Jurnal Agrisep: Kajian Masalah Sosial Ekonomi Pertanian dan Agribisnis. 24 (01): 251-272 (2025)

AGRISEP: Journal of Agricultural Socio-Economics and Agribusiness Studies

https://ejournal.unib.ac.id/agrisep

DOI: http://doi.org/10.31186/jagrisep.24.01.251-272

GENDER-BASED ANALYSIS OF TECHNICAL EFFICIENCY IN RICE FARMING: A CASE STUDY IN DELI SERDANG REGENCY

Jones T Simatupang*; Manaor Bismar Posman Nababan; Aditia Erick Cantona Simatupang

Department of Agribusiness, Faculty of Agriculture, Methodist Indonesia University, North Sumatra, Indonesia

* Corresponding Author: : jones.7matupang@gmail.com

ABSTRACT

Deli Serdang Regency is the foremost rice grower in North Sumatra Province. The disparity in input access between male and female producers is responsible for the low rice output in this region. This study aimed to assess the technical efficiency of rice cultivation among male and female producers and identify the inefficiency sources among rice farmers in Deli Serdang Regency. We employ a stochastic frontier methodology to assess the technical efficiency of rice cultivation and utilize a statistical difference test to evaluate efficiency disparities between the two cohorts of rice growers. Primary data was gathered from 400 farmers during the 2022 planting season. The study revealed that male rice growers exhibited greater efficiency than their female counterparts. Our findings indicate that male rice producers inadequately utilized labor, fertilizer, land, and pesticides, but female rice producers inadequately utilized labor and fertilizer. Factors contributing to inefficiency also included the frequency of extensions, experience with FBOs, agricultural expertise, and access to irrigation. Given that women dedicate considerable time to domestic responsibilities and child-rearing, local governments may establish extension and training initiatives – such as guidance on fertilizer application, pest management, and agricultural record-keeping – alongside health programs routinely administered at integrated service posts (Posyandu) and family welfare programs (PKK). Extension services are essential to enhance the knowledge and abilities of women rice farmers, hence improving technical efficiency, household welfare, and the sustainability of rice growing in Deli Serdang Regency.

* Submitted: 28 June 2024
Reviewed: 9 December 2024
Accepted: 24 December 2024

Keywords: *efficiency, gender, rice, SFA*

***Cite as*:**

Simatupang, J. T., Nababan, M. B. P., & Simatupang, A. E. C. (2025). Gender-Based Analysis of Technical Efficiency in Rice Farming: A Case Study in Deli Serdang Regency. *Jurnal AGRISEP: Kajian Masalah Sosial Ekonomi Pertanian Dan Agribisnis*, 24(01), 251–272. https://doi.org/10.31186/jagrisep.24.01.251-272

INTRODUCTION

The Indonesian government has consistently prioritized rice to sustain political and economic stability, as it serves as a staple food and financial resource for rural areas. The national average rice consumption is 1.51 kg per capita, surpassing other dietary commodities like fish, tempeh, tofu, and cassava (BPS, 2021). Over 13 million rural households engage in rice farming as an economic resource, with around 10 million households relying on it as their primary source of income, while the remainder supplement their income through rice farming (BPS-Statistics, 2018). Rural households engaged in rice cultivation are distributed throughout Java, Sumatra, and Sulawesi islands.

North Sumatra Province is a prominent rice producer in Indonesia, contributing 19% and 4% to the total rice production in Sumatra and Indonesia, respectively. Nonetheless, rice yield in North Sumatra remains 13% inferior to that of West Java (BPS, 2021). Rice productivity in North Sumatra and Indonesia is 50% lower than that of Vietnam compared to rice-producing countries in Asia (USDA, 2022). Deli Serdang Regency is the preeminent rice producer in North Sumatra. Rice productivity in this region has stagnated during the past five years (Angin et al., 2024). Suboptimal rice productivity signifies ineffective rice cultivation in the area.

Rice farming in Deli Serdang Regency demonstrates efficiency due to access to irrigation, affordable input prices, and a stable climate (Angin et al., 2024; Simatupang & Nababan, 2023). Numerous studies indicate that human capital significantly influences efficiency. Farrell (1957), defines technical efficiency as the capacity of agricultural managers to minimize resource waste by maximizing output relative to the potential use of inputs or by utilizing minimal inputs to achieve the maximum possible production output. *Farm inefficiency* refers to the extent to which a producer utilizes excess resources to achieve a specific production level compared to the resources employed by optimal farmers (Alem et al., 2018). Human capital encompasses age, education, and gender (Alem et al., 2018).

Women are considered vital in emerging nations' agricultural and rural economies. Women are accountable for cultivating staple crops (including rice, wheat, and corn), which contribute to 60% to 80% of food production and can sustain food security in impoverished rural regions of developing nations (OECD, 2021). Women play a vital role in agricultural output and food security in North Sumatra (Nadra, 2015; Ririn & Harahap, 2024). Women frequently encounter prejudice due to societal norms and gender inequities, particularly with power imbalances between men and women (Qanti et al., 2022). Gender disparities arise when female heads of families who are either divorced or widowed experience diminished access to land control (Quisumbing & Doss, 2021). Gender disparities manifest in North Sumatra when women are excluded from agricultural collectives. Growers who are not members of farmer organizations face challenges in obtaining affordable inputs, lack access to information exchange, and do not receive agricultural training (Ririn & Harahap, 2024; Wicaksono et al., 2023). Gender disparities affect agricultural competencies and diminish productivity (D. Ali, et al, 2016; Kilic, et al., 2015).

Many experts have focused on gender disparity by assessing agricultural efficiency. Raoul Fani et al. (2023) determined that young female farmers exhibit greater efficiency than their male counterparts, attributable to financial and socio-economic reasons. A study conducted in China by de Brauw et al. (2013) revealed that female managers with access to land, inputs, and other resources achieved efficiency scores equivalent to those of their male counterparts. A study conducted in Northern Ghana (Owusu et al., 2018) demonstrated that rice fields managed by women exhibited more efficiency than those managed by men. The research indicates that women possess access to productive resources, resulting in greater efficiency of their farms compared to those of males. Nevertheless, research indicates that male farm managers exhibit greater efficiency than their female counterparts. All three studies examining the efficiency of rice farming in Ghana concluded that female farm managers were less efficient than their male counterparts (Addisonet al., 2016; Al-hassan, 2012; John-Muoh et al., 2020). According to our restricted understanding, merely three research have focused on gender concerns in rice cultivation in Deli Serdang (Angin et al., 2024; Simatupang & Nababan, 2023; Wibowo et al., 2019). Nonetheless, all three research concluded that gender did not influence the efficacy of rice cultivation.

Efficiency is essential for enhancing productivity despite the scarcity of resources and the restricted opportunity to use new technology. Research on technical efficiency indicates that productivity can be improved by optimizing efficiency without new technology or an expanded resource base (Oyakhilomen et al., 2016). According to prior studies on efficiency and productivity, women's role is essential in rice cultivation. Nevertheless, we have not identified a study that examines the gender disparity in rice cultivation within the Deli Serdang Regency. This study primarily aims to compare the technical efficiency of male and female rice farmers in Deli Serdang Regency. Its secondary mission is to identify the factors affecting the technical efficiency of farmers according to the gender of the farm manager. Both study objectives were analyzed utilizing stochastic frontier analysis (SFA). The efficiency study at the research site enhances the understanding of agricultural economics about input management executed by male and female farm managers. This study can give policymakers essential insights for mitigating gender disparities and improving rice farming efficiency in the Deli Serdang District.

RESEARCH METHOD

This study was performed in Deli Serdang Regency, the predominant rice producer in North Sumatra Province. Rice production in this region constitutes 15.43% of the total rice output in North Sumatra Province (BPS North Sumatra, 2022). We employed a multi-stage sampling methodology to choose rice producers. The initial round involved a deliberate selection from three districts: Tanjung Morawa, Hamparan Perak, and Percut Sei Tuan. The second stage involved the selection of settlements from each subdistrict. This study randomly picked three rice-producing villages, resulting in nine chosen villages. The concluding phase was the random selection of 50 farmers from each town, resulting in a total of 450 rice farmers for this study. The sample was established due to the unavailability of secondary data regarding the population of farmers in each village. The sample of 450 farmers was presumed to represent the population of rice farmers in Deli Serdang Regency. Each hamlet randomly picked 50 farmers, aiming to describe both male and female rice growers from the village. This study primarily utilizes primary data gathered from rice producers in nine villages, focussing on production activities in 2022. Primary data was collected from February to April 2023 by a standardized questionnaire administered to farmers in the designated study locations. The primary data gathered encompassed the socioeconomic attributes of rice producers in the study area, the inputs utilized for rice cultivation each production cycle, and the yield from the rice production cycle. During the data gathering, it was determined that 50 farmer samples were unsuitable for use as they failed to provide ideal responses to the posed questions. Consequently, the total sample deemed appropriate for use consisted of 400 farmer samples. The disparity in sample sizes between male farmers (340 producers) and female farmers (60 producers) arose due to the unavailability of secondary data on the respective populations.

Technical efficiency denotes the capacity of farm managers to achieve optimal production from a specified quantity of productive resources (Coelli et al., 2005). The technical inefficiency of a specific farm manager is quantified by the disparity between the manager's actual output and the production frontier, which signifies the optimal output achievable with identical resources and production technology (Battese, 1992). Stochastic frontier analysis and deterministic methods are frequently employed in the literature to assess frontier production and technical efficiency distributions of farm managers (Greene, 1999). A deterministic approach in DEA exhibits several shortcomings, such as measurement inaccuracies and disturbances that may influence the frontier's shape and position, the exclusion of critical inputs or outputs leading to biased outcomes, the treatment of inputs and outputs as homogeneous commodities despite their inherent heterogeneity, and the failure to consider environmental variances, which can yield a misleading assessment of relative farm managerial efficacy. SFA offers benefits, as this method considers noise and facilitates conventional hypothesis testing (Coelli et al., 2005). This study used a stochastic production frontier methodology to assess the factors influencing technical efficiency distribution among rice producers.

The SFA methodology often employs the Cobb-Douglas and translog production function techniques (Coelli et al., 2005). Both methods presume a singular output derived from several inputs to assess efficiency. The Cobb-Douglas production function entails formulating a logarithmic-linear function to determine the coefficients by linear programming approaches (Giokas, 1991). The Cobb–Douglas production function is appropriate for assessing technological efficiency due to its interpretative and estimative advantages, while its elastic functional shape addresses the challenge of multicollinearity (Ali et al., 2019). Nevertheless, the Cobb-Douglas model consistently presupposes constant returns to scale, which is unattainable. The translog model offers a more adaptable functional form (quadratic in the logarithm) as it refrains from imposing assumptions regarding constant elasticity of production, and its replacement between inputs surpasses that of the first-level functional form, namely the Cobb-Douglas function (Chiang & Cheng, 2014). The output of translog models is more challenging to read, and the extensive number of parameters requiring estimation might exacerbate multicollinearity issues (Iliyasu et al, 2016). Battese & Broca (1997) propose that statistical testing is essential for determining the suitable model for assessing efficiency. Despite the shortcomings of both models, the SFA method is superior to the deterministic approach, as elucidated by Coelli et al. (2005). The subsequent phrase delineates the SFA methodology employing the Cobb-Douglas functional form:

$$\ln y_{ik} = \beta_0 + \sum_{j=1}^{J} \beta_j \ln x_{ijk} + v_i - \mu_i ; k = men(1), women(2) \quad (1)$$

In this context, y_{ik} represents rice output (kg/ha). At the same time, x_i signifies a vector of variable inputs j, which includes labor quantity (person-days/ha), fertilizer application (kg/ha), land area dedicated to rice cultivation (ha), pesticide application (liter/ha), and rice seed quantity planted (kg/ha). β_0 denotes the intercept, and β_j are the parameters that characterize the production frontier technology and require estimation. v_i accounts for random effects beyond farm control, including observation and measurement errors, as well as other stochastic noise. μ_i is a one-sided component that reflects deviations from the frontier due to inefficiencies in farm management. The SFA approach using the translog functional form is given by the following expression:

$$\ln y_{ik} = \beta_0 + \sum_{j=1}^{J} \beta_j \ln x_{ijkl} + \sum_{j=1}^{J} \sum_{n=1}^{N} \beta_{ijkn} \ln x_{ijkn} \ln x_{ijkn} + v_i - \mu_i \quad (2)$$
$$k = men(1), women(2)$$

The parameters concerning the fitness of the frontier model are evaluated using the greatest likelihood-ratio estimator. The comparison of the two models, namely Cobb–Douglas and translog, is predicated on the likelihood ratio statistics (Coelli et al., 2005) expressed as:

$$\lambda = -2(\ln[L[H_0]] - \ln[L[H_1]]) \quad (3)$$

Where λ represents the likelihood ratio, and $ln[L[H_0]]$ denotes the logarithm of the likelihood ratio for the Cobb–Douglas model under constraints, H_0 posits that the Cobb–Douglas model is the most suitable model. Ln $ln[L[H_1]]$ denotes the logarithm of the likelihood ratio for the unrestricted translog model, wherein H_1 posits that the translog model is the most appropriate for this analysis. Bibi et al. (2021) assert that the maximum likelihood ratio follows a Chi-square (χ^2) distribution, with its critical value derivable from Table I in Kodde & Palm (1986).

The inefficiency model delineating the determinants affecting the inefficiency of male and female farmers in the smallholder rice sector is articulated as follows:

$$\mu_{ik} = \delta_0 + \delta_{1ik}Z_{1ik} + \delta_{2ik}Z_{2ik} + \delta_{3ik}Z_{3ik} + \delta_{4ik}Z_{4ik} + \delta_{5ik}Z_{5ik} + \delta_{6ik}Z_{6ik} + \delta_{7ik}Z_{7ik} + \delta_{8ik}Z_{8ik} + \delta_{9ik}Z_{9ik} + \omega_i \quad (4)$$

Where $k = men(1), women(2)$ μ_{ik} denotes the specific technical inefficiency of rice yield, δ_0 is intercept, $\delta_{1ik}, \ldots, \delta_{9ik}$ are the parameters to be estimated, ω_i is the random normally distributed error term, $Z_{1ik}, \ldots, Z_{9ik}$ are inefficient variable factors, including: Z_1 denotes the age of household head (years), Z_2 denotes the household size (numbers), Z_3 denotes gender (men = 1 vs. women = 0), Z_4 denotes frequency of extension services (numbers), Z_5 denotes farming experience (years), Z_6 denotes access to irrigation (yes = 1, no = 0), Z_7 denotes experience in farmer-based organization (FBO) (years), Z_8 denotes number of years of formal education, Z_8 denotes access to credit (yes = 1, no = 0).

To determine the necessity of incorporating inefficiency in the two relevant SFA models by the log-likelihood test (Bibi et al., 2021). The log-likelihood test enables the expression of the error variance ratio parameters, gamma (γ) and sigma squared (σ^2), as $\sigma_w^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma_w^2$ (Battese & Coelli, 1992). The sigma squared value evaluates the appropriateness of data fit within the model, while the gamma value runs from 0 to 1. The parameter $\gamma = 0$ indicates the effect of noise, while $\gamma = 1$ represents the effect of inefficiency (Bibi et al., 2021). This calculation entails evaluating the null hypothesis (Ho), which posits that 'technical inefficiency has no effect on rice farming in the study area' represented as γ=0, versus the alternative hypothesis (Ha), which asserts that 'technical inefficiency affects rice farming' denoted as $\gamma = 1$. The log likelihood test value is compared with the critical value which follows the chi square distribution obtained from Kodde & Palm (1986).

The model estimation findings allow for comparing each farm manager's output with the frontier output level, contingent upon the input utilized. This discrepancy indicates the extent of corporate inefficiency. The technical efficiency score for the ith farm in the sample is defined as the ratio of observed output to the equivalent frontier output, as articulated by Coelli et al. (2005), and is expressed as follows:

$$TE_i = \exp(-\mu_i) \quad (5)$$

Where TE_i denotes the technical efficiency of the farm (0 < TE < 1). When $\mu_i = 0$, the ith farm resides on the stochastic frontier and is deemed technically efficient. If $\mu_i < 0$, farm i is situated beneath the boundary, signifying inefficiency. Calculating output elasticity for each input using variable averaging is crucial for determining the appropriate adjustments in agricultural production inputs (Mango et al., 2015). The flexibility of rice production derived from the SFA model is articulated as follows:

$$E_{ijk} = \frac{\partial \ln y_{ik}}{\partial \ln x_{ijk}} = \beta_j ; k = men(1), women(2) \quad (6)$$

E_{ijk} signifies the output elasticity for the i-th farm concerning the j-th input and the gender of farm managers, y_i indicates the observed output of the i-th sample farm, and x_i represents the vector of observed fundamental inputs.

The return to scale can be ascertained by production elasticity, which is expressed as follows:

$$RTS = \sum_{j=1}^{J} E_{ijk} ; = men(1), women(2) \quad (7)$$

RTS signifies the proportionate variation in output that occurs due to a unit proportional augmentation in all inputs. RTS >1 signifies growing returns to scale, RTS <1 denotes decreasing returns to scale, and RTS =1 represents steady returns to scale.

RESULT AND DISCUSSION

Characteristics of Rice Farmers

Table 1 illustrates the socio-economic features and factors in the production function of a sample of rice farmers, categorized by the gender of agricultural managers and the aggregated sample. Statistical t values are employed to evaluate disparities in input, output, and socio-economic attributes according to the gender of farming managers. The mean rice yield by farmers is 3648.239 kg/ha, and there is no disparity in rice production attributable to the gender of the agricultural manager.

Table 1. Descriptive Statistics of The Variables Used In The Study

Variable		Mean			t-statistic values
		Men (n=340)	Women (n=60)	Full Sample (n=400)	
Production function					
a)	Rice (kg/ha)	3651.176	3631.597	3648.239	0.1333
b)	labour (mandays/ha)	42.716	45.099	43.073	-0.9473
c)	Fertiliser (kg/ha)	352.758	316.693	347.348	1.3881
d)	Land (ha)	0.757	0.568	0.729	2.6863***
e)	Seed (kg/ha)	58.477	56.967	58.251	0.5996
f)	Pesticide (liter/ha)	1.804	1.649	1.781	0.6289
Socioeconomic characteristics					
a)	Age of household head (years)	47.691	53.85	48.615	-4.4419***
b)	Household size (numbers)	4.594	3.6	4.445	4.9209***
c)	Formal education (years)	9.265	8.033	9.08	2.1798**
d)	Extension frequency (numbers)	1.609	0.95	1.51	4.5169***
e)	Experience in FBO (years)	9.197	8.25	9.055	0.8015
f)	Access to irrigation (yes = 1, no = 0)	0.538	0.617	0.55	-1.1248
g)	Farming experience (years)	18.741	25.483	19.752	-3.8523***
h)	Access to credit (yes = 1, no = 0)	0.241	0.083	0.2175	2.7513***
i)	Gender (men = 1 vs. women = 0)			0.85	

***,** denotes significant levels at 1% and 5%, respectively

As presented in Table 1. rice growers utilize 43.073 person-days per hectare, with no gap in labour usage between male and female farm managers. No differences were observed between male and female farm managers for fertilizer, seed, and insecticide utilisation. The mean fertilizer, seeds, and insecticides application by rice cultivators is 347.348 kg/ha, 58.251 kg/ha, and 1.781 litres/ha, respectively. Land ownership varies significantly by the gender of the agricultural manager, with male farmers managing 33.27% more land than female farmers. The disparity in land area arises from male farmers having superior access to economic resources, such as capital from financial institutions or agricultural cooperatives, compared to female farmers. Inputs such as labour, fertilizer, seeds, and pesticides are comparable between male and female rice managers, as both utilize them annually based on established routines. They must adhere to the guidelines of extension training or rice cultivation to maximize input utilization.Most rice farmers in this study were men, while women farmers were only 15% of the total sample. Women farmers are six years older than men, which is significantly different. Women farmers have lower household size, formal education, frequency of attending extension services, and access to credit than their male counterparts, where the differences are significant at the 1% and 5% levels. In contrast, women farmers have significantly longer experience than their male counterparts. Finally, the two farm managers had similar experience in FBOs and irrigation access.

This study mostly took male samples because they are considered heads of families, and they are the ones who predominantly determine economic resources in households, including rice farming. Although men were the majority of the samples in this study, women played a significant role in helping rice farming in the study location, such as plant care. Even women's work was dominant in rice farming because we found women working from planting to harvesting. In contrast, men worked in land management and earned a living outside of agriculture, such as factory workers and construction workers.

Tested Hypotheses

A stochastic production frontier was established via a maximum likelihood estimate method with the Frontier 4.1 software. Before calculating the rice farming efficiency model, all assumptions of the stochastic frontier approach were evaluated. A preliminary evaluation of multicollinearity among the continuous and categorical explanatory factors was performed utilizing the variance inflation factor (VIF). The VIF values for all variables in the model were below 10, signifying a lack of substantial multicollinearity among the explanatory factors.

Secondly, it is essential to identify inefficiencies within the production function within the sample of rice farming households. This test determines if a conventional average production function (OLS) is a superior fit for the dataset relative to a stochastic frontier model (SFM). The evaluation is conducted by estimating a stochastic frontier production function and performing a likelihood ratio test, assuming the null hypothesis of no technical inefficiency. The statistical LR values for the combined male and female samples are 298.38, 245.08, and 56.02, respectively. All three statistical LR values surpass the essential threshold 5.412 at the 1% significance level (Table 2). Consequently, the null hypothesis is rejected, signifying a statistically significant data inefficiency. Consequently, the stochastic frontier production function is appropriate for assessing rice farming efficiency in this research.

Table 2. Tests Of Hypotheses for Model Specification and Statistical Assumptions

Hypothesis	LR test statistics	df	Critical value $(\chi^2, 0.01)$[a]	Decision
OLS models versus stochastic frontier models for pooled samples $(H_0: \gamma = 0)$	298.38	1	5.412	Reject
OLS models versus stochastic frontier models for men samples $(H_0: \gamma = 0)$	245.08	1	5.412	Reject
OLS models versus stochastic frontier models for women samples $(H_0: \gamma = 0)$	56.02	1	5.412	Reject
Cobb–Douglas versus translog $(H_0: \beta_6 = \cdots = \beta_{20} = 0)$	24.34	15	29.927	Accept
Test for no inefficiencies. There is no influence of socio-economic variables on inefficiency for the pooled samples: $H_0: \delta_0 = \delta_1 = \cdots = \delta_9 = 0$	298.38	9	20.972	Reject
Test for no inefficiencies. There is no influence of socio-economic variables on inefficiency for the men samples: $H_0: \delta_0 = \delta_1 = \cdots = \delta_9 = 0$	245.08	9	20.972	Reject
Test for no inefficiencies. There is no influence of socio-economic variables on inefficiency for the women samples: $H_0: \delta_0 = \delta_1 = \cdots = \delta_9 = 0$	56.02	9	20.972	Reject

Note: [a] The critical values are obtained from Kodde & Palm (1986)

Third, the appropriateness of a functional form for the data will be assessed by calculating the log-likelihood proportion between the Cobb–Douglas and Translog production functions. The estimated log-likelihood ratio (LR) was 24.34; the crucial value for 20 degrees of freedom at a 1% significance level was 29.927 (Table 2). Thus, the null hypothesis asserts that the Cobb–Douglas model is the most appropriate. This conclusion suggests that the Cobb–Douglas functional form more accurately describes the data than the translog model. The Cobb–Douglas functional format is utilized to evaluate the technical efficiency of rice farming households in the study area. Abate et al. (2019) & Owusu et al. (2018) concluded that the Cobb–Douglas functional form is superior to the translog model for evaluating the technological efficiency of agricultural families. Iliyasu et al. (2016) and Khan et al. (2021) concluded that the translog model is better for assessing farm technical efficiency.

Fourth, testing technical inefficiency at the rice farmer level is independent of the socio-economic variables in the inefficiency model. The statistical LR values for the pooled men's and women's samples are 298.38, 245.08, and 56.02, respectively. All three statistical likelihood ratios result above the essential threshold of 20.972 at 9 degrees of freedom. The outcome indicates that the null hypothesis (H_0) asserting that the explanatory variables are simultaneously equal to zero is rejected at the 1% significance level. The results suggest that the socio-economic variables used in the model collectively elucidate the origins of efficiency disparities among the sampled farm managers.

Estimation of Production Function and Return to Scale

The stochastic frontier model findings for the aggregated sample demonstrate that four input factors in the production function—labour, fertilizer, land, and pesticides—positively and significantly affect rice production levels. Therefore, augmenting this input will substantially enhance rice output, as anticipated. For the pooled sample, a one per cent increase in workforce, fertilizer quantity, land area, and pesticide application would enhance rice production by 0.53%, 0.61%, 0.26%, and 0.19%, respectively (Table 3). The interpretation of input coefficients in the production function can also be applied to samples of male and female farmers. The findings demonstrate a substantial beneficial effect of labour and fertilizer on rice production for both male and female farmers, suggesting that augmenting labour and fertilizer quantities generally enhances rice production levels for both genders. The coefficients for pesticides and land exhibit a negative yet statistically negligible effect on rice output among female farmers. This finding contradicts Owusu et al. (2018), which identified a statistically favourable correlation between pesticides, land, and rice productivity among women farmers in Ghana. Pesticides and land positively correlate substantially with rice productivity among male farmers. These results align with prior empirical research (Owusu et al., 2018). Moreover, we determined that seeds did not influence rice output for any farm manager.

The derived analytical coefficients of returns to scale for the pooled sample and male farmers are 1.5903% and 1.0672%, respectively, indicating increasing returns to scale (IRS). The IRS suggests that augmenting the proportion of all inputs will proportionately enhance total rice production by over 1%. The coefficient of returns to scale for female farmers is 0.2303%, signifying diminishing returns to scale (DRS). DRS indicates that augmenting the proportion of all inputs will result in a proportional increase in overall rice yield of less than 1%. This analysis aligns with Simatupang & Nababan (2023), who assert that the two rice farming systems exhibit rising returns to scale. Nonetheless, our research diverges from the findings of Hakim et al. (2021), who determined that rice cultivation in Indonesia is experiencing diminishing returns to scale. A study conducted by Owusu et al. (2018) in Ghana indicated that rice farms managed by men experienced falling returns to scale, whilst those overseen by women exhibited increasing returns.

Table 3. Stochastic Production Frontier for Rice Farmers

Variable	Parameter	Men	Women	Pooled
Constant	β_0	7.7928***	7.4527***	7.7824***
Lnlabour	β_1	0.0538***	0.1072***	0.5290***
Lnfertiliser	β_2	0.5329***	0.1231***	0.6092***
Lnland	β_3	0.2782***	-0.6681	0.2632***
Lnseed	β_4	0.3089	-0.2363	0.2065
Lnpesticide	β_5	0.2023**	-0.6122	0.1889***
Sigma squared	σ^2	0.1795***	0.7320***	0.1689***
RTS		IRS	DRS	IRS
Observation	N	340	60	400

Note:***,** denotes significant levels at 1% and 5%, respectively

More than 70% of women in the study sample did not join farmer groups, which has implications for female farm managers who do not get information exchange, do not get cheap inputs, and do not receive training. Possible causes of land, seed, and pesticide inputs do not significantly affect rice production managed by female farm managers because all women in the study sample did not join farmer groups. Another impact of female farm managers who do not join farmer groups is that their farming skills can be higher, and the production scale is in DRS conditions. This study recommends that policymakers develop programs to improve women's skills so that all inputs contribute to increasing rice production.

Distribution of Efficiency Scores

Table 4 displays the mean technical efficiency scores for rice growing. The mean technical efficiency score for the aggregated sample is 0.817. This score indicates that farm managers are functioning optimally if they can enhance rice production by 18.33% by utilizing current resources and technological capabilities. The typical rice farmer decreases his input by 18.33% to get his present output. According to the gender of farm managers, male farmers exhibit greater efficiency than female farmers, with statistical significance at the 5% level. Optimal efficiency can be attained if male and female farmers decrease inputs by 19.2% and 23.9%, respectively. This study aligns with the findings of Simatupang & Nababan (2023) and Sumaryanto et al. (2023), which reported a technical efficiency score of approximately 0.8 for rice growing in Indonesia. Our analysis aligns with rice farming efficiency research in Africa, which indicates that male farm managers exhibit greater efficiency than female managers (Addison et al., 2016; Owusu et al., 2018). Research by Kinkingninhoun-Mêdagbé et al. (2010) revealed no disparity in technical efficiency between male and female rice growers in Benin.

Figure 1 illustrates the frequency distribution of efficiency scores derived from operational farm managers. The frequency distribution of TE differs among farmers, ranging from 0.43 to 0.99. The majority of families exhibit elevated technical efficiency. Consequently, the distribution of TE scores has a rightward skew. Approximately 53% of the sampled farmers possess a TE score of 80% or higher, indicating that both male and female farmers and the aggregated sample still have the potential to enhance rice output by 20%.

Table 4. Technical Efficiency Scores by Gender and Pooled Sample

Variable	Mean			t-Ratio	Kruskal-Wallis rank sum test
	Men	Women	Pooled		
Score technical efficiency	0.808	0.761	0.817	2.0622**	5.938**

Note:** denotes significant levels at 5%

Conversely, there exists a cohort of sample farmers whose efficiency levels require enhancement (below 80%). The frequency distribution of the efficiency indicator indicates significant variability in technical efficiency across rice growers. Consequently, technical inefficiencies can be eradicated by adopting technically proficient rice farming procedures in Deli Serdang Regency. Our results correspond with Sumaryanto et al. (2023), who discovered that most rice farmers in Indonesia achieved technical efficiency levels of over 80%. Hakim et al. (2021) found that most rice farmers in East Java exhibited technical efficiency scores under 40%.

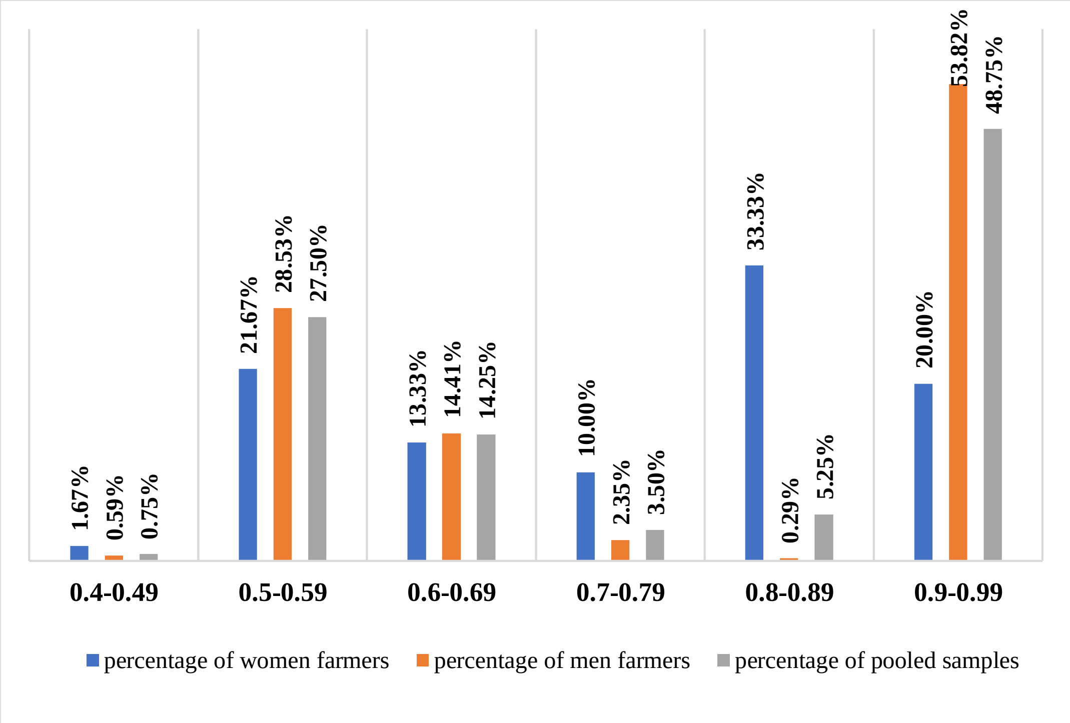

Figure 1.
Frequency Distribution of Rice Farming Technical Efficiency Scores.

Determining Factors of Technical Inefficiency of Rice Producers

The sigma-squared values for the rice production frontier for the pooled sample, male and female farmers, are 0.1689, 0.1795, and 0.7320, respectively, indicating that they are highly dissimilar from zero at a 1% significance level. The substantial value of sigma-squared reflects the adequacy of the proposed assumption on the distribution of composite error terms (Abate et al., 2019). The calculated gamma values for the pooled sample, male and female farmers, are 0.6138, 0.6369, and 0.9999, respectively. All three gamma values are statistically significant at the 1% level. A gamma value of 0.6138 signifies that 61.38% of the overall variation in farm rice yield is attributable to technical inefficiency.

This study identified three variables that significantly affect the technical inefficiency of male rice farmers, two variables that significantly affect the technical inefficiency of female rice farmers, and four variables that significantly affect the technical inefficiency of the combined sample of rice farmers. The employed significance levels are 1%, 5%, and 10%. All pertinent factors exhibit an inverse correlation with technical inefficiency. This outcome indicates that these variables favourably influence or enhance technical efficiency.

The gender of farmers is adversely and strongly correlated with the technical inefficiency of rice farmers at the 10% level. This association suggests that the male leader of the household enhances technological efficiency. This outcome is attributable to the patriarchal framework prevalent in Indonesian society. This structure enables men to make significant household decisions (including social, economic, and political) while their partners merely comply (Harahap, 2022). The significant authority held by male heads of households allows them ample time to engage in external pursuits, especially agricultural endeavours. The extensive investment of time in agricultural endeavours enables male farmers to enhance the use of land, seeds, pesticides, and labour to augment rice yield. Conversely, women assume the role of heads of families due to divorce or the death of their partners. Female heads of households possess lesser educational attainment and are older than their male counterparts, as indicated in Table 1. These qualities will likely prevent women heads of households from optimizing inputs to enhance rice output. A potential cause of diminished rice output in women-led families is the allocation of time between agricultural tasks and domestic responsibilities, including cooking and childcare. This rationale indicates that male heads of households are more inclined to enhance the efficiency of rice cultivation than their female counterparts. This outcome aligns with prior research (Houngue & Nonvide, 2020; Mariko et al., 2019), indicating that the producer's gender adversely affects rice farming efficiency.

The frequency of extension is of statistical significance at 1% and negatively impacts technical inefficiency in rice production. The results demonstrate that rice farmers who consistently utilize extension services display higher technical efficiency than those who infrequently or never engage in such activities. Agricultural extension services enhance the capabilities of farming households by facilitating the adoption of technology that boosts productivity and labour efficiency, broadens market access, and improves the technical efficiency of rice cultivation. This conclusion is corroborated by prior research (Owusu et al., 2018; Konja et al., 2019).

Table 5. Maximum Likelihood Estimates of Factors Affecting Technical Efficiency

Variable	Parameter	Men	Women	Pooled
Constant	δ_0	0.4238***	0.6169***	0.4971***
Socioeconomic characteristics				
Age of household head	δ_1	0.2353	-0.9881	0.1712
Household size	δ_2	0.4324	0.1018	0.3541
Formal education	δ_3	0.1551	0.1331	0.1076
Extension frequency	δ_4	0.6009	-0.3933	-0.7453***
Experience in FBO	δ_5	-0.6421***	0.2708	-0.2426
Access to irrigation	δ_6	-0.1315***	-0.4279***	-0.1253***
Farming experience	δ_7	-0.3185***	-0.2029**	-0.2607**
Access to credit	δ_8	0.2266	0.4882	0.3211
Gender	δ_9			-0.5912*

Variable	Parameter	Men	Women	Pooled
Diagnostic statistic				
Sigma squared	σ^2	0.1795***	0.7320***	0.1689***
Gamma	γ	0.6369***	0.9999***	0.6138***
Log-likelihood	LL	291.1558	70.7503	351.1073
LR test	$\sigma_u = 0$	245.0871***	56.0224***	298.3773***
Observation	N	340	60	400

***,**,* denotes significant levels at 1%, 5%, and 10%, respectively

The involvement of male rice producers in farmer-based organizations (FBO) is statistically significant at 1% and adversely affects the technical inefficiency of rice cultivation. Specifically, one additional year of experience for male farmers in FBO correlates with a 0.64% enhancement in the technical efficiency of rice cultivation. FBO members benefit from savings on input acquisitions, training in input utilization, and access to specific markets, leading to enhanced efficiencies in their rice farming practices. This finding aligns with Ojo & Baiyegunhi (2020), who determined that FBO participation substantially diminished the inefficiency of rice farmers in Nigeria.

Access to irrigation significantly negatively impacts the inefficiency of rice growing across all three scenarios. Adequate irrigation of rice paddies promotes optimal rice growth and enhances the technical efficiency of rice cultivation. Consequently, irrigated rice fields exhibit greater efficiency than non-irrigated ones. This finding aligns with Hakim et al., (2021), who discovered that access to irrigation enhanced the technical efficiency of rice growing in East Java.

Farming experience markedly detrimentally affects rice farming inefficiency across all three models. Experienced rice farmers will possess superior knowledge of efficient resource allocation, technology implementation, and market conditions, enabling them to operate a more effective and lucrative enterprise. Experienced rice farmers are likely to be more efficient than their inexperienced counterparts. This finding aligns with John-Muoh et al. (2020), who indicated that seasoned farmers can enhance the technical efficiency of rice cultivation in Ghana.

CONCLUSION AND SUGGESTION

Conclusion

This study aims to analyze the efficiency disparity related to the gender of rice farmers and evaluate the determinants affecting the technical inefficiency of rice cultivation in Deli Serdang Regency, North Sumatra. A stochastic frontier analysis was conducted to assess technical efficiency, while the t-ratio and Kruskal-Wallis tests were utilized to evaluate variations in efficiency between the two farm managers. This investigation yields several conclusions. Initially, male rice farmers inadequately utilized labor, fertilizer, land, and pesticides, whereas female rice producers insufficiently employed labor and fertilizer. The technical efficiency of rice growers is assessed at 81.3%, with male producers exhibiting more efficiency than their female counterparts. Male rice producers can efficiently optimize labor, fertilizer, land, and pesticides. Information exchange, training, input price discounts when joining farmer groups (FBO), irrigation access, and increased farming experience are essential in supporting them in optimizing input used to achieve efficiency increases. Female producers can be efficient when they can optimize labor and fertilizer. Good irrigation access and increased farming experience can help female producers optimize inputs to achieve efficiency increases. Specifically for all samples, a high frequency of extension services can support rice producers in optimizing input use and achieving efficiency increases.

Suggestion

This study suggests that policy makers make policies that increase the efficiency of rice farming managed by female farm managers. Urgent policies are extension and training programs that target increasing the knowledge and skills of female farm managers. Extension and training programs are recommended related to technical culture (e.g., fertilizer dosage, control of plant pests, planting, etc.), information on credit access, and conducting farm bookkeeping (e.g., recording production costs and farm income). Extension and training programs can also be provided to spouses of male rice managers because they play a significant role in rice farming in the research area. Since women spend much time on household chores and caring for children, local governments can implement extension and training programs concurrent with routine health programs at integrated service posts (Posyandu) and family welfare programs (PKK). Another important policy is the provision of cheap inputs and access to inputs for female farm managers. Reducing gender gaps by improving the knowledge and skills of female farm managers can contribute to the sustainability of rice farming in Deli Serdang Regency.

REFERENCES

Abate, T. M., Dessie, A. B., & Mekie, T. M. (2019). Technical Efficiency Of Smallholder Farmers In Red Pepper Production In North Gondar Zone Amhara Regional State, Ethiopia. *Journal Of Economic Structures*, 8(1), 1–18. doi: 10.1186/S40008-019-0150-6/TABLES/4

Addison, M., Ohene, Y. K., & Fredua, A. E. (2016). Gender Role, Input Use And Technical Efficiency Among Rice Farmers At Ahafo Ano North District In Ashanti Region Of Ghana. *Journal Of Food Security*, 4(2), 27–35. doi: 10.12691/JFS-4-2-1

Alem, H., Lien, G., & Hardaker, J. B. (2018). Economic Performance And Efficiency Determinants Of Crop-Producing Farms In Norway. *International Journal Of Productivity And Performance Management*, 67(9), 1418–1434. doi: 10.1108/IJPPM-01-2018-0026/FULL/PDF

Alhassan, S. (2012). Technical Efficiency In Smallholder Paddy Farms In Ghana: An Analysis Based On Different Farming Systems And Gender. *Journal Of Economics And Sustainable Development*, 3(5), 91–105. Retrieved from https://www.iiste.org/Journals/index.php/JEDS/article/view/1590

Ali, D., et al. (2016). Investigating The Gender Gap In Agricultural Productivity: Evidence From Uganda. *World Development*, 87(2), 152–170. doi: 10.1016/J.WORLDDEV.2016.06.006

Ali, I., et al. (2019). Technical Efficiency Of Hybrid Maize Growers: A Stochastic Frontier Model Approach. *Journal Of Integrative Agriculture*, 18(10), 2408–2421. doi: 10.1016/S2095-3119(19)62743-7

Angin, C. P., Pakpahan, H. T., & Nababan, M. B. P. (2024). Technical Efficiency Analysis Of Rice Farming In Deli Serdang Regency: A Data Envelopment Analysis (DEA) Approach. *Jurnal Sosial Ekonomi Pertanian*, 16(3), 239-252. doi: 10.19184/jsep.v16i3.43016

Battese, G. E., & Coelli, T. J. (1992). Frontier Production Functions, Technical Efficiency And Panel Data: With Application To Paddy Farmers In India. *Journal Of Productivity Analysis*, *3*(1–2), 153–169. doi: 10.1007/BF00158774/METRICS

Battese, G. E. (1992). Frontier Production Functions And Technical Efficiency: A Survey Of Empirical Applications In Agricultural Economics. *Agricultural Economics*, 7(3–4), 185–208. doi: 10.1016/0169-5150(92)90049-5

Battese, G. E., & Broca, S. S. (1997). Functional Forms Of Stochastic Frontier Production Functions And Models For Technical Inefficiency Effects: A Comparative Study For Wheat Farmers In Pakistan. *Journal Of Productivity Analysis*, 8(4), 395–414. doi: 10.1023/A:1007736025686/METRICS

Bibi, Z., Khan, D., & Haq, I. (2021). Technical And Environmental Efficiency Of Agriculture Sector In South Asia: A Stochastic Frontier Analysis

Approach. *Environment, Development And Sustainability*, 23(6), 9260–9279. doi: 10.1007/S10668-020-01023-2/METRICS

BPS. (2021). *Statistik Indonesia*. Jakarta: Indonesia

BPS North Sumatra. (2022). Rice Production by Regency/City in North Sumatra Province. Retrieved from https://sumut.bps.go.id/statictable/2023/03/13/2989/produksi-padi1dan-beras-menurut-kabupaten-kota-di-provinsi-sumatera-utara-2021-dan-2022.html

BPS-Statistics. (2018). *Results Of Inter-Censal Agriculture Survey A2 Series*. Jakarta, Indonesia

Chiang, Y. H., & Cheng, E. W. L. (2014). Estimating Contractors' Efficiency With Panel Data: Comparison Of The Data Envelopment Analysis, Cobb-Douglas And Translog Production Function Methods. *Construction Innovation*, 14(3), 274–291. doi: 10.1108/CI-07-2013-0033/FULL/XML

Coelli, T. J., et al. (2005). An Introduction To Efficiency And Productivity Analysis. *An Introduction To Efficiency And Productivity Analysis*, 1–349. doi: 10.1007/B136381/COVER

De, B. A., et al. (2013). The Feminisation Of Agriculture With Chinese Characteristics. *The Journal Of Development Studies*, 49(5), 689–704. doi: 10.1080/00220388.2012.724168

Farrell, M. J. (1957). The Measurement Of Productive Efficiency. *Journal Of The Royal Statistical Society. Series A (General)*, 120(3), 253-290. https://doi.org/10.2307/2343100

Giokas, D. (1991). Bank Branch Operating Efficiency: A Comparative Application Of DEA And The Loglinear Model. *Omega*, 19(6), 549–557. doi: 10.1016/0305-0483(91)90005-E

Greene, W. H. (1999). Frontier Production Functions. In M. H. Pesaran & P. Schmidt (Eds.), *Handbook Of Applied Econometrics Volume 2: Microeconomics*. Oxford: Blackwell Publishing. doi: 10.1111/b.9780631216339.1999.00004.x

Hakim, R., Haryanto, T., & Sari, D. W. (2021). Technical Efficiency Among Agricultural Households And Determinants Of Food Security In East Java, Indonesia. *Scientific Reports*, 11(1), 1–9. doi: 10.1038/s41598-021-83670-7

Harahap, N. (2022). Communication Interaction Of Double Burden Batak Women In Patriarkhi Family In Gender Analysis In North Sumatra.

International Journal Of Humanities Education And Social Sciences, 2(2), 549–557. doi: 10.55227/IJHESS.V2I2.266

Houngue, V., & Nonvide, G. M. A. (2020). Estimation And Determinants Of Efficiency Among Rice Farmers In Benin. *Cogent Food & Agriculture*, 6(1), 1-21. doi: 10.1080/23311932.2020.1819004

Iliyasu, A., et al. (2016). Technical Efficiency Of Cage Fish Farming In Peninsular Malaysia: A Stochastic Frontier Production Approach. *Aquaculture Research*, 47(1), 101–113. doi: 10.1111/ARE.12474

John M. I. S., Kwame, R. W., & Yangari, O. (2020). Analysis Of Gender Differentials In Technical Efficiency Of Smallholder Rice Farmers In Ashanti Region Of Ghana. *African Journal Of Gender And Women Studies*, 5(1), 1-9. Retrieved from https://www.proquest.com/openview/4080703106ee7e54b074c2552515fd01/1?pq-origsite=gscholar&cbl=6515897

Khan, M. A., et al. (2021). Production Risk, Technical Efficiency, And Input Use Nexus: Lessons From Bangladesh Aquaculture. *Journal Of The World Aquaculture Society*, *52*(1), 57–72. doi: 10.1111/JWAS.12767

Kilic, T., Palacios, L. A., & Goldstein, M. (2015). Caught In A Productivity Trap: A Distributional Perspective On Gender Differences In Malawian Agriculture. *World Development*, 70(1), 416–463. doi: 10.1016/J.WORLDDEV.2014.06.017

Kinkingninhoun, M. F. M., et al. (2010). Gender Discrimination And Its Impact On Income, Productivity, And Technical Efficiency: Evidence From Benin. *Agriculture And Human Values*, 27(1), 57–69. doi: 10.1007/S10460-008-9170-9/METRICS

Kodde, D. A., & Palm, F. C. (1986). Wald Criteria For Jointly Testing Equality And Inequality Restrictions. *Econometrica*, 54(5), 1243-1248. doi: 10.2307/1912331

Mango, N., et al. (2015). A Stochastic Frontier Analysis Of Technical Efficiency In Smallholder Maize Production In Zimbabwe: The Post-Fast-Track Land Reform Outlook. *Cogent Economics & Finance*, 3(1), 1-20. doi: 10.1080/23322039.2015.1117189

Mariko, K., et al. (2019). Stochastic Meta Frontier Analysis Of Smallholder Rice Farmers' Technical Efficiency. *Journal Of Agricultural Science*, 11(8), 31–44. doi: 10.5539/JAS.V11N8P31

Nadra, U. (2015). Dimensi Gender Pada Pertanian Padi Di Kabupaten Toba Samosir Provinsi Sumatera Utara. *Jurnal Agribisnis Dan Sosial Ekonomi Pertanian (JASEP)*, 1(2), 49–57. doi: 10.54895/JSP.V1I2.373

OECD. (2021). *Gender And The Environment: Building Evidence And Policies To Achieve The SDGs*. Paris: OECD Publishing. doi: 10.1787/3d32ca39-en

Ojo, T. O., & Baiyegunhi, L. J. S. (2020). Impact Of Climate Change Adaptation Strategies On Rice Productivity In South-West, Nigeria: An Endogeneity Corrected Stochastic Frontier Model. *Science Of The Total Environment*, 745(1), 1-9. doi: 10.1016/J.SCITOTENV.2020.141151

Owusu, V., Donkor, E., & Owusu, S. E. (2018). Accounting For The Gender Technology Gap Amongst Smallholder Rice Farmers In Northern Ghana. *Journal Of Agricultural Economics*, 69(2), 439–457. doi: 10.1111/1477-9552.12236

Oyakhilomen, O., et al. (2016). Technical Efficiency Of Catfish Farming In Alimosho Local Government Area Of Lagos State, Nigeria: A Gender Perspective. *Agricultura Tropica Et Subtropica*, 49(1–4), 45–49. doi: 10.1515/ATS-2016-0006

Qanti, S. R., Peralta, A., & Zeng, D. (2022). Social Norms And Perceptions Drive Women's Participation In Agricultural Decisions In West Java, Indonesia. *Agriculture And Human Values*, 39(2), 645–662. doi: 10.1007/S10460-021-10277-Z/TABLES/3

Quisumbing, A. R., & Doss, C. R. (2021). Gender In Agriculture And Food Systems. *Handbook Of Agricultural Economics*, 5(1), 4481–4549. doi: 10.1016/BS.HESAGR.2021.10.009

Raoul, F. D. C., et al. (2023). Are Young Maize And Rice Farmers' Profit Efficient? A Gender Differential Analysis. *Cogent Economics & Finance*, 11(2), 1-18. doi: 10.1080/23322039.2023.2236887

Ririn, H., & Harahap, R. H. (2024). Realizing Food Security From The Role Of Women In The Family In Kolam Village Deli Serdang Regency. *Journal Of Peasants' Rights*, 3(1), 52–58. doi: 10.32734/JPR.V3I1.16095

Simatupang, J. T., & Nababan, M. B. P. (2023). Technical Efficiency Of Irrigated And Rain-Fed Rice Farms In North Sumatra, Indonesia. *International Journal Of Multidisciplinary Approach Research And Science*, 1(03), 461–480. doi: 10.59653/IJMARS.V1I03.233

Sumaryanto, S. , Sri Hery Susilowati, S. Saptana, Bambang Sayaka, Erma Suryani, Adang Agustian, A. Ashari, Helena Juliani Purba. (2023). Technical Efficiency Changes Of Rice Farming In The Favorable Irrigated Areas Of Indonesia. *Open Agriculture*, 8(1), 20220207. doi: 10.1515/OPAG-2022-0207

Tasila K, D., Mabe, F. N., & Alhassan, H. (2019). Technical And Resource-Use-Efficiency Among Smallholder Rice Farmers In Northern Ghana. *Cogent Food & Agriculture*, 5(1), 1-15. doi: 10.1080/23311932.2019.1651473

USDA. (2022). *Vietnam: Grain and Feed Update*. Hanoi. Retrieved from https://www.fas.usda.gov/data/vietnam-grain-and-feed-update-20

Wibowo, R. P., Raihan, A., Sumono, & Gunawan, D. (2019). Comparative Analysis Of Technical Efficiency Between Organic And Non-Organic Rice Farming In North Sumatera Indonesia. *IOP Conference Series: Materials Science and Engineering*, 648(1), 1–8. doi: 10.1088/1757-899X/648/1/012038

Wicaksono, M., Mahmudah, & Wahyudin. (2023). Penerapan Fungsi Kelompok Tani Dalam Produktivitas Usahatani Padi Sawah Di Kecamatan Perbaungan Kabupaten Serdang Bedagai Provinsi Sumatera Utara. *Jurnal Pertanian Terpadu Berkelanjutan (JPTB)*, 1(2), 82–93. Retrieved from https://journal.hdgi.org/index.php/jptb/article/view/132