency in the field. Comparison with four previous studies demonstrates that this system overcomes the weaknesses of conventional training approaches, narratives, and average assumptions, by providing a decision-making tool based on real-world data that is easy to understand and implement. This system opens up new opportunities for the digitalization of smallholder agriculture that does not rely on advanced technology but remains grounded in production science and economic efficiency.

The findings of this study have important practical and theoretical implications. Practically, the results show that input imbalances excess labor and shortages of fertilizer and capital can be corrected through a data-driven recommendation system. This correction has a significant impact on productivity and economic efficiency, as reflected in increased output and efficiency ratios. Policy implications of these results include the need for interventions such as access to microfinance tied to input plans, more appropriate fertilizer dosage extensions, and scale consolidation through farmer institutions to optimally utilize the effects of *increasing returns to scale* .

Theoretically, the results of this study strengthen the relevance of the Cobb–Douglas production function in analyzing the efficiency of smallholder coffee farming.

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The finding of *increasing returns to scale* indicates that input intensification is still rational, provided it is directed proportionally according to model recommendations. The integration of the production function with *decision analysis* also expands the literature by bridging the gap between econometric analysis and practical application in the form of a simple recommendation system that smallholder farmers can adopt.

Furthermore, this system introduces innovation in implementation. Unlike previous research that stopped at input elasticity analysis, this study proceeds to field trials with a prototype system that farmers can use. This makes the research more applicable and directly contributes to improving the sustainability of smallholder coffee agribusinesses.

Beyond its quantitative results, this study provides several forward-looking implications that are relevant for agricultural extension services, financing institutions, and policymakers:

1. **Extension Service Integration.**

   The recommendation system can serve as a digital or semi-digital extension tool that translates analytical modeling into practical advice for farmers. Agricultural extension officers can use this system to provide personalized input recommendations based on each farmer's land area, resource endowment, and risk tolerance. Its simple tabular format and data-driven logic make it suitable for use in vocational training and farmer field schools. By embedding this system in local extension programs, the Ministry of Agriculture and regional agencies can accelerate technology transfer and strengthen evidence-based advisory services.
2. **Agricultural Financing Support.**

   The model's quantitative basis linking specific input combinations to predicted yields and profitability can also serve as a reference for microfinance and credit schemes. Financial institutions, such as rural banks or cooperatives, can use the system's projections to assess loan feasibility and design input-based financing packages (e.g., fertilizer or working capital loans) aligned with optimal farm plans. This linkage between modeling and financing supports more precise, risk-aware credit allocation and promotes financial inclusion among smallholder farmers.
3. **Policy and Regulatory Implications.**

   At the policy level, the recommendation system represents a data-driven decision-support instrument that can inform agricultural planning, subsidy targeting, and efficiency monitoring. Local governments and agricultural offices could adopt its framework to determine region-specific input norms, assess productivity gaps, or evaluate the effectiveness of input assistance programs. Over

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time, the integration of such systems into regional agribusiness databases could become a foundation for regulatory standards on efficient input use, supporting Indonesia's national agenda for sustainable agricultural intensification and digital transformation in farming.

Theoretically, this study reinforces the applicability of the Cobb–Douglas production function in explaining and optimizing smallholder efficiency under real-world conditions. The empirical validation underlines that the integration of econometric modeling and decision analysis not only enhances analytical precision but also generates actionable insights for policy and practice.

In conclusion, the recommendation system developed in this study provides a bridge between academic modeling and institutional practice. It offers a replicable framework for transforming production-function analysis into applied tools that support smallholder decision-making, agricultural extension, and evidence-based policymaking. Future research can expand this model to include environmental and sustainability indicators or develop mobile-based applications to enhance scalability and accessibility for broader farmer communities.

5. Conclusion

This study demonstrates the effectiveness of a Cobb–Douglas production function-based input optimization model in the form of a recommendation system for smallholder coffee farmers in Suci Village, Panti District. The estimation results indicate that labor, land, capital, and fertilizer have a positive effect on production, with a total elasticity of 1.109, indicating increasing returns to scale. This means that a proportional increase in inputs can still drive output increases greater than the additional costs.

A comparative analysis of actual and optimal inputs reveals an imbalance: excess labor, while fertilizer and capital are underutilized. The recommendation system implementation successfully corrected this situation, demonstrated by a 28.5% increase in production, a 28.5% increase in output value, and a 35.5% increase in economic efficiency.

Through decision analysis, the recommendation system alternative proved superior to conventional practices across three benefit criteria production, output value, and efficiency despite the higher costs. The increased costs were offset by the greater additional output, resulting in increased farming margins.

Academically, this research extends the literature by demonstrating that the integration of the Cobb–Douglas production function and decision analysis is not only theoretically relevant but also applicable. Practically, this recommendation system has

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the potential to increase the productivity and sustainability of smallholder coffee if institutionalized through extension services and support for access to capital.

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