THE IMPACT OF THE IRRIGATION DEVELOPMENT PROGRAM ON RICE FARMING TECHNICAL EFFICIENCY: A CASE STUDY IN WEST NUSA TENGGARA PROVINCE, INDONESIA

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ABSTRACT

The Integrated Participatory Irrigation Development and Management Program (IPDMIP) was implemented to achieve irrigation system development, supporting rice self-sufficiency in Indonesia. This study sought to analyze the technical efficiency of rice farming in West Nusa Tenggara Province and its determinant factors using data from 240 rice farmers, namely 120 farmers who participated in the program and 120 non-program farmers. A series of field surveys were conducted from October to December 2022. The analysis technique in this study is Stochastic Frontier (SFA) with the Cobb-Douglas production function model. The average levels of technical efficiency for program and non-program farmers are 0.904 and 0.741, respectively. Factors that significantly affect production of the program farmers are land area, seeds, urea fertilizer, and NPK fertilizer. Meanwhile in the case of non-program farmers, land area, seeds, NPK fertilizer, and organic fertilizer are the determinant factors. The significant factors influencing program farmers' inefficiency are formal education, farming experience, distance from house to farm, and family responsibilities. Fertilizer subsidy policies should be improved because program and non-program farmers do not receive the subsidized fertilizer fully. In addition, distribution of the subsidized fertilizers should be closer to the farmers' land areas.

Key words: stochastic frontier analysis, Cobb-Douglass, fertilizer subsidy

INTRODUCTION

Increasing food production has become a government priority in response to Indonesia's growing population. The surge in production depends on the success achieved through increased productivity and cultivated area. However, expanding new planting areas (extensification) has become increasingly challenging due to the costs associated with developing new paddy fields and establishing or rehabilitating expensive irrigation networks (Kusnadi et al. 2011). Rice, as stated by FAO, holds the distinction of being the most widely cultivated crop worldwide, serving as a staple food for over half of the global population. Moreover, rice cultivation plays a vital role in generating income for millions of households globally (Atamja et al. 2019). Extensive research on efficiency in food crop commodity farms has been conducted, indicating production inefficiency as a limitation to agricultural productivity. The sources of inefficiency are diverse, emphasizing the need to enhance the efficiency of inputs use among farmers. A comprehensive understanding of input allocation, risk, efficiency, and the socioeconomic characteristics of farmers affecting efficiency can assist policymakers in designing effective agricultural policies and programs to boost agricultural productiveness (Msuya and Ashimogo 2013).

The value of technical efficiency reported by previous researchers exhibit an average technical efficiency below 100 percent. It implies untapped potential to enhance production along the frontier isoquant curve by employing minimal input at a specific technological level. Conversely, there remains a significant opportunity to augment productivity and achieve greater efficiency using the same production inputs and technology. In that case, it becomes imperative to assess and mitigate the causes of technical inefficiency. Therefore, evaluating and addressing the factors contributing to technical inefficiency is paramount. Technical efficiency is effective when a farming business attains the maximum output from specific inputs (Farrel 1975). Farmers are considered technically efficient if they operate at the production limit level but cannot reach the maximum level due to internal and external factors impeding them from reaching the anticipated limit (Battese and Coelli 1995). It is posited that an efficient production function can be estimated through available methods, with frontier production in this context, describing the maximum output achievable at each level of input utilization (Coelli et al. 1998).

Several factors that cause farmer inefficiency originate from the farmer himself, including age, formal education, farming experience, distance of land from the farmer's house, frequency of attending counseling, and number of family members. Age influences the level of technical inefficiency, since farmer age is related to labor capacity and productivity. Age has a real and positive effect on technical inefficiency. The older the farmer, tends to increase his technical inefficiency (Kusnadi et al. 2011; Mor and Sharma 2011). The higher formal education tends to reduce technical inefficiencies, indicating that the farmers' education level will determine their ability to apply existing technology (Khan et al. 2010). In addition, education has a positive influence on technical efficiency (Fauzan 2020). Extension plays a vital role in providing information to the farmers in managing farming so that they can increase productivity. Farmers who take part in extension services have the opportunity to reduce inefficiencies (Jimjel et al. 2014). However, other research has found that the frequency of extension increases technical inefficiency (Girei et al. 2016).

Currently, the Indonesian Government is introducing the Integrated Participatory Irrigation Development and Management Program (IPDMIP), which designed to support efforts to overcome various obstacles, increase agricultural productivity, reduce poverty in rural areas, promote gender equality, and improve nutrition. On the other hand, this program also contributes in increasing the value of sustainable irrigation agriculture to provide food security and sources of livelihood in rural areas. The output of the IPDMIP program includes strengthening policy and institutional frameworks for irrigated agriculture, improving irrigation system management, improving irrigation system infrastructure, and increasing irrigated agricultural income. Increased income and production will be realized through increased rice productivity and high-economic-value crops. The target of this program is the farmers at the centers of food production with irrigation system (Kementan 2018).

Farmers participating in this program are field school attendees who adhere to a curriculum provided by government agencies. This curriculum covers various aspects of agronomic management and technology utilization. Specifically, it includes technical rice cultivation employing the Jajar Legowo (JARWO)[1] planting pattern, understanding the characteristics of superior rice seed varieties, and the pre-selection of rice seeds. Additionally, participants learn about seedbeds, land preparation, pest and disease control for rice plants by observing the agro-climatological environment and balanced fertilization techniques based on nutrient conditions (N, P, K). They also observe soil conditions using compost from plant materials and household organic waste. The curriculum further encompasses the

[1] Jajar Legowo is a rice planting system in Indonesia which is basically done by adjusting the distance between seeds at the time of planting.

creation of solid organic fertilizer from livestock waste, animals, and plant compost. Participants are trained in the technical management of harvest and post-harvest activities and the analysis and management of farming. Marketing aspects and the farming value chain, understanding bookkeeping and farming administration, financial management in farming, and strengthening farmer group organizations are also covered. The participants gain insights into partnerships in farming. The field school activities are conducted in 12 meetings coincide with the growth period of the rice plants. These meetings occur weekly for 12 weeks, each comprising a separate session. In contrast, non-program farmers do not undergo this structured training. This research aims to analyze the level of technical efficiency and the factors that influence the technical inefficiency of program and non-program farmers' rice farming.

MATERIALS AND METHODS

Study area. This research was conducted in West Nusa Tenggara Province, particularly at two separate islands, namely Lombok Island and Sumbawa Island. The two locations are selected purposively considering that West Nusa Tenggara Province is one of the implementation area out of 16 provinces and 74 districts in Indonesia. Data was collected in 4 districts: East Lombok, Central Lombok, Dompu, and Bima. The data collection (survey) was carried out from October to December 2022.

Sample selection. The sample in this study are 240 respondents, which consist of 120 respondents who are participants of the program, and 120 respondents who are non-program farmers. Determination of the sample size is carried out based on the criteria of rice farmers who participate in the irrigation development program in the four selected districts. As a comparison, the non-program farmers are also selected purposively based on the criteria that they are not participating farmers at the same districts that implement the program. This criterion is intended to avoid differences in productivity caused by differences in agricultural land fertility levels.

Data analysis. This research uses a stochastic frontier production function to simultaneously analyze the efficiency level and factors that influence technical inefficiency. The concept of efficiency measurement consists of two: production frontier and average production function. The advantages of the production frontier are: ability to analyze the efficiency and technical inefficiency of a production process, and can analyze the internal and external factors that allegedly affect technical efficiency in production. Similarly, the factors that affect inefficiency can be determined and estimated simultaneously (Coelli et al. 1998). Therefore, technical efficiency of rice farming in this study was analyzed using Stochastic Frontier (SFA) with the production function model used, namely Cobb-Douglas. The Cobb-Douglas model is used to determine the stochastic frontier production function described by (Coelli et al. 1998):

$$ln\mathrm{Y_i} = \beta_0 + \beta_\mathrm{i}\ ln x_\mathrm{i} + v_\mathrm{i} - u_\mathrm{i} \quad (1)$$

where Y_i represents the output of the farmer i; x_i is the input use of the farmer i; β_i is the parameter to be estimated; v_i is a statistical disturbance; and u_i reflects the technical inefficiency. The measure of technical efficiency (TE) is the ratio of observed output to stochastic frontier output:

$$ET_i = \frac{Y_i}{Y_i^*} = \frac{exp(x_i\beta - u_i)}{exp(x_i\beta)} = exp(-u_i) \quad (2)$$

TE values range between zero and one. TE of rice production was measured by considering the output obtained per farmer as the dependent variable. The independent variable is the production input used by farmers in rice cultivation, so the formula is written as follows:

$$\ln Y = \beta_0 + \sum_{i=1}^{8} \beta_j\ lnX_{ij} + v_i - u_i \quad (3)$$

Where: Y = production (tons) by farmer i; X_1 = land area (ha) owned by farmer i; X_2 = seeds (kg) used by farmer i; X_3 = urea fertilizer (kg) used by farmer i; X_4 = NPK fertilizer (kg) used by farmer i; X_5 = organic fertilizer (kg) used by farmer i; X_6 = pesticide (liter) used by farmer i; X_7 = outside family labor (person-days worked) used by farmer i; X_8 = the amount of family labor (person-days worked) used by farmer i.

Technical inefficiency refers to the model developed by (Coelli et al. 2005). The technical inefficiency value is inversely proportional to the technical efficiency value. The error component or u_i in the production function describes technical inefficiency. The model equation for the effects of technical farming inefficiency is as follows:

$$u_i = \lambda_0 + \sum_{k=1}^{6} \lambda_k Z_{jk} \quad (4)$$

Where Z_1 = age (years); Z_2 = formal education (years); Z_3 = farming experience (years); Z_4 = distance from house to land (meters); Z_5 = extension (frequency); Z_6 = number of family dependents (people).

RESULTS AND DISCUSSION

Characteristics of farmer respondents. The average age of program and non-program farmers is 46.58 years and 49.09 years respectively (Table 1), meaning that the program and non-program farmers are under the category of productive age (BPS 2022), thus they are relatively easier to accept innovations and can produce efficiently. The formal education level of program and non-program farmers is 10.34 years and 10.32 years. Education is an important factor that plays a role in developing farmers' ways of thinking, behavior and decision making. Education increases farmers' capacity to receive and understand information as well as the ability to adapt to new technological innovations. Program and non-program agricultural farming experience are 28.25 years and 12.32 years respectively. The experience they have will influence the farmer's ability to manage their farming business. The area of land cultivated by program and non-program farmers is 0.59 hectares and 0.52 hectares, with production of 4.55 tons and 3.79 tons respectively.

The stochastic frontier estimation results describe the performance of program and non-program farmers at the existing technology level (Table 2). The coefficient on the frontier production function of rice farmers program in land, seeds, urea fertilizer, and NPK fertilizer programs is positive and significant at the 1 percent level. The frontier production elasticity values for the variables land, seeds, urea fertilizer, NPK fertilizer, organic fertilizer, pesticides, labor outside the family, and labor within the family are respectively 0.094, 0.208, 0.253, 0.437, -0.014, 0.007, 0.002 and -0.006. If land, seeds, urea fertilizer, NPK fertilizer, pesticides, and labor outside the family are added by one percent unit of input, then it can increase rice production by 0.094, 0.208, 0.252, 0.437, 0.007, and 0.002 percent, respectively. Organic fertilizer and family labor (labor from the family) are negatively related i.e., -0.014 and -0.006. Thus, if each of two inputs are increased by 1 percent, it could reduce production by -0.014 and -0.006 percent, respectively.

Table 1. General characteristics of farmer program and non-program rice farming in 2022 (N=120)

Items	Program		Non-Program	
	Mean	**SD**	**Mean**	**SD**
Age (years)	46.58	10.99	49.09	10.34
Educational attainment (years)	10.34	3.52	10.32	3.32
farming experience (years)	28.25	12.75	30.58	12.32
Members engage in agriculture (persons)	2.86	1.15	2.81	1.17
land area (ha)	0.59	0.37	0.52	0.33
Production (tons)	4.55	2.79	3.79	2.31

Source: Field survey, 2022

Table 2. Stochastic Frontier production function estimation results using the Maximum Likelihood Estimation (MLE) method.

Variable	Program		Non-Program	
	Coef.	t	Coef.	T
Stochastic frontier				
Intercept	- 2.384	-9.006	1.453	8.925
Land area (LA)	0.094***	2.471	0.849***	19.680
Seed (SD)	0.208***	3.431	0.071**	1.920
Urea fertilizer (UF)	0.253***	3.205	- 0.000	- 0.011
NPK fertilizer (NF)	0.437***	6.852	0.062***	3.757
Organic fertilizer (OF)	- 0.014	-0.536	- 0.001*	- 1.316
Pesticide (PS)	0.007	0.384	0.007	1.041
Labor outside the family (FL)	0.002	0.149	0.019	0.969
Family labor (NF)	- 0.006	-0.344	- 0.007	- 0.394
Log likelihood OLS	34.363		141.418	
Log likelihood MLE	119.536		152.839	

Source: Field survey, 2022
*Note: Significance levels: *** α = 0.01, ** α = 0.05, *α = 0.1*

Land area. Increasing land area can significantly increase rice production (Table 2), indicating that the land cultivated by farmers is still limited. Conditions in the research area show that 82.5 percent (99 people) and 75 percent (90 people) of program and non-program farmers are categorized as small farmers with arable land of less than 1 hectare. The addition of land area can increase rice production, especially for program farmers, because the cultivated land is in irrigation areas according to the targets of the IPDMIP program. However, in the reality is that farmers do not use all their land for rice crops alone but also for high-value commodity crops such as corn and soybeans. The estimation results of land variables having a positive and significant effect on production align with research results (Silitonga 2018; Sok et al. 2023; Lubis et al. 2021; Shi et al. 2021).

Seeds. The addition of seeds in the research area can increase production and significantly affect production. The average seed use of program and non-program farmers is 16.53 kg and 18.9 kg per hectare, respectively. In comparison, the recommended seed use (good quality seed) for program farmers is 15 kg per hectare with the JARWO planting system technology. The target of the IPDMIP program is to increase production by applying this technology. These figures indicate that both the program and non-program farmers have overused seeds than the recommended level. However, additional seeds can be justified since the farmers concern about the external factors that they can't control, such as pests. The estimation results for seed variables have a positive and significant effect on production in line with research conducted by Kazeem (2020), Thuzar and Broos (2019), Bidzakin et al. (2018).

Urea fertilizer. Urea fertilizer of the participating farmers has a genuinely positive and significant effect on production, implying that additional urea fertilizer can boost rice production. The average use of urea fertilizer by program and non-program farmers is 125.65 kg and 109.29 kg per hectare, respectively. The local government's recommended use of urea fertilizer is 225 kg per hectare, indicating that both program and non-program farmers still fall short in utilizing urea fertilizer, underscoring the need to maximize its use following recommendations to enhance production. The use of urea fertilizer is still below the recommended level due to insufficient availability of the subsidized fertilizer compared to the farmers' needs. Additionally, given their limited capital, if farmers resort to non-subsidized fertilizer, the cost becomes prohibitive. The supplementary use of urea fertilizer can elevate production, aligning with research conducted by (Subedi et al. 2020; Konja et al. 2019).

NPK fertilizer. NPK fertilizer has a positive relationship with the production. The average use of NPK fertilizer in the research locations of both program and non-program farmers is 152.97 kg and 118.92 kg per hectare, respectively, while the recommended usage for both program and non-program farmers is 300 kg per hectare. It implies that fertilizer use remains at 50 percent of the recommended level. Although only 6.6 percent of farmers adhere to the recommended use of NPK fertilizer, overall, its use has a positive and significant effect on the production of both program and non-program farmers. NPK fertilizer can enhance production, consistent with research conducted by (Hartono et al. 2022).

Pesticides. Pesticides has a positive but non-significant effect on rice production for both program and non-program farmers. This may occur because the impact of using pesticides lies in reducing weeds that compete with rice plants for soil nutrients. Consequently, the use of pesticides is likely to protect rice production from falling, although this marginal effect is not statistically significant. These findings align with the research of (Mariko et al. 2019; Obianefo et al. 2021).

Labor input. The workers outside the family can increase rice production, but have no significant effect on farmers participating in the program or non-program, revealing that using labor is not optimal. The average use of labor for program and non-program farmers is 31.09 HOK (total man-days during the planting season), while for non-program farmers it is 34.67 HOK. It is suspected that this is because more workers are used from within the family who have a lower level of technical skills than workers outside the family. The addition of workers can increase production. However, this result is not in line with research (Sularso and Sutanto 2020).

Technical efficiency of program and non-program farmers. The results of the technical efficiency analysis (Table 3) indicate that rice farming in West Nusa Tenggara Province has not yet attained the maximum level of technical efficiency (TE = 1.00). However, the technical efficiency values obtained were relatively high, averaging 0.904 for participating farmers in the program and 0.741 for non-program. A technical efficiency value of 0.90 for the program farmers signifies that the farming business has reached 90.4% of its production potential, whereas non-program farmers achieved only 74.1%. The technical efficiency level of program farmers surpasses that of non-program farmers because, in addition to cultivating land in irrigation areas per the IPDMIP program targets, farmers adopt recommended technologies from the irrigation development program, including the JARWO planting system, the utilization of superior seeds, the application of balanced fertilizers as recommended, the use of environmentally friendly pesticides, and proper harvest and post-harvest handling. Despite program farmers implementing technology in line with IPDMIP program recommendations, production has not yet reached its maximum potential.

Table 3. Distribution and average value of technical efficiency of rice farming in West Nusa Tenggara, 2022

Technical Efficiency	Program		Non-Program	
	Total	%	Total	%
0.51 – 0.60	0	0.00	20	16.67
0.61 – 0.70	0	0.00	25	20.83
0.71 – 0.80	7	5.83	35	29.17
0.81 – 0.90	53	4.17	40	33.33
0.91 – 1.00	60	50.00	0	0.00
Average	0.904		0.741	
Lowest	0.794		0.506	
Highest	0.999		0.899	

Source: Field survey (2022)
Notes: Estimation was conducted using FRONTIER 4.1
*Significant levels are shown as follows: *** α = 0.01, ** α = 0.05 and * α = 0.1*

A farming business is deemed efficient if its efficiency value exceeds 0.70 (Coelli et al. 2005). These findings suggest that rice farming in West Nusa Tenggara Province is technically efficient for both program and non-program farmers. The technical efficiency values in this research align with previous studies, demonstrating that technical efficiency in food crop farming, particularly rice, typically ranges from 70% to 92% (Okello et al. 2019; Subedi et al. 2020; Lubis et al. 2021; Melati and Mayninda 2020; Konja et al. 2019; Bidzakin et al. 2018; Mulyana et al. 2020; Jalilov et al. 2019; Ho and Shimada 2019; Thuzar and Broos 2019; Shi et al. 2021).

Technical inefficiency of program and non-program farmers. Table 4 illustrates the technical inefficiency of both program and non-program rice farming. The model elucidates inefficiency by assigning a negative sign to a variable, signifying the positive influence of variables on increasing technical efficiency. Conversely, a positive sign denotes inefficiency. Noteworthy technical inefficiency factors for program farmers encompass formal education, farming experience, distance from residence to land, counseling frequency, and family dependents. Conversely, a significant technical inefficiency factor for non-program farmers is the frequency of extension services.

Table 4. Factors affecting rice farming inefficiency

Variable	Program		Non Program	
	Coef.	t	Coef.	t
Intercept	-5.078	-2.548	-0.038	-0.115
Age (AGE)	0.136	0.221	0.044	0.337
Formal Education (EDU)	0.270**	2.178	0.016	0.579
Farming experience (EXP)	0.453*	1.524	0.006	0.085
Distance from house to land (DST)	0.203***	2.358	- 0.003	-0.289
Frequency of Extension CSL)	-1.082***	-3.574	- 0.069***	-2.346
Family responsibility (FML)	0.777***	4.812	0.005	0.360
Sigma-squared (σ^2)	0.136***	6.298	0.009***	7.489
Gamma (γ)	0,984***	78.403	0.999***	32.397

Source: Field survey (2022)
Notes: Estimation was conducted using FRONTIER 4.1
*Significant levels are shown as follows: *** α 0.01, ** α 0.05 and *α 0.1*

Age. The age variable in both program and non-program rice farming exhibits a positive effect and bears no tangible impact on technical inefficiency. It implies that as farmers age increases, technical inefficiency tends to increase. Field conditions reveal that most program and non-program farmers are approaching the non-productive age, constituting 54.17 percent and 55.83 percent, respectively. As farmers age increase, their work capacity diminishes, with a reduced inclination to adopt innovations. Estimation results for the age variable corroborate a positive impact on technical inefficiency, aligning with prior research (Hakim et al. 2020).

Formal education. Formal education, for both program and non-program farmers positively affects technical inefficiency, albeit without tangible effect for non-program farmers. The positive effect implies that higher formal education levels intensify the technical inefficiency of rice farming. A higher level of formal education among farmers corresponds to heightened technical inefficiency. The condition in the field is that farmers with a high level of education allocate half their time to farming activities; in other words, farming becomes a side job, so farming management is less than optimal. The results of this research align with research conducted by (Kazeem 2020; Mulyana et al. 2020).

Farming experience. The farming experience variable between has a positive effect on technical efficiency, but the non-program does not have a real influence. Farming experience positively affects technical inefficiency, meaning that farming experience can increase technical inefficiency. Conditions in the research area show that most farmers, both program and non-program participants, have more than 30 years of farming experience. It means that whether or not a farming business is efficient is not affected by the length of farming experience, but rather by the level of technical skills and managerial abilities of farmers in managing their farming business. This study's results align with those obtained (Subedi et al. 2020).

Distance from house to farm. The distance between farmers' house and agricultural land positively affects technical inefficiency, meaning that longer distance of farmers' house from the farm will increase the technical inefficiency. The data indicate that the average distance from house to farm is 979 meters. The further the distance from the house to the farm, the longer the travel time, which can reduce working time and require more energy to get to the farm, making time and energy less efficient for work. Meanwhile, non-program farmers negatively influence the technical inefficiency, meaning that the distance from house to farm will reduce technical inefficiency. The distance between the house and the farm of the non-program farmers is 1,213 meters. The habits of non-program farmers better understand the distance from home to land so they bring enough supplies and do not need to go home for rest and eat lunch so that their time working and being on the farm is more effective. The results of estimating the distance from house to farm affect positively technical inefficiency, in contrast to research (Muslimin 2012).

Attendance in extension programs. The frequency of the farmers in attending the extension activities, for both program and non-program farmers, have a negative effect on technical inefficiency, indicating that the frequency with which farmers attend extension services will reduce the technical inefficiency of rice farming. Conditions in the field show that extension activities were carried out 12 times by program farmers with material ranging from soil nutrient analysis to farming analysis. The data show that 92 percent of the participating farmers mainly follow the extension activities according to the schedule. The more frequently farmers attend extension services, the more they master the material and can apply it in farming to reduce technical inefficiencies. The frequency of following extension services has a negative effect on technical inefficiency and is consistent with the findings of Cahyati and Hasan (2021).

Family responsibility. Number of farmer's dependents families has a positive and significant relationship with the technical inefficiency - for the program farmers, while for the non-program farmers it does not significant. The number of family dependents positively affects technical inefficiency, meaning that the larger the number of family dependents will increase the technical inefficiency of rice farming. The data show that the average family member is 3 people, and 88 percent of farmers use labor outside the family. The high or low level of technical inefficiency is not caused by the number of family members involved in farming. The greater the number of household members, the less efficient the farming business. This happens because not all family members are involved in farming. The estimation results for the variable number of family dependents positively affect technical inefficiency (Konja et al. 2019).

CONCLUSION

The average technical efficiency levels for both the program and non-program farmers are 0.904 and 0.741, respectively. Factors that significantly influence the rice production of the program farmers are land area, seeds, urea fertilizer, and NPK fertilizer; while for the non-program farmers are land area, seeds, NPK fertilizer, and organic fertilizer. For the program farmers, formal education, farming experience, distance from house to farm, and family responsibilities significantly affect farmers' rice production inefficiency; while farmers' age and frequency of attending extension activity variables do not significantly affect inefficiency. For the non-program farmers, the variables of age, education, farming experience, distance from the house to the farm and number of family dependents do not significantly affect technical inefficiency.

Fertilizer availability is still problematic to the farmers. The farmers apply less fertilizers (subsidized fertilizers) compared to the recommended levels, for both the program and non-program farmers. This occurs since most of the fertilizers are not sufficiently available in the local areas. Thus, fertilizer subsidy policies must be improved to ensure that the farmers receive sufficient and appropriate proportion of the fertilizers. In addition, locus of fertilizers distribution should also easily accessible to the farmers in order to reduce transportation costs.

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