

Input Allocation and Efficiency to Increase Corn Production

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ABSTRACT

BACKGROUND AND OBJECTIVES

Increasing corn production can currently only be achieved through intensification, where the key is efficiency. Stagnant corn production in the research village over the past three years indicates inefficient use of inputs in corn farming. The first objective of this study is to describe the characteristics of corn farmers. Second, to analyze the allocation of input use by examining the effect of land area, seeds, organic fertilizer, urea fertilizer, phonska fertilizer, NPK fertilizer, pesticides, and labor on corn production. Third, to analyze the technical, allocative, and economic efficiency of input use in corn farming in Dengkol Village.

METHODS

This study conducted in Dengkol Village, Singosari Subdistrict, Malang Regency used quantitative methods. Data were collected through interviews with all 40 corn farmers. This primary data was analyzed using multiple regression with the Cobb Douglas production function approach to identify inputs that significantly affect corn production. Technical, allocative, and economic efficiency were calculated using their respective formulas and the results were then justified according to applicable criteria.

FINDINGS

The results show that only land area and pesticide volume have a significant and positive effect on corn production, while the other six inputs do not. Technical inefficiency stems from the use of land area, seeds, NPK fertilizer, and labor. Meanwhile, the use of all inputs contributes to allocative and economic inefficiency.

CONCLUSION

Corn production can increase if farmers focus on expanding their land and adding pesticides. Farmers should change the combination of inputs that can technically increase production at a lower cost in order to increase their profits. The government and the private sector can facilitate farmers so that their efforts can be achieved. This study is limited to one village and is cross-sectional in nature, so it cannot describe the conditions of villages with different characteristics and the dynamics of change over time.

Keywords: Allocative; Economy; Efficiency; Production; Technical

INTRODUCTION

Corn (*Zea mays* L.) is one of Indonesia's strategic food commodities, occupying an important position after rice (1) as a source of calories, protein, and fat (2) for animal feed and processed food. The increase in the national population and livestock industry has driven up demand for corn. In addition to the number of livestock industries, the increase in demand for corn also stems from the growth of the poultry population from 3.62 billion in 2020 to 3.86 billion in 2022 (3). To meet this demand, farmers must strive to increase their production. However, farmers face serious challenges, including limited land due to conversion, soil fertility degradation, and fluctuations in input prices, which tend to increase. It means that increasing production can no longer be achieved through land expansion (extensification), but must be achieved through increased productivity on existing land (intensification).

Population growth and agricultural intensification began to increase rapidly in the 20th century. In the years following World War II, a paradigm shift in agriculture began to take place in industrialized countries, leading to the large-scale application of genetics, biochemistry, and genetic engineering in crop production. Significant productivity gains were achieved through the use of fossil fuel-powered agricultural machinery, high-yielding crop varieties, irrigation, and agrochemicals. Crop production intensification in developing countries began in earnest in the 1960s, as exponential population growth was accompanied by a significant decline in cereal production, leading to widespread famine (4).

Intensification hinges on efficiency, which is the ability of land to produce a certain amount of output with minimal input, or to produce maximum output with a certain amount of input. In Dengkol Village, the center of corn production in Singosari District, Malang Regency, corn farming is the backbone of the economy for most of the community. However, initial observations and discussions with local farmer groups indicate significant problems. Many corn farmers experience stagnant productivity. These findings are consistent with data (5) showing that over the past three years, corn productivity in this region has been recorded at 63.34 kw/ha. On the other hand, the cost of purchasing inputs such as seeds, fertilizers (urea and NPK), pesticides, and labor has increased over time. This raises strong suspicions that there has been inefficiency in the use of resources, where the allocation of inputs by farmers has not been optimal to achieve the expected level of profit. Farmers often use inputs based on habit or intuition, rather than precise and efficient measurements, resulting in waste of resources and sub-optimal income.

Considering these conditions, research to measure the level of efficiency in the use of inputs in corn farming in Dengkol Village is very important. This research is expected to benefit several parties. For farmers, the results will serve as practical guidance for allocating inputs more wisely, thereby reducing production costs and increasing income. For local governments and relevant agricultural agencies, the findings of this research can serve as an accurate database for designing more targeted extension programs, assistance policies (e.g., fertilizer subsidies), and corn agribusiness development strategies at the local level. For academics, this research will add to the body of knowledge in the field of agricultural economics, particularly regarding the application of efficiency theory at the micro level. What needs to be improved is farming practices

that are wasteful of inputs and unprofitable, moving towards a more efficient, productive, and sustainable system.

A number of previous studies have examined the efficiency of corn farming in various regions in Indonesia, including (6) in Boyolali Regency, (7) in Pohuwato Regency (Sulawesi), (8) on Madura Island, (9) in Biatan Ilir Village (Kalimantan), (10) in Kubu Raya District, (11) di in South Lampung District. However, these studies generally provide an overview of efficiency on a broad regional scale. What is not widely known and constitutes a knowledge gap that this study will fill is a comprehensive analysis of technical, allocative, and economic efficiency on a very specific micro scale, i.e., in Dengkol Village. There is no empirical data that quantitatively shows the extent of inefficiency in the use of production factors such as land area, various types of fertilizers, pesticides, and labor in corn farming in this village.

To fill this gap and improve the existing circumstances, researchers have taken concrete steps through this study. First, researchers collected primary data directly from corn farmers in Dengkol Village regarding the amount of inputs used (land area, seeds, fertilizers, pesticides, labor) and the outputs produced. Second, we identified inputs that significantly affect corn production using the Cobb Douglas production function regression model. Third, we measured the technical, allocative, and economic efficiency levels of the inputs used.

The novelty of this study lies in three main aspects: i) the research location is more specific in Dengkol Village, which produces more applicable and relevant recommendations compared to the large-scale studies in previous research. ii) The identification of determinants of land area, seeds, fertilizers by type, pesticides, and labor is also different from previous studies. iii) The analysis is comprehensive, measuring all three types of efficiency (technical, allocative, and economic), while previous studies focused more on one type of efficiency. The aims of this study were i) to describe the characteristics of corn farmers in Dengkol Village, ii) to analyze the allocation of input use by testing the effect of land area, seeds, organic fertilizer, urea fertilizer, phonska fertilizer, NPK fertilizer, pesticides, and labor on corn production. iii) to analyze the technical, allocative, and economic efficiency of input use in corn farming in Dengkol Village.

RESEARCH METHOD

We used a quantitative approach to analyze input efficiency in corn farming. Our research location was purposively selected in Dengkol Village, Singosari District, Malang Regency. The location was chosen because Dengkol Village is a corn production center in Malang Regency, where most of the population earns a living as corn farmers. In addition, preliminary observations indicated potential problems of inefficiency in corn farming practices in the village, making it a relevant and representative location for research.

The population of this study consisted of all corn farmers who were members of three farmer groups, namely Dewi Sri Farmer Group 1, Dewi Sri Farmer Group 2, and Dewi Sri Farmer Group 3 in Dengkol Village, Singosari Subdistrict, Malang Regency. There are 40 members in these farming groups. Due to the relatively limited population size, all corn farmers in Dengkol Village were designated as respondents.

Data collection was conducted through face-to-face interviews with 40 corn farmers using questionnaires. This primary data included output (corn production in kg per planting season) and inputs covering land area (ha), number of seeds (kg), amount of organic fertilizer (kg), urea fertilizer (kg), phonska fertilizer (kg), NPK fertilizer (kg), pesticide volume (liters), and labor input (man-days). In addition, the researchers also collected information on corn prices and the prices of each input, as well as the socio-economic characteristics of farmers, such as age, education, farming experience, and number of family members. Secondary data was obtained from the village office, the Agricultural Extension Center, and related publications from government agencies, as well as previous studies.

Analytical techniques are adapted specifically to meet each research objective. Data analysis is quantitative, using the Cobb-Douglas production function model. It is expressed in the following equation:

$$Y = b_0 X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} X_8^{b_8} \dots\dots\dots(i)$$

Where: Y = corn production, b_0 = constant, b_i = regression coefficient of each input ($i = 1-8$), X_1 = land area (m^2), X_2 = seeds (kg), X_3 = organic fertilizer (kg), X_4 = urea fertilizer (kg), X_5 = phonska fertilizer (kg), X_6 = NPK fertilizer (kg), X_7 = pesticides (kg), X_8 = labor (man-days)

The model was used to achieve the second objective, which was to analyze the effect of land area, seeds, organic fertilizer, urea fertilizer, phonska fertilizer, NPK fertilizer, pesticides, and labor on corn production. Multiple regression analysis was used with the Cobb Douglas production function approach (equation 1). First, this non-linear function had to be transformed into a natural logarithm-based equation:

$$\ln Y = \ln b_0 + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 \dots (ii)$$

The next step in this analysis is to conduct a classical assumption test (detection of data normality, no heteroscedasticity and multicollinearity) so that the regression model is BLUE. If the assumptions are met, then proceed with the F test and t test to identify which inputs have a significant effect on corn production and how they are related. A positive relationship between inputs and outputs serves as a guideline for farmers to increase the use of the relevant inputs, and vice versa.

To achieve the third objective, which is to analyze technical efficiency, allocative efficiency, and economic efficiency, we use formulas that are relevant to each type of efficiency.

a. Technical Efficiency

$$\text{Formula: } TE_i = \exp(-E[ui|ei]) \quad \text{where } i = 1,2,\dots,n \dots\dots\dots(iii)$$

Where: $0 \leq TE_i \leq 1$; TE = technical efficiency; $\exp(-E[ui|ei])$ = expected value (mean)

b. Allocative Efficiency is a measure of the success of farmers in their farming activities in obtaining maximum profit when the marginal cost of a given production factor is equal to its marginal product (12). Efficiency can be calculated using the formula:

$$\frac{NPM_x}{P_x} = 1 \dots\dots\dots(iv)$$

$$\frac{b.Y.P_y}{X} = P_x$$

$$\frac{b.Y.P_y}{X.P_x} = 1$$

Where: NPM_x = marginal product value of input X ; P_x = price of input X; b = elasticity; Y = output; P_y = price of output; X = amount of input X

Criteria: If $\frac{NPM_x}{P_x} > 1$, it means that using input X is not yet efficient. The amount of input X needs to be increased to achieve efficiency. If $\frac{NPM_x}{P_x} = 1$, it means that using input X is efficient. If $\frac{NPM_x}{P_x} < 1$, it means that using input X is inefficient. The amount of input X needs to be reduced to achieve efficiency.

- c. Economic efficiency is the product of technical and allocative efficiency. Formula:

$$EE = TE \times AE \dots\dots\dots(v)$$

RESULTS AND DISCUSSION

Characteristics of Corn Farmers in Dengkol Village

Corn farmers in Dengkol Village are generally 48 years old, with the majority (75%) being of productive age (35-55 years). Farmers of this age have the potential to increase productivity and adopt technology, but they also have challenges related to farmer regeneration and career change. They tend to have better energy and physical abilities to manage agricultural land and adopt new technologies, and are more open to modern technologies such as digital applications for agricultural management. On the other hand, a regeneration crisis may occur due to the aging of farmers and a decline in the number of young farmers. This will threaten the sustainability of corn farming. Therefore, efforts are needed to attract the younger generation to get involved in farming by improving farmers' welfare, improving the quality of farmers so that they are able to compete and adapt to the times, and developing regeneration programs and policies such as incentives for young farmers, support for technology transfer and agricultural modernization.

In terms of education, most farmers (65%) have only completed primary school, and only a small percentage (10%) have completed secondary school. Farmers with less education tend to have less understanding of modern farming techniques, the proper use of fertilizers and pesticides, and efficient land management. It can also result in poor productivity and income for farmers, and increase food insecurity. Farmers with low levels of education also experience: 1) difficulties in understanding and adopting new agricultural technologies, thereby hindering improvements in the efficiency and productivity of their farms, 2) difficulties in managing farm finances, recording production results, and planning their businesses, leading to waste of resources, financial losses, and difficulties in developing their farms, 3) difficulties in understanding the impacts of climate change and adapting to these changes, which can increase farmers' vulnerability to drought or flooding and food crises. According to (13), education has a significant and positive influence on technical efficiency. There is also a positive relationship between efficiency and formal education and the age of farmers (14).

Eighteen years of corn farming experience indicates that farmers have in-depth practical knowledge gained from generations of tradition. This characteristic suggests that farming

decisions in Dengkol Village are based more on empirical experience than formal knowledge, which could potentially influence how they adopt innovations and manage inputs. Long farming experience has positive implications, namely improving farmers' skills in managing land, making wiser decisions, and adapting to environmental changes. However, long experience can also make farmers less responsive to innovation and more vulnerable to the negative impacts of unsustainable agricultural practices. (15) found that experience and education have a significant effect on technical efficiency. Experience indicates that learning by doing in the long term helps farmers adapt cultivation techniques to the specific conditions of their land.

Input Allocation: Influence of Input Utilization on Corn Production

Testing of classical assumptions (Table 1) shows that the Cobb Douglas production function model designed is BLUE. Kolmogorov Smirnov with sig. 0.511 > 0.05 indicates that the data is normally distributed. The tolerance values for all variables > 0.10 and VIF < 10 indicate that there is no multicollinearity. Meanwhile, sig. values > 0.05 for each input indicate that there is no heteroscedasticity. Therefore, the modeled Cobb-Douglas production function is valid for testing the effect of input use on corn production and its efficiency.

Table 1. Results of Classical Assumption Tests on Input Utilization in Corn Farming

No	Variable	Collinerity statistic		Sig.
		Tolerance	VIF	
1	Land area (X ₁)	0.184	5.424	0.450
2	Seed (X ₂)	0.357	2.803	0.399
3	Organic fertilizer (X ₃)	0.469	2.133	0.207
4	Urea fertilizer (X ₄)	0.333	3.003	0.101
5	Phonska fertilizer (X ₅)	0.771	1.297	0.498
6	NPK fertilizer (X ₆)	0.341	2.931	0.057
7	Pesticides (X ₇)	0.683	1.465	0.641
8	Labor (X ₈)	0.250	3.993	0.325
	Sig. Kolmogorov Smirnov	0.511		

Source: Primary data, 2025

Results of regression analysis justify the Cobb Douglas production function equation in corn farming as:

$$\ln Y = -1,805 + 1,293\ln X_1 - 0,210\ln X_2 + 0,067\ln X_3 + 0,024 \ln X_4 + 0,088 \ln X_5 - 0,008 \ln X_6 + 0,364\ln X_7 - 0,426\ln X_8 \dots\dots\dots (vi)$$

which is then transformed again into:

$$Y = 0,344 X_1^{1,239**} X_2^{-0,210} X_3^{0,067} X_4^{0,024} X_5^{0,088} X_6^{-0,008} X_7^{0,364**} X_8^{-0,426} \dots\dots\dots (vii)$$

R-squared of 0.767 confirms that the regression model is appropriate because the eight types of inputs are able to explain 76.7% of the variation in corn production. However, only two inputs have a significant and positive effect on corn production, namely land area and pesticide volume (see equation 7). Farmers can increase corn production through land extensification. So far, farmers have been using relatively small amounts of pesticides. To increase corn production, farmers can use more pesticides. This finding supports the results of (16), although it differs from (17) which concluded that land and seeds are the most influential factors on corn production. Meanwhile, (18) finds that socio-economic, environmental, physical and technical factors have a significant effect on corn production.

Despite having no significant effect, it turns out that farmers in Dengkol Village use excessive amounts of seeds, NPK fertilizer, and labor. This conclusion is based on the negative regression coefficient, which means that if the amount of these inputs is increased in corn farming, it will actually reduce production. It is possible that farmers apply this allocation to increase production due to the limited amount of land available for corn cultivation.

Input Efficiency in Corn Farming
Technical Efficiency

Technical efficiency relates to an input's ability to produce optimal output. Using the Cobb Douglas production function makes it easier to identify efficiency in input utilization based on production elasticity, where efficient inputs meet the criteria of $0 \leq PE \leq 1$. Equation 7 illustrates that farmers apply organic fertilizer, urea, phonska, and pesticides efficiently from a technical standpoint, while land area is still inefficient. On the other hand, farmers have not been able to make efficient usage of seeds, NPK fertilizer, and labor. The implication is that farmers must increase the planting area, while reducing the usage of seeds, NPK fertilizer, and labor, in order to increase corn production.

Empirical evidence shows that there is potential to increase corn productivity in Dengkol Village through the reallocation of inefficient inputs. Technical inefficiencies serve as a guideline for farmers that production can still be increased by reallocating the combination of inputs in the next planting season. Potential for increased production is also indicated by the increasing returns to scale from Cobb Douglas production function model, which is equal to the sum of the regression coefficients of all inputs, at 1.836. Research findings reinforce evidence that technical inefficiency is a common phenomenon in smallholder farming in Indonesia. Differences may be due to variations in local agroclimatic conditions, technologies used, farmers' socio-economic characteristics, and other specific factors.

These findings are consistent with the results of (19) that input use in corn farming in Muaro Jambi has not been able to produce maximum yields, as well as results from (20). Technical inefficiency in corn farming also occurs in other countries, such as in China, which was studied by (21), Comprehensive technical efficiency in corn production on agricultural land averaged 0.863, and average losses were 13.7%. In Africa, the average technical efficiency of

corn farmland is 0.64, indicating that corn production can be increased by about 36%. There is a positive relationship between land area and technical efficiency for corn production in Rwanda. Therefore, the implementation of land reforms such as land consolidation and increased aggregate productivity growth is necessary (13). These results show that if farms reduce their average input use by 11.3%, they can achieve the same level of output and reach full technical efficiency (15). Corn farming efficiency rates of 0.84 (14) and 0.86 (16), imply that there is space for improvement with current technology.

Allocative and Economic Efficiency

Allocative efficiency calculations for inputs used in corn farming based on equation 4 were presented in Table 2, while technical efficiency, allocative efficiency, and economic efficiency were compared simultaneously in Table 3.

Table 2. Allocative Efficiency of Inputs Used in Corn Farming

No	Variable	B	Y	Py	X	Px	b.Y.Py	X.Px	b.Y.Py/ X.Px
1	Land area	1.293	1431.25	5500	747.5	500	10178334	373750	27.23
2	Seed	-0.210	1431.25	5500	6.6	2500	-1653094	16500	-100.19
3	Organic fertilizer	0.067	1431.25	5500	50.25	4000	527415.6	201000	2.62
4	Urea fertilizer	0.024	1431.25	5500	18.75	2700	188925	50625	3.73
5	Phonska fertilizer	0.088	1431.25	5500	16.5	3000	692725	49500	13.99
6	NPK fertilizer	-0.008	1431.25	5500	28	2500	-62975	70000	-0.90
7	Pesticides	0.364	1431.25	5500	2.24	15000	2865363	33600	85.28
8	Labor	-0.426	1431.25	5500	43.925	30000	-3353419	1317750	-2.54

Source: Primary data, 2025

Allocative inefficiency of inputs by farmers in Dengkol Village is a crucial finding, given that several inputs in corn farming have been technically efficient. It is a sign that the main problem faced by farmers in Dengkol Village lies not only in their technical farming skills, which have been passed down from generation to generation, but also in his inability to allocate inputs proportionally according to the price to achieve minimum costs. Farmers already know how to fertilize, but they are not aware of the cheapest combination of urea and NPK fertilizers for optimal corn production. Generally, farmers face a classic obstacle, namely that they are not systematic in bookkeeping, which prevents them from accurately evaluating their farming activities. Corn farming managed by farmers is on a very small scale (at most only 0.0745 hectares), so they are unable to accumulate capital to expand the scale of their business. Theoretically, it can be said that farmers have not been able to meet the condition where the marginal product value of each input is equal to its input price.

Table 3. A Comparison Of Technical, Allocative, And Economic Efficiency In Input Utilization

No	Variable	Technical Efficiency	Justification	Allocative Efficiency	Justification	Economic Efficiency	Justification
1	Land area	1.293	Not yet efficient	27.23	Not yet efficient	35.21	Not yet efficient
2	Seed	-0.210	Not efficient	-100.19	Not efficient	21.04	Not yet efficient
3	Organic fertilizer	0.067	Efficient	2.62	Not yet efficient	0.18	Not yet efficient
4	Urea fertilizer	0.024	Efficient	3.73	Not yet efficient	0.09	Not yet efficient
5	Phonska fertilizer	0.088	Efficient	13.99	Not yet efficient	1.23	Not yet efficient
6	NPK fertilizer	-0.008	Not efficient	-0.90	Not efficient	0.01	Not yet efficient
7	Pesticides	0.364	Efficient	85.28	Not yet efficient	31.04	Not yet efficient
8	Labor	-0.426	Not efficient	-2.54	Not efficient	1.08	Not yet efficient

Source: Primary data, 2025

Technical, allocative, and economic inefficiencies in the utilization of inputs were found in corn farming in Dengkol Village. This finding confirms the results (22) that corn farming in Ethiopia is still inefficient and also concludes that the important factors affecting technical, allocative, and economic efficiency are family size, education level, extension services, cooperative membership, land area, livestock ownership, and vehicle use. To increase the role of corn in food security and livelihoods, it is necessary to intensify corn production in a sustainable manner while maintaining environmental sustainability, which still requires investment in research (23). Excessive use of chemical fertilizers such as NPK has been shown to cause land degradation (24) and reduce productivity.

CONCLUSION

Land area and pesticide volume have a significant and positive effect on corn production, while the amount of seeds, organic fertilizer, urea, phonska, NPK, and labor have no significant effect. Corn production functions at increasing returns to scale, indicating the potential to increase corn production by adding various inputs. Technically, organic fertilizer, urea, phonska, and pesticides have been used efficiently, while other inputs have not. It shows that farmers have not been able to achieve maximum output due to inefficiencies in land area, seeds, NPK fertilizer, and labor. Allocative inefficiency is present in all input uses. It is a more serious problem. The main constraint for farmers is not only their technical capabilities, but also a lack of ability to choose the most cost-effective combination of inputs to generate a certain amount of output. Economic inefficiency also persists in corn farming. In other words, farmers have not been able to maximize their profitability.

RECOMMENDATIONS

Farmers are advised to i) implement simple farm management practices, namely recording input use and production costs, and preparing a budget plan before the planting season to help allocate inputs more rationally and economically. ii) be more active in farmer groups so they can exchange information about input prices, purchase inputs collectively to get cheaper prices, and learn together about more efficient farming techniques. iii) proactively seek various

information in extension activities and/or consult with field agricultural extension workers. Government needs to i) enrich extension materials that focus on economic and managerial aspects, especially how to calculate costs and profits, analyze the feasibility of simple farming businesses, and strategies for dealing with price fluctuations. ii) assist in overcoming allocative inefficiencies by providing easy, accurate, and real-time access to input and output price information, for example through notice boards in village halls or simple applications. iii) strengthen and facilitate farmer groups so that they can function as independent economic units through the joint procurement of inputs or collective marketing of crops. As this study is limited to one village, future researchers are advised to conduct comparative studies between villages with different socioeconomic characteristics to obtain a more comprehensive picture. Analyzing changes in efficiency over time using panel data analysis (observing the same farmers over several growing seasons) will provide a better understanding of the impact of policies or technological changes from year to year.

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AUTHOR CONTRIBUTIONS

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	Contributions	Conducting all stages of research, including data collection, tabulation, data analysis, interpretation, and drafting articles.
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