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Estimating efficiency of soybean farming through stochastic frontier analysis

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Abstract

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The low productivity of soybeans farming in Indonesia makes the low performance of soybean production. This research aims to analyze the efficiency and inefficiency of soybean production, given the low productivity of soybeans. The study utilizes the stochastic frontier analysis to calculate efficiency, including a new variable such as irrigation. Additionally, inefficiency analysis is used to measure the location's inefficiency. The study uses a stochastic frontier regression approach with 200 samples from the center of soybean production. The results show that soybean farming is still not efficient. The factors affecting soybean production include land area, fertilizer, irrigation, seed, and labor. Moreover, this research found that farming routine and experience significantly impact inefficiency. Overall, this study highlights the need to improve soybean production efficiency, primarily by addressing farming routine and experience.

Keywords: soybeans; efficiency; inefficiency; frontier

Introduction

In the period from 2015 to 2019, Indonesia's soybean production continued to decline quite significantly (Ministry of Agriculture, Directorate General of Food Crops, 2020). So far, Indonesia is still dependent on imported soybeans, especially when there is a shortage of stock. This is partly due to the fact that production in producing areas tends to fluctuate, while demand in the market has increased.

The decrease in the planted area was followed by a fall in soybean production at producer centers in Java Island. The productivity of local soybeans is still below the productivity of the main soybean-producing countries in the world. This decreased planting area indicates that there is a reluctance to plant soybeans or a massive land conversion has resulted in a decrease in production. These conditions have an impact on short-term efforts to import soybeans. National food security will certainly be difficult to achieve with high dependence on imports due to low domestic production.

The demand for soybeans shows a significant increase in line with the increase in population and people's income. The ability to produce soybeans in the country has not been able to meet the increase in demand. The inability of local soybeans to meet demand causes soybean supply in the country to depend on imports.

Setiawan & Bowo (2017) in their research stated that soybean farming was still not efficient. This inefficiency condition occurs because farmers are considered to use production factors excessively. In line with this, research conducted by Akhilomen et al. (2015) showed that although land area and labor have a significant effect on production efficiency, costs and output have a significant effect on cost efficiency. The decrease in the planting area, low productivity, and finally production which tends to decrease need to be of particular note.

The problem of the low productivity of soybean farming certainly raises questions about how the factors of production are used. Whether there has been efficiency in the use of factors of production or not, given that efficiency is the relationship between the use of inputs and the resulting output. Empirical studies on the efficiency of soybean farming and other agricultural commodities such as sweet potatoes, rice, corn and cassava have been carried out by Amirudin et al. (2020), Setiawan et al. (2019), Setiawan & Bowo (2017) Akhilomen et al. (2015), Ndlovu et al. (2014), Orewa & Izekor (2012), Ainsworth et al. (2012), and Chiang et al. (2004). All of these studies use frontier stochastic production functions. This study adopts the same analytical technique, namely by using frontier stochastic production functions. The difference lies in the dependent variable used, this study suspects that the irrigation network is also an input factor that affects the technical efficiency of soybean farming. The irrigation network variable has never been used in previous studies. In this study, the irrigation network variable was represented in dummy form.

In the analysis of the inefficiency of this study, it also provides a novelty using the dependent variable, namely the planting routine dummy. This study suspects that if a farmer has a routine of growing soybeans in a sustainable manner for a long period of time, the farmer will understand optimal input utilization techniques, climatic characteristics, and other factors that affect the technical efficiency of soybean production. With this assumption, this study uses a dummy variable farmer's routine in planting soybeans as the dependent variable, which is also a new variable that has never been used in previous studies.

In addition, the novelty of this research lies in the analysis of price efficiency which uses the production function as well. Considering other studies regarding efficiency in Indonesia, price efficiency calculations are carried out using the net profit margin. This study also examines the factors that cause inefficiency, which has never been studied in Indonesia, especially using the stochastic frontier production model. The majority of previous studies have also focused on agricultural production input variables, which were thought to be the cause of inefficiency in soybean production. However, this study incorporates socioeconomic variables to provide empirical results.

Material and Methods

This study discusses the efficiency and technical inefficiency in soybean farming. Soybean centers in Indonesia are centered on Java Island, with Central Java province as the second largest producer nationally. In 2019 total production reached 106.09 thousand tons with the largest planting area in Indonesia.

Inefficiency analysis was carried out on a sample of selected farmers who met the criteria for the population and sample of this study. The population in this study were soybean farmers spread across Grobogan and Blora Regencies. Based on data from the Agriculture Office of Central Java Province, the number of farmers in Blora Regency in 2021 is 20 968 people; the number of farmers in Grobogan Regency is 269 731 people. Overall, the total population of this study was 290 699 soybean farmers.

Determination of the proportion of the sample is determined by considering the percentage of the total population of farmers from each district. Grobogan Regency with a population of 269 731 farmers has a percentage of 92.8% (rounded up to 93%), while Blora Regency with a population of 20 968 farmers has a percentage of 7.2% (rounded up to 7%) of the total study population. By knowing the number of research samples as many as 200 respondents, the number of respondents based on the percentage of the population for Grobogan Regency is 186 farmers and Blora Regency is 14 farmers (Table 1).

Calculation of technical efficiency in this study uses the frontier stochastic approach. This approach was chosen because it is based on a linear production function. So that it will be possible to obtain the predicted value of the output with a fixed input predictor. By using several research variables described in Tables 2 and 3, it will be used as the basis for preparing a technical inefficiency model.

By considering a production with one product output and k as inputs. It is formulated that $y = f(x)$ is a production function, where y is the output quantity and x are the k×1 vector with an input quantity of k. Technical inefficiency can occur if the observed (y, x) is not included in the production possibility frontier. According to Liu (2021), the production function with technical inefficiency in it for a company or farming business is formulated as follows:

$$y_i = f(x_i)e^{-u_{pi}}, \quad (1)$$

where y_i is company production output i; $x_{i1}, x_{i2}, \ldots, x_{ik}$ is vector input with k input, and element x_{ij} is the quantity for farming i, and $e^{-u_{pi}}$ is *technical inefficiency term*, $u_{pi} > 0$, so *technical inefficiency* (TE) for company i are as follows (Battese & Coelli, 1988):

$$\mathrm{TE_i} = \frac{y_i}{f(x_i)} = < 1 \quad (2)$$

Furthermore, stochastic frontier Production model to estimate technical efficiency represented as follows (Aigner et al., 1977 by defining the disturbance term as the sum of symmetric normal and (negative; Battese & Coelli, 1988):

$$\ln y_i = \ln f(x_i;\beta) + v_{pi} + u_{pi}, \quad (3)$$

Table 1. Operational definition variable of efficiency analysis

No	Variables	Operational definition	Units
Production Model for Stochastic Frontier			
1	Production	The amount of soybean production in one planting period.	kg
2	Land Area	The total area of land used by farmers to grow soybeans in one planting period.	M^2
3	Fertilizer	The total amount of fertilizers used in the soybean farming process includes: Urea fertilizer, drum fertilizer, and Phonska fertilizer.	kg
4	Pesticide	The total amount of liquid pesticides used in one soybean planting period.	Ml
5	Stimulant	The total amount of liquid drugs (stimulants) used in one planting period	Ml
6	Labor	The number of workers employed in farming multiplied by the number of working days in one growing season.	Labor/day
7	Seed	The total number of seeds used in one soybean planting period.	kg
8	Irrigation	Score 1 for farming that has a technical irrigation network; and a score of 0 for farming that does not have a technical irrigation network.	*Dummy*
Ineficiency Model			
1	Ineficiency	The magnitude of utilization of input factors that are not yet optimal in producing output at the level of utilization of certain technologies in the production of soybean farming.	Parameter
2	Age	Farmer ages	Tahun
3	Farming Experience	The length of time a farmer has in pursuing the profession and working in soybean farming.	Tahun
4	Education Level	Score 1 for farmers who have an education equivalent to or exceeding Senior High School (SMTA). Score 0 for farmers who have education below Junior High School (SMTP).	*Dummy*
5	Farmer Group Participation	Score 1 for participating farmers in the farming group. Score 0 for farmers who do not participate in the farming group.	*Dummy*
6	Planting Routine	Score 1 for farmers who routinely plant soybeans in farming within the last 3 years. Score 0 for farmers who do not routinely plant soybeans in farming in less than the last 3 years.	*Dummy*

Source: Data processed, 2023

where β is vector parameter, v_{pi} is *two-sided random error*, and u_{pi} is *one-sided random error* with positive average to calculate the *technical inefficiency*. With the amount value of (y_i, x_i), $i = 1, 2, \dots n$ from farming n, vector parameter β dacan be estimated using *maximum likelihood estimations* (MLE).

Cost efficiency occur when TC $(x_i, w_i) > C\ (y_i, w_i)$ with total cost, output quantity, and input price from company $i = 1, 2, ..., n$, *stochastic frontier* cost model to estimate the cost inefficiency are as follows (Kumbhakar, 1997):

$$\ln TC\ (x_i, w_i) = \ln C\ (y_i, w_i, \gamma) + v_{ci} + u_{ci}, \quad (4)$$

where γ is vector parameter, v_{ci} is two-sided random error term, and u_{ci} is one-sided random error with positive average for cost inefficiency estimation pre-observed.

By taking the total derivation of the production function, this shows that η is a measure of economies of return to scale (Battese & Coelli, 1988). The production function adopted in this study is the Cobb-Douglass stochastic frontier production function. The estimating model for the technical efficiency of the frontier stochastic production function of soybean farming in this study is as follows:

$$\text{LnY} = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \\ + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 D_1 + v_i + u_i \quad (5)$$

The technical efficiency equation for the frontier stochastic production function produces two error components namely v_i which is a random error and u_i which is a technical inefficiency error. The technical inefficiency model for the frontier stochastic production function is written as follows:

$$\mu_i = \delta_0 + \textstyle\sum_{i=1}^{5} \delta_i Z_i + \omega_i, \quad (6)$$

where δ_0 is constanta, δ_i is parameter of inefficiency variables estimated, Z_i is inefficiency variables, and ω_i is error term to obtain inefficiency effect unobserved in the model. So the equation for estimating technical inefficiency through the frontier stochastic production function in this study is as follows:

$$\mu_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4, \quad (7)$$

where μ_i is technical efficiency; α_0 is constant or intercept; $\alpha_1, \dots \alpha_5$ is the scale of estimators parameter; Z_1 is farmer ages; Z_2 is farming experience; Z_3 is farmer education level, Z_4 is farmer group participation, and Z_5 is planting routine.

Result and Discussion

Technical efficiency of soybean farming in this study using the Cobb-Douglas production function using the frontier stochastic approach. The use of the Cobb-Douglas function is intended to determine the effect of input factors on soybean production in soybean farming. The results of the estimation of the frontier stochastic production function for soybean farming are described in Table 2 as follows:

Table 2. Estimation of frontier stochastic regression with the cobb-douglas production function of soybean farming

Variable	Coefficient	Std. error	Prob
Constant	2.855727	.2817526	0.000**
Land Area	.1263755	.0506952	0.013*
Fertilizer	.2771679	.0393649	0.000**
Pesticide	.0295759	.0243647	0.225
Seed	.4098967	.0489624	0.000**
Labor	.0552215	.0280769	0.049*
Stimulant	.0100484	.0122288	0.411
Irrigation	.1189325	.039992	0.003**

Note: *indicates a significant P-value > 1%; ** P-value significance > 5%.
Source: Processed Data, 2023

Based on the estimation results, it is known that land area, fertilizer, seeds, labor, and type of irrigation have a significant effect on increasing soybean production. Referring to the results of the frontier stochastic regression estimation above, the econometric model obtained from the Cobb-Douglas production function of soybean farming in Blora and Grobogan Regencies is as follows:

$$\begin{aligned} LnProd = {} & 2.855727 + 0.126*LnLand + \\ & + 0.277*LnFertilizer + \\ & + 0.029*LnPesticide + 0.409*LnSeed + \\ & + 0.055*LnLabor + 0.010*LnStimulant + \\ & + 0.118*Dirrigation + v_i + u_i \quad (7) \end{aligned}$$

Overall, the frontier stochastic function above succeeded in proving that the input factor plays an important role in determining the amount of soybean production as a farming output. Agricultural inputs such as land area, seeds, fertilizers, labor, and irrigation have been shown to significantly increase soybean production. Seed is the input that has the greatest impact in increasing the production of soybean farming, so farmers must pay more attention to the use of seeds so that the yield can be more optimal.

The agricultural drugs used in the cultivation stage did not have a significant effect on soybean production, this was probably due to the different types of pesticides and stimulants used by farmers, which in the end were unable to make a significant difference to soybean production. Excessive use of stimulants and pesticides is also considered to be detrimental to soil quality and has an impact on reducing farming productivity so that some farmers use only a few stimulants and pesticides in the soybean cultivation process.

Technical Efficiency

By knowing the coefficient value of each production input of soybean farming, technical efficiency analysis can be carried out. Technical efficiency is calculated by calculating the efficiency of production input utilization to produce production output from each respondent in this study. So that the value of the technical efficiency of production of soybean farming in Blora and Grobogan Regencies is the average value of the technical efficiency of 200 soybean farmers who are the subjects of this study. Stata MP 17 software was used to calculate the technical efficiency values for soybean production. Table 3 shows the technical efficiency values for each research subject as well as the average technical efficiency values for soybean farming.

Table 3. Result of technical efficiency estimation of soybean farming

Efficiency score	Farmer amount
< 0.40	0
0.41–0.61	2
0.61–0.80	26
0.81–1	172
Average	0.8664

Source: Data Processed, 2023

Based on the estimation results in Table 3, it is known that the average value of the technical efficiency of soybean farming is 0.866407279 which is less than 1. These results indicate an empirical finding that soybean farmers are still not able to manage their inputs efficiently to produce production optimal soybean, or in other words not technically efficient. According to observations, it was also found that some farmers still did not have adequate irrigation facilities. This was also one of the other factors that triggered the inefficient production of soybean farming.

However, most farmers are at an efficiency score of 0.80–1, meaning that even though they are not yet efficient, the level of efficiency is close to the optimal scale. This condition gives a signal that soybean farming is on a good track to improve its performance.

Technical inefficiency of soybean farming

By knowing the condition that soybean farming in Blora and Grobogan Regencies is still not technically efficient, this indicates that there are indications of factors other than production inputs that cause production to not be achieved optimally. Previous research explained that socioeconomic factors also play an important role in influencing the production efficiency of farming. By using the average value of efficiency obtained from the estimation above, it can be estimated the value of inefficiency.

This study will further analyze the technical inefficiency of soybean farming by using socioeconomic variables including farmer's age, farmer's education, farmer's experience, membership of farmer groups, and routines in planting soybeans. Table 4 shows the results of the estimation of the technical inefficiency of soybean farming in Blora and Grobogan Regencies.

Table 4. Estimation results of the technical inefficiency model of soybean farming

Variables	Coefficient	Std. error	Prob
Constant	.1306994	.1347967	0.333
Age	.0402941	.0398366	0.313
Education Level	.0203643	.012668	0.110
Farming Experience	-.0559252	.0158481	0.001**
Farmer Group Participation	.0164824	.013434	0.221
Planting Routine	-.0446488	.0112707	0.000**

Note: *shows significant at P-value > 1%; ** significant at P-value > 5%.
Source: Data Processed, 2023

Based on the results of the regression estimation above, an econometric model is obtained from the technical inefficiency model of soybean production in soybean farming in Blora and Grobogan Regencies as follows:

$$LnIP = 0.1306994 + 0.040*Age + 0.020*DEducation - 0.055*Experience + 0.016*DParticipation + 0.044*DRoutine + \quad (8)$$

Based on the analysis, it was found that the age of the farmer has no significant effect on inefficiency so that the inefficiency of farming is basically not too much affected by the age of the farmer.

Furthermore, the level of education does not have a significant effect on inefficiency, so that the increase in the inefficiency of soybean farming production is basically not too much influenced by the education level of farmers.

Farming experience is proven to have a significant effect on reducing production inefficiencies. Farming experience is a socioeconomic factor that is thought to influence soybean production, the longer a farmer's experience in managing soybean farming is thought to be able to produce a higher level of production, through his skills and adaptability and this assumption was successfully proven in this study.

The planting routine is proven to have a significant effect on reducing the inefficiency of soybean production. More specifically, if farmers regularly plant soybeans in the last 3 years or more, they will be able to reduce soybean production inefficiencies by 0.044% higher than farmers who do not regularly plant soybeans. This is an empirical finding where farmers who consistently plant one commodity continuously will have a better understanding and adaptability in the soybean cultivation process, compared to farmers who plant many types of commodities (Table 5).

Table 5. Estimation of frontier stochastic regression with soybean farming cost function

Variables	Coefficient	Std. Error	Prob
Constant	5.097424	.4382409	0.000**
Land Rent Cost	-.0247142	.0286799	0.389
Fertilizer Cost	.3040459	.0428541	0.000**
Pesticide Cost	.022363	.0229472	0.330
Seed Cost	.5111038	.0446466	0.000**
Labor Wages	.0476495	.030906	0.123
Stimulant Cost	.0021649	.0121276	0.858

Note: *shows significant at P-value > 1%; ** significant at P-value > 5%.
Source: Data Processed, 2023

Based on the estimation results of the Maximum Likelihood Estimation regression above, the econometric model obtained from the soybean production cost efficiency model of soybean farming is as follows:

$$LnTPC = 5.097424 - 0.024*Lrc + 0.304*Fc + 0.022*Pc + 0.511*Sc + 0.047*Lw + 0.002*Stc + u_i + v_i \quad (9)$$

Overall, through this price efficiency model, several empirical findings can be obtained where the total production cost is very sensitive to changes in seed and fertilizer input costs. This can happen because the price of seeds purchased by farmers is a seed price that has been distorted by the government's policy of providing price cuts through subsidies. The same goes for fertilizer input costs, which receive price subsidies from the government. These two input costs also play an important role in determining the total production cost of soybean farming, this is because seeds are the main input in the planting process, while fertilizer is a very essential input during the cultivation period so that both are very concerned about the amount of use and automatically the total production costs will be very sensitive to changes in the cost of these two types of inputs.

By knowing the coefficient value of each production cost of soybean farming in Blora and Grobogan Regencies, input costs can be identified that significantly affect the total production costs. The next step in the analysis is to estimate price efficiency for each respondent in this study, totaling 200 soybean farmers. This price efficiency analysis is carried out to find out whether farmers have been able to optimally utilize their production costs through the right cost allocation for each production input.

Based on the estimation results in Table 6, it is known that the average value of production price efficiency for soybean farming in Blora and Grobogan Regencies is 0.862186578, which is less than 1. These results show an empirical finding while proving that soybean farmers in Blora Regency and Grobogan Regency is still not able to efficiently manage its input costs to produce minimal soybean production but is able to produce maximum output.

Table 6. Price efficiency estimation results of soybean farming business

Efficiency score	Amount farmer
< 0.40	0
0.41–0.61	5
0.61–0.80	30
0.81–1	165
Rata-rata	0.8621

Source: Data Processed, 2023

However, most farmers are at an efficiency score of 0.80–1, meaning that even though they are not yet efficient, the level of efficiency is close to the optimal scale. This condition gives a signal that soybean farming is on a good track to improve its performance.

Economic efficiency of soybean farming

Differences in the ability of farmers to manage their farms also affect the differences in the level of economic efficiency achieved. Economic efficiency is also called cost efficiency (CE) which shows the ability of farmers to choose the minimum production cost to produce a certain output. To test the level of economic efficiency, it is determined according to the ratio of the value of the marginal product and the marginal cost for each factor of production. Table 6 presents the value of the economic efficiency of soybean farming in Blora and Grobogan Regencies.

Based on the estimation results above, it is known that the average value of the economic efficiency of soybean farming in Blora and Grobogan Regencies is 0.747004726. This shows that soybean farming in Blora and Grobogan Regencies is still not economically efficient in applying minimum production costs to produce certain products. These results also explain that the allocation of soybean production costs can still be optimized up to 25.3% more to achieve optimal economic efficiency. The hypothesis which states that soybean farming has not yet achieved full economic efficiency has been proven. This is based on the results of an economic efficiency score that is less than 1.

One of the factors causing the problem due to other factors beyond the control of farmers. One example found in the field is the price of seeds and fertilizers which increased significantly during the growing season, which in turn resulted in a large increase in the total cost of production. This ultimately makes economic efficiency unattainable because farmers have to incur too high costs, thereby reducing their profitability.

Discussion

The land is one of the most important inputs in supporting the production process of agricultural commodities, so that the area of land used for planting agricultural commodities will also determine the amount of production of these agricultural commodities. Through the estimation of the frontier stochastic production function, it was found that land area was proven to be significantly able to increase soybean production in soybean farming. This finding is in accordance with the Cobb-Douglas production function which states that land input is one of the forming components of production, so that an increase in this input will encourage agricultural production.

The results of this research are in line with several previous studies, such as those conducted by Setiawan & Bowo (2015) who found that food crop commodities consisting of rice, corn and soybeans were not efficient. This study also succeeded in proving that land area is a factor that has a significant influence on the level of production of rice, corn and soybean commodities at the same research location.

One of the most important factors in supporting crop quality and agricultural commodity productivity is fertilizer. This research managed to find that increasing the use of fertilizers in agricultural processes will encourage a significant increase in soybean production. These findings are in line with research conducted by Ndlovu et al. (2014) which proved several agricultural input factors, one of which was fertilizer which was proven to be able to increase agricultural production in one planting period.

This research succeeded in proving that increasing the use of soybean seeds was proven to be able to encourage the growth of soybean production in farming. The results of this study are in line with the findings of Akhilomen (2015) who also found that the input factors that affect the production of soybean agricultural commodities are land area, labor, fertilizers, seeds and medicines used.

Pesticides revealed that has a positive but not significant effect on the growth of soybean production. These results are in line with the findings of a study conducted by Nugraha et al. (2019), who found that there was no significant effect between the use of pesticides on increasing soybean production. Ainsworth (2012) in his research emphasized that the excessive use of chemicals can reduce the productivity of agricultural land.

Furthermore, this study also found that labor has significant effect to enhance agriculture production. This result is in line with a research conducted by Akhilomen et al. (2015), who found similar results where land area and labor have a significant effect on production efficiency. Deepening the findings of this research, Ndlovu et al. (2014) also added other factors besides labor that were proven to affect the production of soybean farming, namely rainfall and soil slope.

This study managed to find that the dummy type of irrigation has a positive and significant effect on increasing soybean production in soybean farming. More specifically, this means revealing the fact that farmers who have technical irrigation will be able to produce soybeans at a higher rate than farmers who do not have irrigation networks. These findings are in line with research conducted by Ndlovu et al. (2014) who found that the use of technology has a positive and significant impact on increasing the productivity of corn commodity farming. More specifically, the use of technology used in this study refers to auto-farming systems, and the creation of integrated irrigation networks through the use of technology.

Soybean Farmers in Grobogan and Blora Regency concluded that still not technically efficient. The findings of this study are in line with the results of research conducted by Setiawan & Bowo (2017) on soybean farming in Grobogan Regency which found that their farming business was not technically efficient. In other commodities such as sweet potatoes as research conducted by Setiawan et al. (2019), also found empirical evidence that the average efficiency of sweet potato farming in Semarang Regency is 0.75, using the Bayesian stochastic frontier model Chakuri et al. (2022) managed to reveal that peanut farmers produce at an increased yield scale of 1.10. The average technical efficiency of farmers was found to be 70.5%, with a minimum value of 13.0% and a maximum of 95.1%.

In general, most farmers believe that increased use of factors of production leads to more production. Even though this is not the case, the actual use of production factors must be used proportionally to create technical efficiency. Excessive use of production factors actually reduces productivity and production results. This is because excessive use of inputs actually reduces production because excessive use of inputs damages plants and is not good for plant growth. This condition is in line with The Law of Diminishing Return which was developed by Ricardo. Where soybean production in the Grobogan and Blora regions has decreased because farmers provide too much fertilizer. Soil fertility is reduced, but fertilization actually damages soil conditions and reduces productivity. This phenomenon is reinforced by the findings of Asmara & Hanani (2017) that farmers generally have difficulty balancing the input and output aspects of large-scale soybean production.

Furthermore, several previous studies also recommended carrying out mentoring and empowering activities for soybean farmers to improve their skills, furthermore it was also recommended to reduce consumption of pesticides and plant drugs to maximize production, and use quality and certified soybean seeds. The same thing was also recommended by Ugbabe et al. (2017), suggests that soybean farmers through extension assistance are encouraged to adhere strictly to recommended soybean production practices to ensure efficient utilization of available resources.

From inefficiency model, the results showed that increasing the age of farmers did not significantly cause technical inefficiencies in soybean farming. This result is in line with the findings of Aziz & Hanani (2018) who found that the age of the farmer has no significant effect on the technical inefficiency of farming.

Farming experience is a socioeconomic variable that is also often used in modeling the technical inefficiency of agricultural commodity farming. This study found that farming experience has a negative and significant impact on the technical inefficiency of soybean farming. This means that increasing farmer experience will reduce technical inefficiencies in the production process of soybean farming. These findings are in line with research conducted by Kadakoğlu & Karli (2022) which managed to reveal several factors that significantly affect the technical inefficiency of potato production, including: farmer age, farmer education level, potato farming experience, number of plots of agricultural land, and variables dummy farmer debt. Similar results were also found for the rice commodity in Karanganyar Regency, Central Java through research conducted by Barokah et al. (2022) who analyzed the technical efficiency determinants of rice farming in Karanganyar Regency after 1 decade of reform.

Lastly, is the soybean planting routine which is one of the novelties of this research. The results of this study reveal that planting routines have a negative and significant influence on the technical inefficiency of soybean farming in Blora and Grobogan Regencies. The results of this study explain that the more consistent a farmer is in planting soybeans, the better understanding, skills, and adaptability they will have in dealing with obstacles in the process of planting to harvesting soybeans, which in turn optimizes their yields and minimizes inefficiencies.

Conclusion

Based on the findings of this research, it can be concluded that the input factors of land area, fertilizers, seeds, labor, and the type of irrigation play a crucial role in the production process of soybean farming. These input factors have a significant positive impact on the growth of soybean production, which is in line with the Cobb-Douglas production function theory that states that these inputs contribute to the overall production of agricultural commodities. However, the use of pesticides, which is also considered an important input factor in soybean farming, was found to have a positive but not significant effect on the growth of soybean production. This is in contrast to the perception of some farmers who believe that pesticides play a crucial role in maintaining the quality and safety of soybean crops. In the other hand, farming experience and planting routine could decrease the inefficiency of soybean farming.

The soybean farming is not efficient both technically and allocative. It is also worth noting that the findings of this research are consistent with several previous studies that have been conducted on agricultural commodity production. This suggests that the input factors identified in this study may also apply to other crops, beyond soybeans.

Overall, the results of this research can provide useful insights for farmers, policymakers, and researchers to optimize the use of input factors in agricultural production processes, and ultimately, to increase agricultural efficiency through the uses of production factors.

References

Aigner, D., Lovell, C. A. K. & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21–37. https://doi.org/10.1016/0304-4076(77)90052-5.

Ainsworth, E. A., Yendrek, C. R., Skoneczka, J. A. & Long, S. P. (2012). Accelerating yield potential in soybean: potential targets for biotechnological improvement. *Plant, Cell & Environment*, *35*(1), 38-52.

Akhilomen, L. O., Bivan, G. M., Rahman, S. A. & Sanni, S. A. (2015). Economic efficiency analysis of pineapple production in Edo State, Nigeria: a stochastic frontier production approach. *American Journal of Experimental Agriculture*, *5*(3), 267-280.

Amirudin, A., Fajri, F. & Rusdi, M. (2020). Effectiveness of the management of Pajale Food Security Program (rice, corn, and soybean) in West Aceh Regency. *International Journal of Multicultural and Multireligious Understanding, 7*(6), 517-526.

Asmara, R. & Hanani, N. (2017). Technical, cost, and allocative efficiency of rice, corn, and soybean farming in Indonesia: Data envelopment analysis approach. *Agricultural Socio-Economics Journal*, *17*(2), 76–80.

Aziz, Y. & Hanani, N. (2018). Technical efficiency of tidal rice farming in South Kalimantan, Indonesia: Stochastic frontier analysis approach. *RJOAS*, *84*(12), 237–243.

Balanay, R. & Laureta, R. (2021). Towards boosting the supply chain of soybeans for food security and import substitution in Caraga Region, Philippines. *Journal of Ecosystem Science and Eco-Governance*, *3*(1), 37-49.

Barokah, U., Rahayu, W., Agustono, A. & Antriyandarti, E. (2022). Determinants of rice farming efficiency in Karanganyar Central Java in the period of one decade. *Journal of Environmental Science and Sustainable Development, 5*(1), 109–129.

Battese, G. E. & Coelli, T. J. (1988). Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of Econometrics*, *38*(3), 387–399. https://doi.org/10.1016/0304-4076(88)90053-X.

Bowo, P. A. & Nurayati, A. (2016). Analysis of competitiveness and government policy on rice, corn and soybean farming. *JEJAK: Jurnal Ekonomi Dan Kebijakan*, *9*(2), 159-169.

Chakuri, D., Asem, F. E. & Ebo Onumah, E. (2022). Bayesian technical efficiency analysis of groundnut production in Ghana. *Cogent Economics and Finance*, *10*(1). https://doi.org/10.1080/23322039.2022.2074627.

Chiang, F. S., Sun, C. H. & Yu, J. M. (2004). Technical efficiency analysis of milkfish (*Chanos chanos*) production in Taiwan—an application of the stochastic frontier production function. *Aquaculture*, *230*(1-4), 99-116.

Coelli, T. (1998). A multi-stage methodology for the solution of orientated DEA models. *Operations Research Letters*, *23*(3-5), 143-149.

Coelli, T. J., Rao, D. S. P. & Battese, G. E. (1998). An Introduction to Efficiency and Productivity Analysis, Kluwer-Nijhoff, Boston.

Coelli, T., Rao, D. S. & Battese, G. E. (1998). Efficiency measurement using data envelopment analysis (DEA). In: *An introduction to efficiency and productivity analysis*, 33-160. Springer, Boston, MA.

Edison, E. (2021). Determinants of technical efficiency in smallholder corn crop farming: Application of stochastic frontier production function. *International Journal of Science, Technology & Management*, *2*(6), 1900–1906. https://doi.org/10.46729/ijstm.v2i5.335.

Giraudo, M. E. (2019). Dependent development in South America: China and the soybean nexus. *Journal of Agrarian Change*, *20*(1), 60-78.

Kadakoğlu, B. & Karli, B. (2022). Technical efficiency of potato production in Turkey by stochastic frontier analysis. *Custos e Agronegocio*, *18*(2), 163–178.

Kementerian, P. (2015). Outlook Komoditas Pertanian Tanaman Pangan Kedelai: Pusat Data dan Sistem Informasi Pertanian Kementerian Pertanian .

Kumbhakar, S. C. (1997). Modeling allocative inefficiency in a translog cost function and cost share equations: An exact relationship. *Journal of Econometrics*, *76*(1–2), 351–356. https://doi.org/10.1016/0304-4076(95)01796-8.

Liu, T. (2021). Measuring cost inefficiency: A dual approach. *Economic Modelling*, *99*, 105471. https://doi.org/10.1016/j.econmod.2021.02.012.

Ndlovu, P. V., Mazvimavi, K., An, H. & Murendo, C. (2014). Productivity and efficiency analysis of maize under conservation agriculture in Zimbabwe. *Agricultural Systems*, *124*, 21-31.

Nugraha, I., Sutopo, W., Hisjam, M. & Oktyajati, N. (2019). The Dynamic Simulation Model of local soybean competitiveness policy to support the soybean price stabilization. *2nd International Conference on Materials Technology and Energy*.IOP Conference series: Materials Science and Engineering, Volume 943, Miri, Malaysia, 6 – 8 November 2019.

Nuraini, R., Noor, T. I. & Isyanto, A. Y. (2020). Analisis efisiensi teknis usaha tani kedelai di desa margalayu kecamatan pancatengah kabupaten tasikmalaya. *Jurnal Ilmiah Mahasiswa Agroinfo Galuh*, *7*(3), 652–659. http://www.tjyybjb.ac.cn/CN/article/downloadArticleFile.do?attachType=PDF&id=9987.

Orewa, S. I. & Izekor, O. B. (2012). Technical efficiency analysis of yam production in Edo state: A stochastic frontier approach. *International Journal of Development and Sustainability*, *1*(2), 516-526.

Oumer, A. M., Mugera, A., Burton, M. & Hailu, A. (2022). Technical efficiency and firm heterogeneity in stochastic frontier models: application to smallholder maize farms in Ethiopia. *Journal of Productivity Analysis*, *57*(2), 213–241. https://doi.org/10.1007/s11123-022-00627-2.

Setiawan, A. B. & Bowo, P. A. (2015). Technical, allocative, and economic efficiencies of rice cultivation. *JEJAK*, *8*(2), 149-159.

Setiawan, A. B. & Bowo, P. A. (2017). Technical efficiency of soybeans commodity. *KINERJA*, *21*(1), 1-16.

Setiawan, A. B., Ngatindriatun, N. & Karsinah, K. (2019). Technical efficiency of yam commodity in Semarang Regency. *Jurnal Pendidikan Ekonomi Dan Bisnis (JPEB)*, *7*(2), 137-145.

Soekartawi, T. E. P. (1990). *Teori Ekonomi Produksi: Dengan Pokok Bahasan Analisis fungsi Cobb-Douglas*. Jakarta: Radae Jaya Offset.

Ugbabe, O. O., Abdoulaye, T., Kamara, A. Y., Mbavai, J. & Oyinbo, O. (2017). Profitability and technical efficiency of soybean production in Northern. *Tropicultura*, *35*(3), 203–214.

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