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THE IMPACT OF IRRIGATION ON THE ALLOCATIVE AND ECONOMIC EFFICIENCIES ON RICE FARMING: A CASE STUDY IN WEST NUSA TENGGARA PROVINCE

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Abstract: The Integrated Participatory Development and Management Irrigation Program (IPDMIP) is an innovative approach to achieve a sustainable irrigation system. This effort is expected to support the achievement of rice self-sufficiency in accordance with the Indonesian Government's Nawacita program. The purpose of this study was to estimate the technical, allocative and economic efficiencies of rice farming in West Nusa Tenggara Province. Data were collected purposively from 240 samples, with 120 samples that followed the program, and 120 samples non-program. Estimation of allocative and economic efficiency using Stochastic Frontier (SFA) with Cobb-Douglas production function model. The results showed that the factors affecting program rice production were land area, seeds, urea fertilizer, and NPK fertilizer, while non-program were land area, seeds, NPK fertilizer, and organic fertilizer. The average achievement of technical, allocative, and economic efficiency of the rice farming program was 0.906; 0.839, and 0.761 while the non-program was 0.741; 0.794, and 0.892. To achieve the level of allocative and economic efficiency, farmers need to improve the achievement of technical efficiency.

Keywords: economic efficiency, irrigation, production factors, rice paddy

Abstrak: *Program Pengembangan dan Pengelolaan Irigasi Partisipatif Terpadu atau Integrated Participatory Development and Management Irrigation Program (IPDMIP) merupakan suatu pendekatan inovatif di bidang irigasi yang bertujuan untuk mencapai keberlanjutan sistem irigasi, Upaya ini diharapkan dapat mendukung tercapainya swasembada beras sesuai program Nawacita Pemerintah Indonesia. Tujuan makalah ini untuk mengestimasi efisiensi alokatif dan efisiensi ekonomi usahatani padi di Provinsi Nusa Tenggara Barat yang menerapkan program pengembangan irigasi dan non-program. Sampel sebanyak 240 sampel yaitu 120 sampel yang mengikuti program dan 120 sampel non-program. Sampel ditentukan secara sengaja (purposive). Estimasi efisiensi alokatif dan ekonomi menggunakan Stochastic Frontier (SFA) dengan model fungsi produksi Cobb-Douglas. Hasil penelitian menunjukkan bahwa Faktor-faktor yang mempengaruhi produksi padi program adalah luas lahan, benih, pupuk urea dan pupuk NPK sedangkan non program luas lahan, benih, pupuk NPK dan pupuk organik. Rata-rata capaian efsiensi teknis, alokatif, dan ekonomi usahatani padi program adalah sebesar 0,906;0,839 dan 0,761 sedangkan non program 0,741;0,794 dan 0,892. Untuk mencapai tingkat efisiensi alokatif dan ekonomi, petani perlu meningkatkan capaian efisiensi teknis.*

Kata kunci: *efisiensi ekonomi, faktor produksi, irigasi, padi*

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INTRODUCTION

The agricultural sector is still the mainstay of food fulfillment. Food security in Indonesia is still often associated with the level of food production, especially rice. If there are problems in the food sector, it will have a significant impact on the overall economy. As long as the problem of food security has not been solved in a sustainable manner, the development of the non-agricultural sector can be hampered (Anggraini et al. 2017).

Rice is a major food source and is consumed by more than 50 percent of the world's population (Rizwan et al. 2020). Rice is a very important staple food in many countries and is growing rapidly across continents (Dyna, 2006; Koirala et al. 2014). The increasing population, especially in big cities, has led to a high gap between demand and supply, especially of the staple food, rice (Okon et al. 2010) while rice production is in the hands of small farmers who have a narrow land area with low resources so that local production is largely insufficient to meet consumer needs (Kaddy et al. 2014).

Rice production in Indonesia in 2021 was 31.33 million tons while consumption was 30.77 million tons. Rice production in Indonesia is 88 percent or 27.57 million tons contributed by 12 provinces that are production centers. West Nusa Tenggara Province is a rice-producing center with a medium group category and can contribute 2.53 percent of the total rice production in Indonesia, which is 778,481 tons (Sehusman 2022). In farming activities, farmers act as managers, workers, and investors. The ability of farmers to combine various production inputs in such a way will affect the level of production produced. The results of previous studies show that the production factors that have a significant and most dominant effect are land area, seeds, and organic fertilizers (Aliyu and Shelleng 2020; Ari et al. 2021; Hidayah and Susanto, 2013). This indicates that differences in rice production still depend on the area of land cultivated, not due to differences in the management of better production factors. Management in the use of production factors can be described through the level of efficiency. Appropriate use of production inputs (allocative efficiency) and the achievement of technical efficiency are important in increasing production in farming. Technical efficiency describes the potential production that can be achieved at a certain level of input, and allocative efficiency describes the ability of farmers to use optimal inputs at minimum cost at certain price and technology levels (Farrel, 1957). The combination of technical efficiency and allocative efficiency results in economic efficiency.

Production efficiency consists of technical and allocative components. Technical efficiency (TE) is the ability of a business unit to be able to produce along the isokuan curve, to produce the optimal output possible with a certain combination of inputs and technology (Farrel, 1957). Allocative efficiency (AE) reflects the ability of a business unit to use inputs in optimal proportions, according to their respective prices and production technology. These two measures are then combined to measure total economic efficiency.

Research on the technical efficiency of rice farming under the SL-PTT program in Sukabumi District (Lasmini et al. 2016) showed that the average value of technical efficiency for all respondents was 0.83. The average value of technical efficiency of farmers participating in the SL-PTT rice program (0.84) was higher than the average value of the technical efficiency of non-participants of the SL-PTT rice program (0.82). The development of the SL-PTT program can be done by improving the method of delivering information on PTT technology to farmers.

Research on the economic efficiency of rice farming in Lampung province (Ari et al. 2021), shows that the variables of land area, seeds, fertilizers, and pesticides have a significant effect on rice production in Lampung. The average level of technical, economic, and allocative efficiency is 0.91; 0.80, and 0.88 respectively. Singh dan Chand (2011) in his research on the economic efficiency of rice farming in urban north India stated that the average technical, allocative, and economic efficiency of 69%, 66%, and 54% respectively. The value of technical efficiency is higher than the economic and allocative efficiency due to high input costs and the use of inputs that are not by recommended recommendations so that the use of inputs is not rational and recommended efficient and optimal use of inputs for sustainable rice farming.

Economic efficiency can be divided into two components, namely technical and allocative efficiency, which when combined will form economic efficiency (Meeusen and van den Broeck, 1977). The goal is to maximize profits by minimizing costs. In addition, productivity in agriculture is measured in terms of efficient use of inputs (Farrell, 1957). Low productivity is caused by inefficient use of input allocation (Adedoyin et al. 2016)

Previous research focused more on technical efficiency (Wijaya et al. 2022; Lema and Tessema, 2017; Asefa, 2011). This study determines allocative efficiency and economic efficiency. A farming business is said to be economically efficient if the commodities produced are technically and allocatively efficient. Technical efficiency considers the level of input use, external factors and technical inefficiency, while allocative efficiency is the ability of farmers to allocate minimum input use. The aim of this research is to determine economic efficiency and allocative efficiency in rice farming by farmers participating in the program and non-program.

METHODS

Research on the impact of irrigation development programs on allocative and economic efficiency in West Nusa Tenggara Province. Location selection was done purposively (purposive) This study uses primary data. In this study the sample used as many as 240 samples. The sample consists of 120 rice farms that follow the irrigation development program and 120 rice farms that do not follow the program. The sample was determined purposively in 4 districts that followed the irrigation development program.

The stochastic frontier production function is used to analyze the factors that affect rice production and the level of technical efficiency, as follows:

$$Y_i = \alpha LA^{\beta1}SD^{\beta2}UF^{\beta3}NF^{\beta4}OF^{\beta5}PS^{\beta6}FL^{\beta7}NL^{\beta8} \quad (1)$$

Coelli et al. (2005) explains that in the stochastic model ther error component error (ε) consists of two types, namely v_i and u_i, so that:

$$\varepsilon_i = v_i - u_i \quad (2)$$

The error component is related to external factors such as weather, pests, and diseases, and so on, including input variables that are not specified in the production function. Meanwhile, the error component related to internal factors that affect inefficiency.

Furthermore, to facilitate the analysis and estimation of coefficients, the production function is transformed into a multiple linear form with natural logarithm (ln) transformation as follows:

$$LnY_i = \beta_0 + \beta_1 LnLA + \beta_2 LnSD + \beta_3 LnUF + \beta_4 LnNF + \beta_5 LnOF + \beta_6 LnPS + \beta_7 LnFL + \beta_8 LnNL\ (v_i - u_i) \quad (3)$$

Where: (production (tonnes)); LA (land area (ha)); SD (seed (kg)); UF (urea fertilizer (kg)); NF (NPK fertilizer (kg)); OF (organic fertilizer (kg)); PS (pesticide (liters)); FL (outside family labor (hok)); NL (family labor (hok)); (intercept); (estimated coefficient); (error variable); (non-negative error variable caused by technical inefficiency).

The results of the production function estimation were then used to measure the technical efficiency of farming. The calculation method of technical efficiency refers to (Coelli et al. 2005) as follows:

$$ET_i = Y_i/Y_i^* = \exp(x_i\beta - u_i)/\exp(x_i\beta) = \exp(-u_i) \quad (4)$$

Where: ET (Technical efficiency ($0 \le ET \le 1$)); Y_i (actual production); Y_i^*(frontier production)

A farm is categorized as technically efficient if it has an ET value > 0.70 (Coelli et al. 2005). The effect of technical inefficiency refers to the model developed by (Coelli et al. 2005). Technical in-efficiency is described by the error component in the production function. The value of technical in efficiency is inversely proportional to the value of technical efficiency. The equation of the farming technical in-efficiency effect model is as follows:

$$TI_i = \delta_0 + \delta_1 AGE + \delta_2 EDU + \delta_3 EXP + \delta_4 DST + \delta_5 CSL + \delta_6\ FML \quad (5)$$

Where:TI_i (technical in-efficiency effect); δ_0(intercept); AGE (farmer age (years)); EDU (formal education (years)); EXP (farming experience (years)); DST (distance from home to farm (meters)); CSL (frequency of attending extension services (times)); FML (number of family dependents (people)); δ (parameter to be estimated); Wi (random error term which is assumed to be independent and normally truncated distribution with N (0,σ^2)).

Allocative efficiency and economic efficiency are analyzed with an input-side approach. The analysis of allocative efficiency and economic efficiency can be done by using a dual frontier cost function derived from a homogeneous production function (Debertin, 2006). The cost function uses the Cobb-Douglas production function as follows:

$$Y_i = \alpha LA^{\beta 1} SD^{\beta 2} UF^{\beta 3} NF^{\beta 4} OF^{\beta 5} PS^{\beta 6} FL^{\beta 7} NL^{\beta 8} \quad (6)$$

Where: Y_i (refers to production), LA (land area), SD (seed), UF (urea fertilizer), NF (NPK fertilizer), OF (organic fertilizer), PS (pesticides), FL (outside family labor), NL (total family labor), β_i (estimated coefficient).

With cost equation:

$$C = P_1LA + P_2SD + P_3UF + P_4NF + P_5OF + P_6PS + P_7FL + P_8NL \quad (7)$$

Where: C (refer to total cost), LA (land area), SD (seed), UF (urea fertilizer), NF (NPK fertilizer), OF (organic fertilizer), PS (pesticides), FL (outside family labor), NL (total family labor), P_i (input prices).

Economic efficiency is the ratio of the minimum total cost to the actual total cost, so economic efficiency can be obtained from:

$$EE = C^*/C \quad (8)$$

Economic efficiency is a combination of technical efficiency and allocative efficiency so that allocative efficiency can be calculated using the following equation:

$$EA = EE/ET \quad (9)$$

Where: C* (minimum total cost); C (actual total cost); EE (economic efficiency ($0 \le EE \le 1$)); EA (allocative efficiency ($0 \le EA \le 1$)); P_i (input price (land price, seed price, urea fertilizer, NPK fertilizer, organic fertilizer, pesticide, Family Labor)); X_i (number of inputs (land area, number of seeds, urea fertilizer, NPK fertilizer, organic fertilizer, pesticides, Family labor and non-Family Labor)); Y (rice production); α (coefficient); β_0 (exponentiated intercept)); β_i (coefficient of each input variable)

RESULTS

Factors Affecting Rice Production

The results of the estimation of the stochastic frontier production function of rice farming with the Maximum Likelihood Estimation (MLE) method are shown in Table 1. The sigma-squared value of 0.136 is significant at α of 1% indicating that the diversity of rice paddy production comes from in-efficiency effects and external effects have a real variation. The gamma value of 0.983 means that differences in technical efficiency cause 98.3% of the variation in rice production. Technical inefficiency and external factors such as the influence of pests and plant diseases, climate change, and errors in modeling only affect 1.7%. These results indicate that technical inefficiency factors have a real effect on variations in rice production that occur at the farm level. The production factors of land area, seeds, urea fertilizer, NPK fertilizer, pesticides, and non-family labor are positive, indicating that each additional input will increase production by the coefficient of each production factor. The negative sign of organic fertilizer means that its addition will decrease production. This condition occurs because the use of organic fertilizer does not directly have an impact on increasing production. Organic fertilizer with a negative sign means that its addition will actually reduce production. This condition occurs because the use of organic fertilizer does not directly have an impact on increasing production but has sustainable agricultural benefits. This is different from other production factors such as land, seeds and inorganic fertilizers which have a direct impact on increasing production, so a proportional allocation of input use is needed. The coefficient of the production factor of in-family labor is negative, indicating that the increase in the number of family members or in-family labor cannot increase production because family members are not involved in farming.

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Partial test results show that the production factors of land area, seeds, urea fertilizer and NPK fertilizer have a real effect on the production of rice farmers who follow the program. While non-program production factors that influence are land area, seeds, urea fertilizer and organic fertilizer. Land area is a very responsive variable because it has a large enough coefficient. This result is consistent with the results of research (Silitonga, 2018). which reported that land area input has a positive and significant effect on rice production. This implies that the addition of land area needs to be the government's concern if it wants to increase rice production for both program and non-program farmers. Seed input significantly affects rice paddy production with a positive frontier production elasticity (0.208). This means that an additional amount of seed as much as 1% will be able to increase production by 0.208%. This is in accordance with the results of research (Nurjati et al. 2018) where seeds significantly affect production.

NPK fertilizer is a very responsive variable because it has a fairly large coefficient. This implies that NPK fertilizer has a real influence on rice production with positive production elasticity. This means that the additional allocation of NPK fertilizer will increase rice production. This condition is due to the use of NPK fertilizer according to the recommended dosage. These results are in accordance with the findings (Hartono et al. 2022) which states that the use of NPK fertilizer according to recommendations will be able to increase rice production but if the use of excessive NPK fertilizer will actually reduce production and has no real effect on production. Ahmad et al. (2016) The allocation of additional N fertilizer will reduce rice production and is harmful to plants and the environment.

In general, variable costs including seeds and fertilizer are production factors which always occupy the largest cost post in rice farming, namely 97% or 7,753,014 rupiah the largest cost posts in rice farming (Kasmin and Darsana, 2019). In contrast to non-program farmers, the use of NPK fertilizer is not significant because farmers are unable to allocate the input according to the proper dose, so the five right principles must be applied by farmers in using fertilizers. So that farmers should be more careful in allocating these production factors so that they can further save production costs. The five principles must be applied by farmers in the use of fertilizers and pesticides, including the right type, right time, right dose, right way, and right place.

Table 1. The estimation result of Stochastic Frontier production function with Maximum Likelihood Estimation (MLE) method

Variable	Program		Non-Program	
	Coef.	t	Coef.	t
Stochastic frontier				
Intercep	- 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
Pesticides (PS)	0.007	0.384	0.007	1.041
Outside family labor (FL)	0.002	0.149	0.019	0.969
Labor in the family (NL)	- 0.006	-0.344	- 0.007	- 0.394
Sigma-squared	0.136	6.293	0.009	7.482
Gamma	0.983	78.408	0.999	323.971

Notes: significant at level *α 10%, **α 5% ***α 1%

Technical Efficiency, Allocative Efficiency, and Economic Efficiency

The distribution of the level of technical efficiency, allocative efficiency, and economic efficiency of rice farmers participating in the program and non-program is shown in Table 2. The average level of technical efficiency of rice farmers in the program and non-program was 0.906 and 0.741, respectively. Farmers with the highest technical efficiency level of the program and non-program respectively at 0.959 and 0.899 and the lowest at 0.715 and 0.506. The number of farmers with program and non-program technical efficiency values of more than 0.710 were 120 farmers (100%) and 90 farmers (83.33%) respectively. This means that farmers who follow the program can be said to have been technically efficient while non-program 90 farmers (83.33%) can be said to be technically efficient and 30 farmers (16.67%) still experience inefficiency. Differences in farm management and technology application cause differences in efficiency levels among farmers. Fauzan (2020) states that internal factors of farmers such as age, experience, and education as well as external factors of farmers such as counseling are the main causes of differences in farm management and technology application by farmers.

The level of allocative efficiency achieved by program and non-program rice farmers ranged from 0.447 to 1, with the highest percentage in the group of efficiency levels 0.91-1.00 and 0.81-0.90 at 55.00 percent and 35 percent respectively. Farmers with allocative efficiency levels between 0.81-1.00 occupy the most positions, but there are some farmers at the level of allocative efficiency below 0.50 or 0.83 percent. This shows that relatively few rice farmers who participated in the program or non-program were in an allocative in-efficient condition. The average level of allocative efficiency that farmers can achieve is 0.839 and 0.794 respectively. This figure indicates that there is still allocative in-efficiency so it is still open for program and non-program farmers to improve it. Allocative inefficiency is caused by farmers not being precise in allocating resources or inputs in the production process, for example using too little input or conversely using too much input. In rice farming, if farmers use fertilizer in small amounts or lower than the recommended standard size, it will cause the productivity of the rice produced to decrease, while other input costs such as labor wages per day do not decrease and land rental costs certainly do not decrease. This causes the profits obtained to be reduced because it only saves on the use of fertilizer. On the other hand, if farmers allocate resources or inputs excessively, it is also inappropriate. In rice farming, the use of fertilizer that exceeds the standard usage limit will cause damage to the organic elements of the soil which in the long term will actually damage the fertility of the soil itself which will result in a decrease in rice productivity. Excessive use of fertilizer also of course increases the cost of purchasing fertilizer. This will cause farmers' profits to be less than optimal.

The combined effect of technical efficiency and allocative efficiency of program farmers showed that the level of economic efficiency achieved ranged from 0.504 to 0.967, with the highest percentage in the 0.81-0.90 efficiency level group at 39.17%. Meanwhile, the number of farmers at the efficiency level of 0.61-7.00 was the second highest with a percentage of 21.67 percent. The average level of economic efficiency was 0.761 and 0.892, respectively. The analysis shows that the average program and non-program farmers in the sample will be able to achieve the maximum level of economic efficiency by saving production costs by 21.3% (1-[0.761/0.967]) and 10.4% (1-[0.892/0.995]) respectively. The most inefficient farmers were also able to achieve maximum economic efficiency by saving production costs by 47.9% (1-[0.504/0.967]) and 59.4% (1-[0.404/0.995]), respectively. Program and non-program farmers can improve economic efficiency by increasing technical efficiency. This can be increased because the allocative efficiency index is already quite high (allocative efficiency index greater than 0.84 and 0.79). Efforts made by farmers to improve technical efficiency are to improve their farms (Kune et al. 2016) by increasing their ability in the technical aspects of cultivation and the adoption of new and better technological innovations.

Managerial Implications

The level of allocative efficiency which is still relatively low compared to the technical efficiency value indicates that it is necessary to optimize the use of production inputs at the most appropriate price level for these inputs. The implication is that it is necessary to increase farmers' managerial capacity regarding price and marketing information through increasing the role of agricultural institutions (government and private). To be able to increase the allocation of use of production inputs, it is necessary to have input and output price policies such as fertilizer subsidies and output price stabilization.

Table 2. Frequency distribution of technical, allocative, and economic efficiency

Efficiency Level	Technical efficiency				Allocative efficiency				Economic Efficiency			
	Program		Non-Program		Program		Non-Program		Program		Non-Program	
	Total Farmer (person)	(%)	Total Farmer (person)	(%)	Total Farmer (person)	(%)	Total Farmer (person)	(%)	Total Farmer (person)	(%)	Total Farmer (person)	(%)
<0.50	0	0.00	0	0.00	0	0.00	1	0.83	2	1.67	2	1.67
0.51-0.60	0	0.00	1	0.83	7	5.83	7	5.83	21	17.50	18	15.00
0.61-0.70	0	0.00	19	15.83	16	13.33	19	15.83	26	21.67	46	38.33
0.71-0.80	5	4.17	25	20.83	24	20.00	35	29.17	14	11.67	37	30.83
0.81-0.90	49	40.83	35	29.17	17	14.17	35	29.17	47	39.17	10	8.33
0.91-1.00	66	55.00	40	33.33	56	46.67	23	19.17	10	8.33	7	5.83
Total	120		120		120		120		120		120	
Average	0.906		0.741		0.839		0.794		0.761		0.892	
Min.	0.715		0.506		1.00		0.447		0.504		0.404	
Max.	0.959		0.899		0.535		1.00		0.967		0.995	

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Factors affecting program rice production are land area, seeds, urea fertilizer, and NPK fertilizer while non-program land area, seeds, NPK fertilizer, and organic fertilizer. The average achievement of technical, allocative, and economic efficiency of the rice farming program is 0.906; 0.839, and 0.761 while the non-program 0.741; 0.794, and 0.892. To achieve the level of economic efficiency, farmers need to improve their technical and allocative efficiency achievements.

Recommendations

Increasing rice productivity in Indonesia, especially in West Nusa Tenggara province, requires the support of all parties. Collaboration between farmers and the government must be maintained in order to increase technical efficiency and allocative efficiency in rice farming, both program and non-program. farmers continue to improve managerial management in their farming businesses and the government improves the quality of extension institutions by increasing the role and activity of farmer groups so that they become a community that synergizes with the government in making extension activities more effective and disseminating information regarding the ability of rice farmers to be more efficient in allocating the use of their inputs according to standards and advice on farming, dissemination of information related to prices, appropriate technology and other market information. Apart from that, it is necessary to strengthen policies related to protecting input prices so that they are more affordable for farmers and securing the price of grain at harvest with the hope that farmers will still receive incentives. If farmers are efficient in allocating their inputs according to recommended standards and input prices are well controlled, then farmers will obtain high productivity so that their income and profits will also increase. With an increase in profits, it is hoped that there will be an increase in farmer welfare. Suggestions for further research, there is a need for further research in different regions or provinces that participate in programs and non-programs to find out overall productivity, the impact of irrigation development programs and farmers' behavior in facing production risks so that it is known whether farmers who participate in programs and non-programs are responsive. risk taker or risk averse regarding the allocation of input use so that the government can formulate policies that are right on target

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