

A comparative study of the economic efficiency of ritual-based *Sorghum bicolor* farming in Indonesia

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Abstract. Lanamana W, Fatima I, Supardi PN. 2026. A comparative study of the economic efficiency of ritual-based *Sorghum bicolor* farming in Indonesia. *Asian J Agric* 10 (1): g100149. <https://doi.org/10.13057/asianjagric/g100149>. *Sorghum bicolor* is an alternative food source in the Ende District, East Nusa Tenggara, Indonesia, given its low productivity and inefficient yields. Farming rituals have been proven to increase *S. bicolor* productivity. Therefore, this study aims to analyze the economic efficiency level of farmers who engage in *S. bicolor* farming ritual practices, and who do not, as well as to review the factors affecting both practices. The Cobb-Douglas Stochastic Frontier production function analysis was adopted. Production variables included land, seeds, fertilizers, labor, and pesticides. This study was conducted in four *S. bicolor* potential sub-districts, using a census method with 385 farmers as respondents. The farmers from three sub-districts who practiced farming rituals included Wolojita (50 farmers), Lepembusu Kelisoke (75 farmers), and Kotabaru (50 farmers). A total of 210 farmers from the Nangapenda Sub-district did not practice farming rituals. The results showed that farming rituals were more effective, with technical, allocative, and economic efficiencies of 91%, 95%, and 92%, respectively. However, without farming rituals, 78%, 78%, and 64% were achieved in technical, allocative, and economic efficiencies, respectively. A benefit-cost ratio analysis of >1 showed that *S. bicolor* farming was feasible. Factors that positively affected economic efficiency comprised education, farmer group membership, and rituals. Local governments need to ensure agricultural extension schedules support traditional calendars to facilitate simultaneous planting. The transformation of farmer groups into agricultural input providers was also required.

Keywords: Farming efficiency, farming rituals, *S. bicolor* cultivation, Stochastic frontier analysis

INTRODUCTION

Sorghum bicolor is an alternative food source and a rice substitute, successfully cultivated in Ende District, East Nusa Tenggara, Indonesia. Economic viability and adaptability originated from its ability to thrive in various conditions, alongside resistance to drought and pests (Aulani et al. 2025). Meanwhile, the Head of the Ende Agriculture Office stated that the average productivity has reached 2.5 tons per hectare. This is lower than the Indonesian and global averages of 4 tons per hectare and 3.2 tons per hectare, respectively (Hossain et al. 2022).

Agricultural practices in Ende District are closely associated with the implementation of farming rituals, largely characterized by the adoption of environmentally friendly methods. These rituals are based on local value systems and ancient knowledge that have been preserved and passed down from one generation to another (Macusi et al. 2023; Bordoloi 2025; Hasanah et al. 2025). The diverse practices reflect cultural communication and behavior that comprise metaphysical, religious, and aesthetic aspects (Kurniawati et al. 2024). Furthermore, farming rituals symbolize a profound relationship between humans, ancestors, and nature.

Agrarian communities have strong cultural traditions, comprising all stages of cultivation, from land preparation to harvest thanksgiving (Mangku et al. 2024). Moreover, farming rituals incorporating supplication and gratitude

tend to generate economic, social, and ecological benefits (Afriawan et al. 2024; Utami et al. 2024; Danugroho et al. 2025). This inspires farmers to develop an integrated method to increase productivity using modern technology and traditional agricultural practices (Chapke et al. 2025).

Over the past decade, modernization in Ende District has triggered a decline in the intensity of farming rituals in almost half of the villages. This affected resource sustainability, social functions, and agricultural coordination. The phenomenon also weakened farmer motivation and discipline, while increasing vulnerability to production risks (Limpo et al. 2022).

Several studies have shown that *S. bicolor* productivity could be increased through technical efficiency methods. Based on this perspective, the methods have the capacity to increase productivity and profitability by optimizing input usage without additional efforts, thereby minimizing production costs (Adnan et al. 2021). The ineffective implementation of the concept was due to limited agricultural inputs. Previous studies on farming efficiency used various models, datasets, and locations (Ahdiningtyas et al. 2023). However, empirical analysis examining the efficiency between farmers who engage in ritual practices and those who do not is limited.

Following the description above, previous results focused largely on the use of agricultural inputs and capital. However, the current study integrated socio-cultural factors as determinants of efficiency, acknowledging

dissimilarities in farmers' behavior due to cultural interventions. This study further expanded the theory of economic efficiency by incorporating the institutional dimension.

Farming rituals were regarded as customary law; therefore, its implementation was mandatory and consciously observed by communities. These rituals serve to enhance coordination, constituting the collective norms governing the production system. Additionally, coordination improved the accuracy of labor allocation, collectively managed production risks, and established simultaneous planting and harvest schedules. It also implements a cooperation system, local seeds, and organic fertilizers used to limit certain inputs, such as traditional cropping patterns. Based on this perspective, farmers tend to use inputs with high availability and low cost.

Empirical evidence comparing the efficiency performance between farmers who engage in farming rituals and those who do not is limited. Therefore, this gap was addressed by evaluating the economic efficiency of *S. bicolor* farmers who engaged in farming rituals and those who did not in Ende District. The current study also analyzed the factors affecting efficiency levels. It was hypothesized that farming rituals provided higher levels of technical, allocative, and economic efficiency. In addition, the increased efficiency was attributed to more coordinated input, labor, and social enforcement arrangements.

MATERIALS AND METHODS

Research location and time

The current study was conducted in the Sub-districts of Wolojita, Lepembusu Kelisoke, Kotabaru, and Nangapenda from June to July 2025. These four sub-districts are dryland areas, characterized by hilly topography, low to moderate rainfall, and limited soil fertility. Furthermore, the main occupation is farming. The sub-districts were selected based on the cultivation of *S. bicolor* and engagement in farming rituals.

Population

A census method was adopted to survey the entire population of 385 *S. bicolor* farmers. However, of the 175 farmers who practiced farming rituals, 50 were from Wolojita Sub-district. These farmers consisted of 30 people from Nggela Village and 20 from Wolojita Village. Another group of 50 farmers was from Kotabaru Sub-district, with 15 people from Tou Timur Village and 35 from Kotabaru Village. Meanwhile, 75 farmers were from Lepembusu Kelisoke Sub-district, which included 20 people from Rutujeja, 30 from Detuara, and 25 from Tani Woda Village. A total of 210 *S. bicolor* farmers from Nangapenda Sub-district did not engage in farming rituals. The farmers consisted of 52 people from West Ondorea, 75 from Malawaru, 45 from Tenda Ondo, and 38 from Sangaroro Villages.

The census method was selected because the population size logistically allowed for full coverage and ensured full representation of farmer characteristics, heterogeneity, and

socio-cultural contexts that affected ritual practices. The examination of the entire population enabled the avoidance of potential sampling biases. This included selection bias due to respondent accessibility and inaccurate subgroup representation. The examination process also eliminated sampling error, thereby enabling the results of the analysis to accurately reflect the conditions of the *S. bicolor* farming population in the study area.

Types and sources of data

Cross-sectional data drawn from primary and secondary sources were collected. In addition, primary data were collected through structured and in-depth interviews with farmers and agricultural extension officers, respectively. A series of interviews was also conducted with tribal chiefs (*Mosalaki*) from four different sub-districts to gather information on farming rituals. Based on this perspective, secondary data was collected from relevant institutions.

Interviews held with *Mosalaki* and village heads in Wolojita Sub-district were officially approved through a ceremony at a traditional house. In Kotabaru and Lepembusu Kelisoke Sub-districts, interviews were conducted using written questionnaires, and based on the consent of the respondents.

Data analysis techniques

A stochastic frontier production function analysis tool was used to measure the technical efficiency of *S. bicolor* farming. This led to the adoption of the Cobb-Douglas stochastic frontier production function, alongside the homogeneity, simplicity, and reduced risk of multicollinearity. The estimation process presented challenges due to the interaction between input variables and the calculated parameters. In addition, the more input variables, the greater the estimated parameters (Huan et al. 2022).

The adoption of the Stochastic Frontier Analysis (SFA) model considered the fact that agricultural production generally faced significant stochastic shocks (for example, climate/rainfall variations, as well as pest and disease outbreaks) and the potential for measurement errors common in farm survey data. SFA also separated deviation into statistical noise (v_i) and non-negative inefficiency components (u_i), thereby providing more precise efficiency estimates. This tool provided an econometric framework for hypothesis testing as well as modeling the determinants of inefficiency. As a result, the mathematical model for estimating the stochastic frontier production function for *S. bicolor* farming is stated as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_4 \ln X_{4it} + \beta_5 \ln X_{5it} + E_j D_j + (V_{it} - U_{it})$$

Where:

Y: Production

X₁: Land area (ha)

X₂: *S. bicolor* seed (kg)

X₃: Fertilizer (kg)

X₄: Labor (workers/day)

X₅: Pesticide (ltr)

E_j: Dummy variable coefficient

D_j : Dummy variable for farming rituals ($D=1$: Farmers who practiced farming rituals in Wolojita, Lepembusu, Kelisoke, and Kotabaru sub-districts. $D=0$: Farmers who did not practice farming rituals in Nangapenda sub-district).

β_i : Regression coefficient ($i: 0, 1, 2, \dots, 5$)

V_{it} : Random disturbance/error

u_{it} : Random variable representing technical inefficiency, sample farmer i in period t

The technical efficiency of *S. bicolor* farming was measured using the following formula:

$$TE_{it} = \frac{Y_{it}}{Y_{it}^*} = \frac{\exp(\beta_{it} + V_{it} - U_{it})}{\exp(\beta_{it} + V_{it})} = \exp(-u_{it})$$

Where, Y_{it} shows the actual production, while Y_{it}^* represents the estimated frontier production obtained from the stochastic frontier production function. Stochastic frontier estimation was conducted using FRONTIER 4.1c by Coelli, via the error-components model. The noise component is assumed to follow $v_i \sim N(0, \sigma_v^2)$. The inefficiency component is assumed to follow a half-normal distribution $u_i \sim |N(0, \sigma_u^2)|$, which is indicated in the output by the parameter restriction $\mu = 0$ (μ is restricted to be zero). Given the cross-sectional nature of the data ($T=1$), the time-varying inefficiency parameter is restricted to $\eta = 0$ (η is restricted to be zero).

Allocative and economic efficiency analyses were conducted using the Stochastic frontier cost function method. Therefore, the empirical model was formulated as follows:

$$\ln C_{it} = \alpha_0 + \alpha_1 \ln P_{X_{1it}} + \alpha_2 \ln P_{X_{2it}} + \alpha_3 \ln P_{X_{3it}} + \alpha_4 \ln P_{Y_{4it}} + E_j D_j + (V_{it} + U_{it})$$

Where:

C : Production cost (Rp)

X_1 : Seed price (Rp)

X_2 : Fertilizer price (Rp)

X_3 : Labor wages (Rp)

Y_i : Total output (kg)

E_j : Dummy variable coefficient

D_j : Dummy farming ritual ($D = 1$: Farmers who practiced farming rituals in Wolojita, Lepembusu, Kelisoke, and Kotabaru sub-districts. $D=0$: Farmers who did not practice farming rituals in Nangapanda sub-district).

$V_{it} + u_{it}$ = Error term component

Cost inefficiency is the ratio between the actual total cost (C) and the estimated minimum total cost (C^*). Based on this perspective, cost inefficiency values range from 1 to infinity.

$$CE_{it} = \frac{C_{it}}{C_{it}^*} = \frac{E(C_{it} U_{it}, Y_{it}, P_{it})}{E(C_{it} U_{it} = 0, Y_{it}, P_{it})} = \exp(-u_{it})$$

Allocative efficiency values within the range of 0 to 1, reflect the relationship between costs and output, derived using the formula $AE_i = 1/CE_i$. Economic efficiency is obtained by multiplying technical and allocative efficiencies, $EE_i = TE_i \cdot EA_i$. Additionally, it is achieved

when both technical and allocative efficiencies are actualized.

The model included a dummy variable for farming rituals aimed at analyzing the effect on production and costs. It was also used to compare the technical, allocative, and economic efficiencies between farmers who engaged in farming rituals and those who did not practice farming rituals. The factors affecting technical, allocative, and economic efficiencies included age, education, length of farming experience, farmer group membership, credit access, and land ownership status (Agza et al. 2021; Lanamana and Nona 2025). Furthermore, this analysis used a multiple linear regression model:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + E_j D_j$$

Where:

U_i : Technical, allocative, and economic efficiencies

Z_1 : Age (years)

Z_2 : Education (years)

Z_3 : Years of farming (years)

Z_4 : Dummy for farmer group membership (1 = if the farmer is a group member, 0 = if the farmer is not a group member)

Z_5 : Dummy for credit access (1: if there is credit access, 0: if there is no credit access).

Z_6 : Dummy variable for land ownership status (1: landowner, 0: sharecropped land).

E_j : Coefficient of dummy variable

D_j : Dummy for farming rituals ($D=1$: Farmers who practiced farming rituals in Wolojita, Lepembusu, Kelisoke, and Kotabaru Sub-districts. $D=0$: Farmers who did not practice farming rituals in Nangapanda Sub-district).

The costs incurred during *S. bicolor* farming activities included the procurement of seeds, fertilizers, pesticides, labor, land rent, taxes, depreciation, and transportation. The feasibility of *S. bicolor* farming was analyzed using the B/C ratio formula, which is equivalent to total income (gross profit) divided by total costs. This was based on the criteria that if $B/C > 1$, then the farming business is feasible to implement, $B/C < 1$ is not feasible, and if $B/C = 1$, the farming business is considered break-even.

RESULTS AND DISCUSSION

The effect of farming rituals on the technical efficiency of *S. bicolor* farming

Stochastic frontier production function

The data in Table 1 shows that the results of the stochastic frontier estimation obtained using the MLE method were superior to OLS. The log likelihood function value of 287.220 for the MLE method is greater than the OLS of 269.774. The gamma value of 0.966 suggested that most of the deviations (96.6%) were due to technical inefficiency, with only 3.4% caused by random factors.

Variables such as land area, seeds, fertilizers, and pesticides have a significant and positive effect on production. This showed that a 1% increase in the variables increased *S. bicolor* production per hectare by 0.382%,

0.122%, 0.108%, and 0.050%, respectively. The production response to changes in land area, seeds, fertilizers, and pesticides was inelastic, relatively less than 1. Furthermore, the labor variable has a significant and negative effect on production, showing excessive labor use.

The variable farming rituals showed that farmers who engaged in these practices have higher production than those who did not engage in the rituals. The t-stat value (12.502), which is statistically greater than the t-table suggests, ritual practices are additional variables, as well as significant differentiating factors in production results. Moreover, the ritual coefficient is positive and significant (0.172), implying the Marginal Product (MP) of other physical inputs (land, seeds, fertilizers, pesticides) is higher in the group that did not practice farming rituals.

In this context, the seeds used are known in the local language as *lolo poe* and *lolo merah*. Other local seeds found include *lolo kowe*, *lolo maju*, *lolo koja*, and *lolo telo leko*. In the Nangapenda Sub-district, the majority of farmers used the number variety. The number of workers or laborers is relatively limited, and the village community still practices a system of mutual cooperation.

The farmers often encountered difficulty in obtaining inorganic fertilizers; therefore, agricultural and livestock waste served as organic fertilizers. The people in Nggela Village, Wolojita Sub-district, believed in the seven-year soil fertility restoration. This led to the division of agricultural land into seven years on the west and east. The practice is locally called *gaga wera mena*, *gaga wera ghale*. In several villages in Lepembusu Kelisoke, land is divided into a year or more to limit excessive tillage and restore soil nutrient levels.

Limiting tillage for more than a year served as an ecological conservation measure that maintained soil structure and organic matter. Additionally, the maintenance of natural fertility served as a substitute for external inputs, minimizing dependence on chemical fertilizers without reducing productivity. This result explained why the adherence to rituals was positively correlated with cost efficiency. Previous studies reported that soil fertility was also maintained through natural mechanisms (Hidayat et al. 2025).

The farming rituals in Wolojita Sub-district were carried out throughout the year, from land preparation to harvest thanksgiving. These activities started in September and continued throughout the season until July of the following year. The farming rituals included *dero mbeo* (preparation ritual), *mapa* (climate forecasting and land preparation ritual), *nduru* (initial planting), *more* (simultaneous planting), *bake ria* (maintenance), *bake lo'o* (maintenance), *fowo* (pest and disease control), *balu re'e* (maintenance of flowering plants), *balu ji'e* (maintenance of mature corn and *S. bicolor*, as well as flowering rice), *basse*, *loka lolo* (*S. bicolor* harvest), and *mala*, *base ae* (rice harvest), *dero*, *base gaga* (summer ritual), which ended in July. The rituals performed in Kotabaru and Lepembusu Kelisoke Sub-districts were relatively brief. Furthermore, *Po'o* (a ritual of supplication followed by land preparation), and *nggua wenggo ulu eko tanah*

(planting), ended with *nggua pesa uta no mi are* (a celebration of thanksgiving for the harvest).

The respondents selected were smallholder farmers with an average farm size of 0.25 ha. These farmers depended on high input subsidies and limited market access (Lowder et al. 2025). The farmers' livelihoods varied; some were employed in the service sector with limited income (Campos et al. 2025). Meanwhile, *S. bicolor* was cultivated using various methods, namely intercropping with corn, rice, or as a companion crop.

The main challenge encountered in *S. bicolor* farming was limited processing and marketing technology. Young farmers left their main jobs and got employed in the service sector with limited income. As a result, the community's food needs were actualized through government-assisted rice, with over half of the villages in Ende District found to be waning in the practice of farming rituals. Hidayat et al. (2025) further reported an increasing duration of food insecurity.

The technical efficiency level of S. bicolor farmers with and without farming rituals

Table 2 shows that the average technical efficiency level of *S. bicolor* farmers who practiced farming rituals reached 91%. Based on this perspective, the maximum and minimum values were 97% and 72%, respectively. The result suggested that farmers could achieve an average of 91% of the production potential obtained from a combination of related inputs. The average technical efficiency level of farmers who did not engage in farming rituals was 78%, with the maximum and minimum values equivalent to 97% and 40%, respectively. Furthermore, it suggested that farmers were able to achieve an average of at least 78% of the production potential. The Standard Deviation value showed that the variation in actual production among farmers who practiced farming rituals was relatively lower compared to those who did not engage in farming rituals.

The effect of farming rituals on the allocative efficiency of S. bicolor

Table 3 shows the estimation results of the cost function showed that the seed prices, fertilizers, and labor have a significant and positive effect on total costs. Changes in seed prices significantly affected farming costs, thereby making seeds a critical cost component. The effects of fertilizer and labor prices were more moderate. The use of agricultural waste as fertilizer reflected an adaptive strategy to reduce input cost pressures. Furthermore, consistent increases in production volume were accompanied by a rise in cost. This suggested the normal relationship between output scale and production costs. Previous studies reported that the use of contract labor improved cost efficiency in small-scale farming (Akite et al. 2022).

The farming ritual variable has a significant and negative effect on total costs, implying a reduction in production costs. The diverse activities are related to agreements on terracing (*kebe kolo*) and the use of local seeds (*lolo poe*), resistant to pests and diseases. Simultaneous planting and harvesting showed an integrated

pest management strategy (Pitriana et al. 2025). This included the division of agricultural land into western and eastern fields to be worked on annually, with the intent of restoring soil nutrient content. Additionally, soil fertility was maintained through natural mechanisms during the fallow period.

The allocative efficiency level of S. bicolor farmers with and without farming rituals

Table 4 shows that *S. bicolor* cultivated after performing farming rituals achieved an average allocative efficiency of 95%, with maximum and minimum values of 99% and 67%, respectively. This showed that the average minimum cost level achieved by farmers was approximately 95% of the frontier cost.

Table 1. Estimation of the production function on *S. bicolor* farming using the MLE method

Variables	Coefficient	Standard error	t-stat
Intercept	4.331***	0.450	9.623
X1 Land area (ha)	0.382***	0.100	3.814
X2 <i>S. bicolor</i> seeds (kg)	0.122***	0.054	2.233
X3 Fertilizer (kg)	0.108*)	0.061	1.754
X4 Labor (workers' day)	-0.198***)	0.060	-3.281
X5 Pesticide (ltr)	0.050**)	0.022	2.272
D1 Dummy farming ritual	0.172***)	0.013	12.502
Sigma - Squared	0.040		
Gamma	0.966		
Loq Likelihood Function (MLE)	287.220		
Loq Likelihood Function (OLS)	269.774		
LR test = 34.892			
X ² = 6.630			

Note: ***, **, and *: Significant at 1, 5, and 10% respectively. Variable dependent on production (kg). T table $\alpha=0.01=(0.01, df 378)=2.588$. T table $\alpha=0.05=(0.05, df 378)=1.966$. T table $\alpha=0.10=(0.10, df 378)=1.648$

Table 3. Estimation of the cost function on *S. bicolor* farming using the MLE method

Variable	Coefficient	Standard error	t-ratio
Intercept	-63.163***)	2.991	21.117
PX ₁ Seed Price (Rp)	6.862***)	0.307	22.339
PX ₂ Fertilizer Price (Rp)	0.550***)	0.108	5.059
PX ₃ Labor Wages (Rp)	0.468*)	0.243	1.922
Y Total output (kg)	0.316**)	0.156	2.020
D ₁ Farming Ritual Dummy	-2.070***)	0.246	-8.414
Sigma - Squared	0.057		
Gamma	0.988		
Loq Likelihood Function (MLE)	50.237		
Loq Likelihood Function (OLS)	20.664		
LR test = 59.146			
X ² = 6,631			

Note: ***, **, and *: Significant at 1, 5, and 10% respectively. Dependent variable: ln total cost (Rp). T table $\alpha=0.01=(0.01, df 378)=2.588$. T table $\alpha=0.05=(0.05, df 378)=1.966$. T table $\alpha=0.10=(0.10, df 378)=1.648$

Farmers who did not practice rituals achieved an average allocative efficiency of 78%, with maximum and minimum values of 92% and 70%, respectively. This value showed that the average minimum cost level achieved by farmers was roughly 78% of the frontier cost. The results suggested failure to respond to agricultural input price signals, which resulted in higher production costs economically. Social capital or cultural values associated with farming rituals served as quality control mechanisms or knowledge transfer that reduced the risk of resource waste. The standard deviation showed that actual production variation among farmers who did not engage in farming rituals was lower than among those who practiced farming rituals.

Table 2. The technical efficiency level of *S. bicolor* farmers with and without farming rituals

Range of technical efficiency levels	Farmers who practiced farming rituals		Farmers who did not practice farming rituals	
	Number of farmers	%	Number of farmers	%
up to 0.70	-	-	71	34
0.71-0.80	3	2	39	18
0.81-0.90	39	22	46	22
0.91-1.00	133	76	54	26
Total	175	100	210	100
Average technical efficiency level	0.910		0.781	
Standard deviation	0.031		0.130	
Minimum	0.721		0.402	
Maximum	0.971		0.970	

Note: Field survey data analysis in 2025

Table 4. The allocative efficiency level of *S. bicolor* farmers with and without farming rituals

Range of allocative efficiency levels	Farmers who practiced farming rituals		Farmers who did not practice farming rituals	
	Number of farmers	%	Number of farmers	%
Up to 0.70	6	3	13	6
0.71-0.80	11	6	170	81
0.81-0.90	3	2	10	5
0.91-1.00	155	89	17	8
Total	175	100	210	100
Average allocative efficiency level	0.956		0.782	
Standard deviation	0.072		0.046	
Minimum	0.673		0.700	
Maximum	0.997		0.929	

Note: Field survey data analysis in 2025

Economic efficiency levels of *S. bicolor* farmers with and without farming rituals

Table 5 shows that *S. bicolor* farmers who practiced farming rituals have an average economic efficiency of 92%, with maximum and minimum values of 98% and 59%, respectively. Meanwhile, those who did not practice farming rituals have an average economic efficiency of 64%, with maximum and minimum values of 91% and 43%. The standard deviation proved that these rituals led to lower variability in actual production compared to not engaging in farming rituals.

Factors affecting technical and economic efficiencies of *S. bicolor* farming

Table 6 presents the determinants of technical and economic efficiency. Education, farmer group membership, credit access, land ownership status, and farming rituals are positively associated with technical efficiency. Regarding economic efficiency, education, farmer group membership, and farming rituals show a positive influence, whereas age, farming experience, and credit access have a negative impact. Conversely, age and farming experience are negatively associated with technical efficiency. Finally, land ownership status does not have a statistically significant effect on economic efficiency.

Feasibility analysis of *S. bicolor* farmers with and without farming rituals

The data in Table 7 shows that *S. bicolor* farming in Ende District is feasible to develop, with a B/C ratio >1. Meanwhile, farming rituals have a statistically significantly higher B/C ratio compared to non-ritual practices. This is associated with the use of local seeds, which reduced purchase costs and increased adaptation to territorial agroecology (Nolan et al. 2023). Aditia et al. (2025) reported that synchronized planting times facilitated more efficient work planning. Mutual cooperation has been proven to increase efficiency in the allocation of labor, capital, and time (Salfarini et al. 2025). Additionally, the use of semi-organic fertilizers reduced production costs (Silvania et al. 2025).

The results of the Independent Sample T-Test analysis using SPSS produced a sig (2-tailed <0.05). This represented a significant difference in profitability between farmers who engaged in farming rituals and those who did not practice farming rituals.

Discussion

The data in Table 6 shows that age has a significant and negative effect on *S. bicolor* farming efficiency. Furthermore, increasing age correlated with a decline in physical and cognitive capacity to adopt technology. Older farmers tended to face greater information asymmetry regarding input-output price fluctuations, resulting in difficulty reaching the production possibility frontier. Some older farmers allocated limited capital for the practice of farming rituals to maintain social status or spiritual beliefs, rather than spending it on productive input. This is

consistent with the study conducted by Geffersa and Agbola (2025). However, the result was inconsistent with the studies by Agza et al. (2021) and Maulidiyah et al. (2024), which stated that older farmers had a better understanding of the appropriate planting times or how to respond to extreme weather changes intuitively than younger farmers.

In this context, education has a positive and significant effect on *S. bicolor* farming efficiency. Educated farmers have greater capability to adopt cultivation technologies, thereby minimizing input waste. In terms of economic efficiency, education reduces information barriers to price fluctuations. This caused farmers to perform more accurate marginal calculations in allocating resources based on the principle of profit maximization. Farmers often select the farming rituals to be performed (determining planting times in harmony with the climate, planting simultaneously to break pest cycles), including being more rational in allocating capital, if it requires costs. The result was in line with Abdulahi et al. (2024), but inconsistent with the studies by Agza et al. (2021) and Geffersa and Agbola (2025) that educated farmers often had side jobs, leading to a lack of focus on farming activities.

Farmer group membership has a significant and positive effect on *S. bicolor* farming efficiency. These groups serve as collective information providers. Technically, interaction between members hastens farmers' learning in cultivation methods. The groups also play an economic role in increasing bargaining power and reducing input procurement costs, as well as output marketing. The function of these groups synchronizes ritual-based planting schedules with modern agronomic practices. Integration within farmer groups and adherence to farming rituals create social and technical control mechanisms that motivate farmers to work more efficiently. As a result, this study is consistent with the review by Selorm et al. (2023).

Table 5. Economic efficiency levels of *S. bicolor* farmers with and without farming rituals

Range of economic efficiency levels	Farmers who practiced farming rituals		Farmers who did not practice farming rituals	
	Number of farmers	%	Number of farmers	%
Up to 0.70	8	5	172	82
0.71-0.80	13	7	20	10
0.81-0.90	7	4	15	7
0.91-1.00	147	84	3	1
Total	175	100	210	100
Average economic efficiency level	0.922		0.640	
Standard deviation	0.078		0.087	
Minimum	0.594		0.437	
Maximum	0.986		0.915	

Note: Field survey data analysis in 2025

Table 6. Factors affecting the technical and economic efficiency of *S. bicolor* farming

Variables	Technical efficiency			Economic efficiency		
	Coefficient	Standard error	t-ratio	Coefficient	Standard error	t-ratio
Z0 Constant	0.975***	0.052	17.527	0.689***	0.044	15.506
Z1 Age (years)	-0.003***	0.001	-5.344	-0.004***	0.001	-5.440
Z2 Education (years)	0.016***	0.002	4.593	0.008***	0.002	5.283
Z3 Years of farming (years)	-0.042***	0.001	-5.440	-0.004***	0.001	-3.196
Z4 Farmer group membership dummy	0.033***	0.010	5.981	0.062***	0.008	7.364
Z5 Credit access dummy	0.019***	0.007	2.639	-0.014**	0.006	-2.339
Z6 Land ownership status dummy	0.039***	0.014	2.698	0.002	0.120	0.164
Z7 Farming ritual dummy	0.102***	0.005	19.732	0.279***	0.004	63.431

Note: ***, **: Significant at 1, 5 % respectively. Variable-dependent technical efficiency and economic efficiency. T table $\alpha=0.01=(0.01, df 377)=2.588$. T table $\alpha=0.05=(0.05, df 377)=1.966$. T table $\alpha=0.10=(0.10, df 377)=1.648$

Table 7. B/C ratio values on *S. bicolor* farmers with and without farming rituals

Average	Farmers who practiced farming rituals	Farmers who did not practice farming rituals
Gross income per hectare (IDR) (B)	5,992,653	5,042,652
Cost Per Hectare (IDR) (C)	3,113,870	3,983,131
B/C Ratio	1.921	1.260

Note: Field survey data analysis in 2025

Credit access has a significant and positive effect on technical efficiency; additionally, capital enabled the allocation of agricultural inputs in a timely and appropriate manner. This tends to shift the production process closer to the technical frontier. Credit access also has a significant and negative effect on economic efficiency. The results showed that half of the loans were allocated to non-productive activities. Interest payments were continuously made, while the capital did not generate added value to *S. bicolor* output. This caused the ratio of marginal product value to marginal cost to be suboptimal. The result is consistent with Danso-Abbeam et al. (2021) and Ruzhani and Mushunje (2025), but differs from Asodina et al. (2021) and Abdulahi et al. (2024).

The variable of farming experience has a significant and negative effect on *S. bicolor* farming efficiency. Experience tended to increase efficiency through a learning-by-doing process. In this case, long experience created behavioral rigidity. Farmers were trapped in traditional practices and loyal to old methods, which prevented the optimal reallocation of inputs.

The variable of land ownership status has a significant and positive effect on technical efficiency. This result supported the argument about land tenure security. Moreover, land ownership reduced the risk of 'eviction' or sudden changes to lease contracts, causing farmers to willingly adapt to cultivation technologies. The process allowed farmers to operate closer to the production frontier. Farming rituals were perceived as spiritual as well as affirming land and ecosystem rights. Based on this perspective, *Mosalaki* provided land to the community for economic use. The result was in line with the study by

Pierrri et al. (2025), although it was inconsistent with the analysis by Maulidiyah et al. (2024), which reported that tenant farmers or sharecroppers were burdened with rent or sharecropping, leading to more persistent hard work than the owner.

Farming ritual variables have a significant and positive effect on *S. bicolor* farming efficiency. As an informal institution, it provided rules or norms that bound the entire farming community, thereby shaping economic behavior (Nainggolan et al. 2023). The reference to institutional theory showed that the role of appropriate institutions increased farming efficiency and productivity.

The farmers' participation in farming rituals in the Wolojita, Lepembusu, Kelisoke, and Kotabaru Sub-districts was structurally determined by customary norms. Traditional sanctions, such as animal fines, were imposed particularly when the land was not cultivated, and rituals were ignored. The non-compliance with established rituals was believed to disrupt the cosmic order, potentially causing crop failure and triggering disease or disaster (Adha et al. 2023) as a result, individual self-selection bias was minimal in this study. In Nangapenda Sub-district, customary institutions were weakening, and rituals tended to be less effective.

Within the framework of Production Economic, technical efficiency was achieved when farmers produced maximum output from a given combination of inputs. However, economic efficiency was achieved when farmers were able to produce maximum output and sell at high prices with low input costs (Imran and Indriani 2022). Farming rituals acted as a determinant factor that reduced technical inefficiency effects by standardizing planting time management, resulting in a shift to the production frontier. The use of locally selected seeds and organic inputs enabled farming rituals to support the achievement of *S. bicolor* economic efficiency through a system of mutual cooperation. This created a mechanism for input substitution, thereby minimizing cash expenditures.

Farming rituals played a crucial role in determining the harvest allocation patterns that must be met during the Thanksgiving ceremony (*are wati, moke boti, manu eko*/rice, wine, and chicken). This phenomenon is presumed to increase opportunity costs. Therefore, it is essential to rationalize ritual costs and ensure efficiency without sacrificing cultural identity. The essence and

significance of rituals should be based on the ideal principle (Basri et al. 2023).

Ritual practices have been shown to be an integral part of the farming institutional system. The current study limited the discussion to institutional aspects and did not include an in-depth analysis of agronomic variables, climate, or market access, considering that these variables played significant roles in agricultural economic literature (Mesfin and Girma 2022).

The current study has limitations related to the type of data used, which is cross-sectional. As a result, it limited the ability to define changes in efficiency over time. This analysis also focused on measurable economic and technical variables, as well as reduced complex cultural practices to simple binary variables, with yes-no preferences (0 and 1). Despite the limitation in generalizability, farming rituals were perceived as manifestations of specific cultural traditions.

In conclusion, the results showed that *S. bicolor* farmers who practiced farming rituals had a higher efficiency level with an average technical, allocative, and economic efficiencies of 0.910, 0.956, and 0.922, respectively. This was compared to the average technical, allocative, and economic efficiencies of 0.781, 0.782, and 0.640 actualized by those who did not engage in the rituals. The feasibility analysis showed that *S. bicolor* farming in Ende District was feasible, as evidenced by the B/C ratio value >1. Meanwhile, the B/C ratio value for those who practiced farming rituals was 1.921 higher compared to farmers who did not carry out the rituals, with a B/C ratio of 1.260. The factors that significantly and positively affected technical efficiency included education, farmer group membership, credit access, land ownership status, and farming rituals. The factors that significantly and positively affected economic efficiency consisted of education, farmer group membership, and farming rituals. The local government should ensure the agricultural extension schedule supports the traditional calendar to facilitate simultaneous planting. Furthermore, the transformation of farmer groups into institutions provided agricultural inputs that were easily accessible at affordable prices.

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