THE IMPROVEMENT PRODUCTION AND EFFICIENCY OF UPLAND RICE IN BOYOLALI DISTRICT CENTRAL, JAVA, INDONESIA

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ABSTRACT

This study aims to determine the economic efficiency of the upland rice farming system in Boyolali Regency. The proportional sampling method was used to select 30 farmers that planted upland rice using the Jajar Legowo (Legowo Row Planting System, LRPS), and another 30 that use the Conventional Planting System (CPS) only. Data collection was approached using the proportional sampling method and then computed following the descriptive statistics and stochastic production frontier analysis. The results showed that LRPS and CPS farmers achieved an average economic efficiency of 97%, and 71%, respectively. This showed that the use of LRPS is associated with technical and allocative efficiency, while CPS is technically inefficient. Therefore, to increase the general economic efficiency of farmers, it is necessary to change the planting system from CPS to LRPS.

Keywords: Production, Efficiency, Upland Rice, CPS Farmers

INTRODUCTION

Globally, rice is one of the most widely consumed staple food, and in Indonesia, it constitutes an important part of the national economy. Therefore, as the main source of carbohydrates and food for the community, there is a need to improve its production because rice demand tends to increase over time with population growth.

The Central Java Province Central Bureau of Statistics (2019) reported that in 2018, 951,243.4 tons of rice were produced in an area of 1,680,406 ha at the rate of 5.66 tons/ha. In addition, 34,277.7 Tonnes of dry land rice were also produced in an area of 77,532 ha at the rate of 4.42 tons/ha. The expansion of planting areas by opening new rice fields is difficult to develop due to the construction of roads, offices, housing, and industrial estates (Sihombing et al., 2019; Paulina et al., 2020). Therefore, production is increased by expanding the planting of upland rice in rain fed areas or dry land, supported by the potentials of dry land in Central Java, covering an area of+2 million ha.

To solve the problems associated with upland rice development in dry lands, technological innovations were disseminated to farmers to increase production and efficiency. They include the use of superior and droughtresistant varieties, balanced fertilization, control of pests and plant diseases, as well as improvement of planting systems by regulating spacing and plant populations. (Susilastuti et al., 2018) stated that distance planting to optimize plant populations is known as Legowo Row Planting System (LRPS). This type of cropping pattern involves alternating between two or more (generally two or four) rows of plants and one blank row at a spacing of 40 x 20 x 12.5 cm (Fausayana & Tarappa, 2018). Furthermore, this method provides optimal growth space, facilitate plant care, creates a less conducive environment for pests, and increases the regular or tile planting population by approximately 15 to 20% (Darmawan, 2016). Several studies have shown an increase in the application of LRPS in rice production by relatively 100 to 691 kg/ha (Paulina et al., 2020; Witjaksono, 2018). This process was also achieved by optimally applying technological innovations using production inputs.

The application of the LRPS is mostly done on the lowland of rice fields and not much done in rain fed or dry land so that the efficiency analysis is more focused on lowland rice production. Taking into consideration the changes in the planting system of upland rice to determine the economic interests and benefits for farmers. This study also explains the economic efficiency obtained by farmers if they apply the LRPS and CPS. Therefore, this study aims to determine the economic efficiency of upland rice farming using LRPS and CPS.

RESEARCH METHODS

Place and Time

This study was carried out in Musuk, Nogosari, and Mojosongo sub-districts, Boyolali Regency. In each sub-district, a village with drylands was selected to cultivate upland rice. The purposive sampling method was used to determine the sub-districts and villages in accordance with the following considerations, (i) the largest area for the production of paddy fields, (ii) the largest number of farmers, and (iii) the most commonly cultivated area, when compared to the sub-districts or villages in other areas in Boyolali Regency. The study was carried out from January to April 2020 with data obtained during the 2019/2020 growing season.

Sources and Data Collection

Primary data were collected through interviews and by distributing questionnaires to determine the quantity and price of grain and production inputs, the number of workers and their wages, as well as the socio-economic data of farmers. Furthermore, the simple random sampling process was used to determine farmers that planted upland rice using LRPS and CPS.

Data analysis

The stochastic frontier production function model for rice farming using both the LRPS and CPS were analyzed based on the following equation (Lema et al., 2017; Binuyo et al., 2016)

$$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_4 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + (v_i - u_i)$$

Where

Y=rice production (kg)
X_1=land area (m2)
X_2=the number of rice seeds (kg),
X_3=amount of single fertilizer (kg),
X_4=amount of Phonska fertilizer (kg),
X_5=amount of organic fertilizer (kg), and
X_6=total labor (man days).

The method used to measure the technical inefficiency used in this study is in accordance with the model designed by Erhabor and Ahmadu (2013), which is mathematically stated as follows:

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \varepsilon_i$$

Where

μ_i =inefficiency effect
Z_1=farmer age (years),
Z_2=formal education (years),
Z_3=farming experience (years)
ε_i =error term

RESULTS AND DISCUSSION

Socio-Economic Characteristics

The farmers' socio-economic characteristics, such as age, education, experience, occupation, and family size, are shown in Table 1. The average age of farmers categorized under the group that planted rice using the LRPS was 57.60 years, with the largest age range within 40 to 60 years (as much as 60.00%). Conversely, the average age of those categorized under the group that planted upland rice using the CPS was 61.83 years, and the largest age range was above 60 years (56.67%). Both groups indicate that most farmers are over 40 years old and this is consistent with the study carried out by Nurliza, et al., (2017). According to Nurliza (2017), the younger generation is not interested in the agricultural sector in rural areas; therefore, farming is dominated by farmers above 40 years.

Approximately 46.66% and 43.33% of the respondents in the LRPS and CPS groups had a formal education at the elementary school level. The education supports the age of workers is dominated by older farmers above 40 years. The proportion of farmers with higher educational qualifications (senior high school) is between 16.67% to 26.67%, while approximately 0 to 10% are undergraduates. Farmers that possess higher educational qualifications are expected to positively influence others by applying technological innovations in farming activities. Mwatete, et al., (2015) stated that education is an important instrument for acquiring skills and adopting new technologies.

The rice farmers in the LRPS and CPS group have 18.97 and 33 years of experience, respectively. Farmers with over 10 years are expected to be able to adopt the necessary habits, skills, and expertise needed to achieve the expected outcome (Wengkau et al., 2017). Furthermore, they are expected to become more responsive to technological changes.

Table 1
SOCIO-ECONOMIC CHARACTERISTICS OF FARMER'S RESPONDENT

No	Variable	Statistics	
		LRPS[1]	CPS[2]
1	Average age of farmers (years)	57.6	61.83
	<40 years (%)	3.33	0
	40 to 60 years (%)	60	43.33
	>60 years (%)	36.67	56.67
2	Average farmer education (years)	8.33	8.8
	Elementary school (%)	46.66	43.33

	Junior high school (%)	26.67	30
	Senior high school (%)	26.67	16.67
	Undergraduate program (%)	0	10
3	Average farming experience (years)	18.97	33
	<0 years (%)	16.67	3.33
	10 to 20 years (%)	56.67	23.33
	>20 years (%)	26.67	73.34
4	Occupation:		
	Farmer	90	53.33
	Seller	6.67	0
	Farmworkers	3.33	16.67
	Village government officials	0	13.33
	Others	0	16.67
5	Average number of family members (persons)	3.87	2.4
	2 to 4 persons	70	96.67
	>4 persons	30	3.33

Note: [1]LRPS, Legowo Row Planting System; [2]CPS, Conventional Planting System.

Farming is the main occupation of 90% of rice farmers that adopted the LRPS and 53.33% for those in the CPS group. This proportion indicates that apart from farming, farmers also engage in other side jobs, such as selling, farmworkers, village government officials, etc. Based on the number of family members, farmers in the LRPS and CPS groups have an average of 3.87 and 2.40 people, respectively. These numbers make it impossible for them to manage the farm alone, therefore, they employ workers for assistance.

Use of Production Inputs

Generally, to obtain maximum production the farmers utilize several production inputs in rice farming, including rice seed, urea, SP-36, Phonska, organic fertilizers, and labor as well. The number of production inputs for upland rice farming with different cropping systems is presented in Table 2.

Table 2
THE USE OF PRODUCTION INPUTS IN RICE FARMING

No	Types of Production Inputs	Planting System	
		LRPS[1]	CPS[2]
1	Seed (kg/ha)	30.83+3.85	40.50+5.45
2	Fertilizers (kg/ha):		
	a. Urea	191.01+21.69	346.30+32.51
	b. SP-36	15.60+18.93	107.39+18.81
	c. Phonska	244.95+19.69	376.89+38.24
	d. Organic (kg/gha)	2596.33+311.29	1602.99+376.78
3	Labor (man days)	95.05+8.28	94.52+8.00

Note: [1]LRPS, Legowo Row Planting System; [2]CPS, Conventional Planting System.

The farmers planted seeds of approximately 30 to 40 kg/ha, which is above the stipulated standard of 30 kg/ha. (Chidiebere & Mark et al., 2019) carried out a research using 30 kg of seeds in dry lands, rice fields, and swamps to determine production inputs. Furthermore, (Hidayati et al., 2019) carried out a research in Sumber Ngepoh Regency using planted seeds weighing as much as 45 kg/ha. The seeds were used different because the planting system and spacing adopted varied (Permata, 2017)

Farmers plant upland rice on dry land once a year and at the beginning of the rainy season. Dry lands are characterized by insufficient nutrients therefore; fertilization is required to support plant growth. However, the amount of fertilizer used varies in different planting systems. For instance, those that planted upland rice with the LRPS use as much as 191.01 kg/ha urea, 15.60 kg/ha SP-36, and 244.95 kg/ha Phonska, while the average organic fertilizer used is 2,596.33 kg/ha. Farmers that adopted the CPS, applied an excess number of inorganic fertilizers, namely 346.30 kg/ha urea, 107.39 kg/ha SP-36, and 376.89 kg/ha Phonska with organic fertilizer relatively small at 1 602.99 kg/ha.

In Boyolali District, the average of employed farm labor was 95 man/d/ha. This was almost equal to that of the labor hired in the upland rice farming in Tasikmalaya, West Java, which was 81 person/d/ha. But it was less than the employment of labor in Ebonyi State, Nigeria 141 person/d/ha; (Chidiebere-Mark et al., 2019). The differences in the employment of labor can be due to the level of land fertility, the amount of production input, and the planting system.

Estimation of Production Function Stochastic Frontier in Upland Rice Farming

The production function of upland rice was estimated using the MLE method in accordance with the Frontier program.

Estimation of Upland Rice Production Functions

The 6 independent variables, namely planting area, seeds, single; Phonska, organic fertilizers, and farmworkers, only planting area, seeds and fertilizers had a significant effect on the production of upland rice. Consequently, the CPS comprised of the planting area, seeds, and single fertilizer. The land areas in both planting systems significantly and positively affected production and efficiency. According to (Bamiro & Aloro, 2013; Magreta et al., 2013; Budiono & Adinurani, 2017), land areas have a positive effect on rice production. This shows that the planting area's expansion is needed to improve production because it tends to increase the population

Table 3
RESULT OF MAXIMUM LIKELIHOOD ESTIMATION OF STOCHASTIC FRONTIER FUNCTION.

No	Variable	Planting System			
		LRPS[1]		CPS[2]	
		Koefisien	Std.Error	Koefisies	Std.Error
	Efficiency factor:				
1	Constant	4.01***	0.25	2.56***	0.87
2	Planted area	1.26***	0.4	0.43***	0.18
3	Rice seeds	0.42***	0.31	0.26***	0.17
4	Single fertilizer	0.49***	0.24	0.03***	0.01
5	Phonska fertilizer	1.01***	0.26	0.01***	0.02
6	Organic fertilizers	0.01***	0.01	-0.04***	0.07

7	Labor	-0.05***	0.23	0.17***	0.16
The Inefficiencies factor:					
1	Constanta	0.11***	0.91	0.97***	1.13
2	Age	-0.02***	0.01	0.02***	0.02
3	Education	0.09***	0.05	0.02***	0.03
4	Farming safety	0.02***	0.01	-0.03***	0.09
5	Sigma-squared	0.01***	0.03	0.09***	0.04
6	Gamma (γ)	0.05***	0.2	0.84***	0.93
Note: 1LRPS, Legowo Row Planting System; 2CPS, Conventional Planting System; ***, **, and * indicates the statistically significance at 1%, 5% and 10%, respectively.					

In the LRPS, the variable regression coefficient of the seeds, significantly affects production at 0.42. This means that production and technical efficiency is improved by increasing the number of seeds currently used (30.83 kg/ha) to a certain amount or usage limit. The process is achieved by modifying the spacing. In general, LRPS and CPS farmers use a distance planting of 20 x 40 x 15 cm, and 20 x 40 x 12.5 cm or 15 x 40 x 12.5 cm to increase the number of seeds. According to (Susilastuti et al., 2018), in the LRPS, the distance planting used is 25 x 50 x 12.5 cm. Meanwhile, Fausayana & Tarappa (2018) stated that the distance planting commonly used in this planting system is 20 cm, which was changed to 22.5 cm or 25 cm by considering the species of rice to be planted or the level of soil fertility. Therefore, the need for seeds is influenced by the distance planting used by farmers.

The seed variable's regression coefficient in the LRPS has a significant effect on production with a positive sign. This means that the increase in production is due to an increase in the number of seeds. (Ayedun & Adeniyi, 2019) stated that the positive regression coefficient of a variable indicates that its increase tends to improve the level of production or technical efficiency.

On the contrary, the research carried out by (Ebele & Eric, 2017) on rice farming in the lower irrigation project in Anambra, Nigeria, showed a significant effect with negative attributes. The excessive use of seeds was due to the use of a poor planting system or broadcasting method. Based on the research carried out in Sengah Temila District, Landak Regency by (Pudaka et al., 2018), it was stated that the seed variable regression coefficient had an insignificant effect on rice production with a negative sign.

The use of single fertilizers with 191.01 kg/ha urea and 15.60 kg/ha SP-36 in the LRPS showed a significant effect with a positive sign on rice production with a regression coefficient of 0.49. These results indicate that the addition of 100% single fertilizer tends to increase production by 49% in accordance with the assumption of ceteris paribus. It is important to understand that the cultivation of upland rice on infertile soils requires fertilizer intake. This is because, to some extent, the additions of Urea and SP-36 aids in increasing rice productivity and the need to add fertilizers to meet nutritional needs.

Phonska and organic fertilizers significantly affect rice production with regression coefficients of 1.01 and 0.01 respectively in the LRPS. This shows that the addition of 100% Phonska fertilizer tends to increase upland rice productivity by 101%. The potential for improving productivity in this area is quite enormous, one of which is by increasing the dosage of compound fertilizers, such as Phonska, which contains elements of N, P, and K needed by rice plants. Likewise, the addition of organic fertilizers also increases production. This is because dry land requires high amounts of organic fertilizer because of its slow-release nature and the ability to provide nutrients gradually and indirectly to plants (Gusmiatun et al., 2019).

In the CPS, single fertilizers (Urea and SP-36) significantly affected production with a regression coefficient of 0.03. On the contrary, Phonska and organic fertilizers had an insignificant effect on production. These results indicate that 346.30 kg/ha of urea and 107.39 kg/ha of SP-36 still need to be increased to improve rice production irrespective of the fact that 3% yield does not match the sacrifices in the form of input. Furthermore, maximum doses of Urea and SP-36 fertilizers are used in the CPS. Similarly, the application of Phonska and organic fertilizers do not affect rice production, meaning that the doses applied are in accordance with the plant's needs.

The farmworker regression coefficient in the two cropping systems has an insignificant effect on upland rice production. Therefore, it is assumed that the number of labors used is balanced, namely 95 man/d/ha. This is consistent with the research carried out by (Bui et al., 2018), which stated that the use of labor as many as 37.71 man/d/ha in Vietnam had an insignificant effect on upland rice production. These results indicate that farmers still rely on labor compared to mechanization because the area of land being cultivated is relatively small and, therefore, inadequate for technological innovations (Ebers et al., 2017).

Factors Affecting the Technical Inefficiency of Upland Rice Farming

The sigma squared (σ2) in Table 3 is relatively small, with values of 0.01 and 0.09 in the LRPS and CPS, respectively, which shows significant effect. This means that the error term inefficiency in upland rice farming is normally distributed. The gamma (γ) value obtained in the LRPS is 0.05, which means that there is only 5% variation during production at the farm level due to differences in inefficiency. However, the CPS sigma squared is bigger at 0.84, thereby indicating that 84% of the variation is caused by inefficient factors.

The regression coefficient of farmers' age in the LRPS group has a significant effect with a negative sign, which means that the older the farmers' age, the lower the inefficiency or, the higher the efficiency. The average age of farmers is 57.6 years, therefore a better understanding or knowledge of upland rice farming techniques aids in reducing less efficient tasks, and aids them to properly carry out farm management (Yoko et al., 2014). This is consistent with the studies carried out by Noer, et al., (2018), Ayedun & Adeniyi (2019), which stated that young farmers increase inefficiency. However, the older ones are more courageous because they need to make decisions to carry out their activities more efficiently.

Farmers' education is one of the factors causing inefficiency in the LSPS group with a positive regression coefficient value and a significant effect on the 95% confidence level. These results indicate that the higher their formal education, the lesser their efficiency. This is because properly educated farmers prefer not to work in the agriculture sector. Therefore, farming activities are improperly managed. Furthermore, this is consistent with the research carried out by (Hidayati et al., 2019), which stated that poorly educated farmers are more productive than those that are properly educated thereby, resulting in lesser farming efficiency. However, this is in contrast with the studies carried out by (Binuyo et al., 2016; Dang, 2017; Bui et al., 2018), which stated that education has a significant effect on inefficiency with a negative sign, meaning that the higher the educational qualification of the farmers, the higher the efficiency obtained. These are interpreted as variations in the farmers' agricultural systems and status both in Indonesia and other countries.

The average experience of farmers involved in upland rice production for 19 years has a significant effect on technical inefficiency with a positive sign. The longer the farmer indulges in farming activities, the lower the efficiency. This phenomenon occurs due to habitual factors that have been carried out by farmers for several years. Therefore, they are less likely to adopt technological innovations. This is supported by relatively poor education thereby, increasing farming inefficiency.

Economic Efficiency of Upland Rice Farming

Technical Efficiency of Upland Rice Farming

The values of the technical efficiency obtained from the stochastic frontier model are shown in Table 4. The values obtained from the LRPS range from 0.56 to 0.99, with an average of 0.87. The results obtained show that upland rice farming using the LRPS is 87% efficient, which means that farmers tend to reduce the input use by 13% to produce an equivalent output (Lema et al., 2017).

Table 4
DISTRIBUTION OF TECHNICAL EFFICIENCY OF UPLAND RICE FARMING

No	Technical Efficiency Range	LRPS[1]		CPS[2]	
		Quantity	%	Quantity	%
1	≤ 0,50	0	0	2	6.67
2	0.51 – 0.60	4	13.33	4	13.33
3	0.61 – 0.70	3	10	6	20
4	0.71 – 0.80	2	6.67	9	30
5	0.81 – 0.90	1	3.33	6	20
6	0.91 – 1.00	20	66.67	3	10
	Minimum		0.56		0.44
	Maximum		0.99		0.93
	Average		0.87		0.73

Note: LRPS, Legowo Row Planting System; CPS, Conventional Planting System

The technical efficiency values in the LRPS range from 0.44 to 0.93, with an average of 0.73. These results indicate that upland rice production using the CPS technique is not as efficient as the LRPS. This is consistent with the study carried out by (Athipanyakul et al., 2014), which stated that the efficiency of upland rice in Ban Head District, Khon Kaen Province, northeast Thailand ranges between 0.22 and 0.94 with an average of 0.70. The range of technical efficiency obtained means that farmers have not been able to achieve an efficient condition. Therefore, they need to increase efficiency by saving costs or by reducing production inputs. A lesser technical efficiency (0.54) of upland rice farmers was obtained from research carried out by (Ifeanyichukwu et al., 2018) in Ebonyi State, Nigeria, which ranges between 0.23 and 0.95. This indicates a large difference in the ability of farmers to achieve efficient conditions.

Allocative Efficiency

The value of allocative efficiency obtained from upland rice farming reflects the production efficiency level from the cost frontier. When the value of the efficiency obtained equals one, it means the farmer efficiently utilizes farming costs. However, when the efficiency value obtained is greater than one, it means the farmer is inefficient (Rido, 2014).

The analysis of upland rice farming allocative efficiency in Boyolali Regency is shown in Table 5. The allocative efficiency using the LRPS varies between 0.85 and 1.00 with an average of 0.97. Consequently, 93.33% of farmers effectively used the production inputs as indicated by the allocative efficiency ranging between 0.91 and 1.00. In addition, 6.67% of the farmers were unable to achieved efficiency. In CPS, the allocative efficiency varies between 0.86 and 0.99, with an average of 0.97. These results indicate that according to respondents, farmers' efficiency is 90.00 and 10.00.

Table 5
DISTRIBUTION OF ALLOCATIVE EFFICIENCY OF UPLAND RICE FARMING

No	Allocative Efficiency Range	LRPS[1]		CPS[2]	
		Quantity	%	Quantity	%
1	≤ 0,50	0	0	0	0
2	0.51 – 0.60	0	0	0	0
3	0.61 – 0.70	0	0	0	0
4	0.71 – 0.80	0	0	0	0
5	0.81 – 0.90	2	6.67	3	10
6	0.91 – 1.00	28	93.33	27	90
	Minimum		0.85		0.86
	Maximum		1		0.99
	Average		0.97		0.97

Note: [1]LRPS, Legowo Row Planting System; [2]CPS, Conventional Planting System

The results obtained, the minimum cost for farmers that used the LRPS and CPS is approximately 97% of the frontier approach. Therefore, when they are able to operate at an efficient cost, their losses or expenses are expected to be reduced by 13%. However, farmers in the activity locations achieved allocative efficiency.

This is in contrast with the research carried out by (Pudaka et al., 2018) which stated that farmers in Sengah Temila District, Landak Regency, used production inputs and experience price inefficiencies. Allocative inefficiency is caused by the high cost of production input, particularly the prices of fertilization and farmworkers' wages, which leads to inefficiency.

Economic Efficiency

Economic efficiency is a combined effect of both technical and allocative efficiencies. Therefore, farming is expected to be economically efficient when the two other factors have been achieved. The distribution of economic efficiency in the LRPS was found in 56.67% of farmers with 0.90 significance. However, in the CPS, 3.33% of the farmers achieved economic efficiency, as shown in Table 6.

Table 6
DISTRIBUTION OF THE ECONOMIC EFFICIENCY OF UPLAND RICE FARMING

No	Economic Efficiency Range	LRPS[1]		CPS[2]	
		Quantity	%	Quantity	%
1	≤ 0,50	0	0	3	10
2	0.51 – 0.60	6	20	4	13.33

3	0.61 – 0.70	2	6.67	3	10
4	0.71 – 0.80	1	3.33	13	43.33
6	0.81 – 0.90	4	13.33	6	20
7	0.91 – 1.00	17	56.67	1	3.33
	Minimum		0.87		0.44
	Maximum		0.99		0.91
	Average		0.97		0.71
Note: [1]LRPS, Legowo Row Planting System; [2]CPS, Conventional Planting System					

Table 6 shows that farmers used average technical, allocative, and economic efficiencies, of 0.97. Meanwhile, farmers that used the CPS only achieve allocative efficiency without economic efficiency, as indicated by an average value of 0.71. This failure is due to technical problems, such as inefficient farming. This is consistent with the study carried out by (Noer et al., 2018), which stated that farmers in the South Lampung Regency were able to achieve allocative efficiency although they are not economically efficient.

CONCLUSION

Farmers who have grown upland rice with the Legowo Row Planting System (LRPS) achieved better economic efficiency compared to the farmers who have revolved around the Conventional Planting System (CPS). This study provides evidence that the LRPS is technically and allocative efficient, while the CPS is only allocative efficient but technically inefficient. Therefore, to increase the economic efficiency, it is necessary to replace the CPS with the LRPS for growing rice in Boyolali Regency.

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Conflicts of Interest

The authors declare no conflict of interest.

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