Assessing the Impact of Jajar Legowo Planting System on Wetland Paddy Productivity and Income of Farmers in Indonesia

Prasetyo, Octavia Rizky and Kadir, Kadir

BPS-Statistics Indonesia, BPS-Statistics Indonesia

11 August 2023

Assessing the Impact of *Jajar Legowo* Planting System on Wetland Paddy Productivity and Income of Farmers in Indonesia

Octavia Rizky Prasetyo[1], Kadir[2]

[1,2] *Badan Pusat Statistik (BPS) – Statistics Indonesia*
Jl. Dr. Sutomo, 6-8, Jakarta 10710, Indonesia
Telp. (62-21) 3841195 Fax. (62-21) 3857046
Pos-el: octavia.rizky@bps.go.id, kadirsst@bps.go.id

ABSTRACT

This study aims to assess whether *Jajar Legowo* planting system has a significant impact on increasing the productivity of wetland paddy and the income of the paddy growers in Indonesia. We applied a linear regression model to the results of the 2017 National Cost Structure of Paddy Cultivation Household Survey conducted by BPS-Statistics Indonesia in all 34 provinces. The main contribution of this study is to provide an evaluation of the performance of *Jajar Legowo* planting system in increasing paddy productivity and income of the farmers. Therefore, our research can be used by the government as a reference for future improvement of the implementation of *Jajar Legowo* cultivation system. Our findings show that the new cultivation system has a significant impact on increasing the productivity of wetland paddy. Without controlling for other variables affecting productivity, the estimation result pointed out that on average, the new cultivation system can increase productivity by about 10 per cent. However, after controlling for other variables (the farmers and other cultivations characteristics), the magnitude decreases to around 5 per cent. Moreover, our estimation results also show that the income of the farmers rises by around 12 per cent by implementing *Jajar Legowo*. Our study indicates that the implementation of *Jajar Legowo* planting system results in better efficiency than that of the conventional one.

Keyword: *Jajar Legowo*, productivity, the income of farmers

INTRODUCTION

Paddy is an extremely strategic commodity in Indonesia. The demand for rice continues to increase along with population growth since most Indonesians rely on rice as their staple food. As a consequence, paddy production plays a vital role in maintaining national food security. In recent years, the Indonesian government has been implementing several programs focusing on both expanding paddy fields and increasing productivity (yield per hectare). However, the former measure is costly and quite challenging to implement. The area for paddy cultivation is limited, and the paddy area has been decreasing for many years because of the massive conversion of agricultural land, especially paddy fields, into non-agricultural uses, such as residential and industrial land. In 2018, the paddy field area was 7,105,145 hectares[1] shrinking by around 8 per cent compared to the paddy field area in 2013, which was 7,750,999 hectares. Therefore, the last strategy increasing productivity becomes the most promising one.

To boost the productivity of wetland paddy, the Ministry of Agriculture has introduced a new cultivation technique so-called *Jajar Legowo* planting system as a flagship program. Technically, it tries to optimize the population of paddy plants per hectare by adjusting the space or the distance between the plants. The implementation of the technique is also expected to enhance the income of the farmers. It happens as a result of better efficiency.

So far, several studies have confirmed that the implementation of *Jajar Legowo* planting system could produce higher productivity compared to the conventional ones, such as the tile planting system (Susilastuti et al., 2018; Toyibah et al., 2017; Darmawan, 2016; Hamdani & Murtiani, 2014). However, those studies generally are case studies in the form of an experimental design with minimal research coverage so that not yet be able to represent the performance of *Jajar Legowo* on a national level. For these reasons, our study tries to fill this gap by scaling up the coverage of those studies. In doing so, we made use of the results of a national-scale survey, namely Cost Structure of Paddy Cultivation Household Survey 2017 (SOUT2017). To the best of our knowledge, studies on the impact of the *Jajar Legowo* planting system on wetland paddy productivity and income of farmers in Indonesia using the results of extensive scale survey as SOUT2017, are still very limited. This study aims to assess whether *Jajar Legowo* cultivation planting technique as the new government's flagship program has a significant impact on increasing the productivity of wetland paddy and the income of the paddy growers in Indonesia. Besides, we also analyze other variables that also may have an impact on productivity and income, like farmer demographic characteristics (Suyatno et al., 2018; Paltasingh & Goyari, 2018; Sriwardana et al., 2014).

The main contribution of this study is to provide an evaluation of the performance of the *Jajar Legowo* planting system in increasing paddy productivity and income of the farmers in Indonesia. Thus, our study can be used by the government as a reference for future improvement of the implementation of the *Jajar Legowo* cultivation system. This study is also expected to be able to enrich research on the impact of the implementation of the *Jajar Legowo* planting system on productivity and farmers' income in Indonesia.

METHODOLOGY

Jajar Legowo Planting System

At first, *Jajar Legowo* planting system was commonly applied to areas where there were many pests and diseases. This planting system then develops to get a higher yield than the tile system through population addition. It is also observed that *Jajar Legowo* planting system makes controlling pests, diseases, weeds, and fertilizing activity easier.

Jajar Legowo planting system is a modified cultivation system to get more than 160,000 plant population per hectare, which is the typical plant population amount of a tile planting system. Besides, *Jajar Legowo* planting system is also able to increase

[1] Based on the Minister of Agrarian and Spatial Planning (ATR) / Head of the National Land Agency (BPN) decree No.399/Kep-23.3/X/2018 dated on In 2018, October 8th

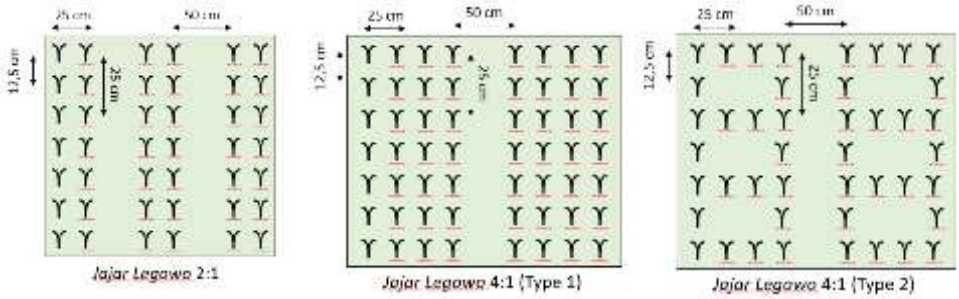


Figure 1. Illustration of *Jajar Legowo* Planting System

the circulation of sunlight and air around the periphery plants so that plants can photosynthesize better. Furthermore, the edge crops are expected to provide higher production and better grain quality, given that the row of *Jajar Legowo* planting system has 25-50 per cent open space, so the plant can receive optimal sunlight which is useful for the photosynthesis process. It is recommended to use a distance of 25 cm x 25 cm between clumps in rows, 12.5 cm space in rows, and 50 cm as the distance between rows or the aisles (Abdulrachman et al., 2013).

In practice, the implementation *Jajar Legowo* planting system has several forms, such as *Jajar Legowo* 2:1 planting system, *Jajar Legowo* 4:1 planting system (type 1), and *Jajar Legowo* 4:1 planting system (type 2). The illustration of *Jajar Legowo* planting system for each form given in Figure 1.

The Data

This study used microdata from the results of the Cost Structure of Paddy Cultivation Household Survey 2017 (SOUT2017) conducted by BPS-Statistics Indonesia. SOUT2017 was conducted in 34 provinces in Indonesia by interviewing the farmers and was designed to photograph the cost structure of food crops in Indonesia, including paddy. Furthermore, SOUT2017 also collected information on production, farmer profiles, and cultivation characteristics. The number of wetland paddy cultivation households analysed in this study was 98,165 households. The variables used in this study and their brief explanation are presented in Table 1.

In analysing the impact of *Jajar Legowo* planting system on wetland paddy productivity and the income of farmers, we also tried to figure out the impacts of other variables, such as farmers' characteristics (gender, education, age), government assistance, counselling, bank access, agricultural equipment and types of machinery, type of land, and fertilizer.

Table 1. Definition of Variables

Variables	Description
Productivity	Paddy yield in the form of dry harvested paddy quality measured in tons per hectare.
Income of Farmers	Calculated by subtracting the production value by the production cost.
Planting system	Categorized into *Jajar Legowo* and non-*Jajar Legowo* group (reference category).
Gender	Gender of the main farmers (a farmer with the largest harvested area in a selected household). Gender consists of two categories, male and female (reference category).
Education	Based on the highest level of educational attainment completed. Reference category is never/has not graduated yet from elementary school.
Age	Farmers age are in years.
Age^2	The use of quadratic of age variable aims to capture the non-linear effect of age to productivity and income.

Variables	Description
Government Assistance	Receiving assistance regarding paddy cultivation. The reference category is not receiving government assistance.
Counselling	Receiving counselling in terms of paddy cultivation management. The reference category is not receiving counselling
Bank access	Having access or loan from a public bank or communal bank for paddy cultivation. The reference category is not having access to the bank.
Agricultural equipment and machinery	The use of farm equipment and machinery. The reference category is not using farm equipment and machinery.
Type of land	Categorized into irrigated wetland and non-irrigated wetland (reference category).
Fertilizer	The use of fertilizer for wetland paddy. The reference category is not applied fertilizer in paddy cultivation.

To be noted, there is a limitation of the methodology used in collecting data of SOUT2017--the survey used so-called recall-based or self-reporting method. The survey collected data by interviewing selected households/farmers so that the issue of accuracy from farmers' memory recall could not be avoided. According to David (1978), farmers generally underestimated the crop area. In other words, there is a possibility of the reported data regarding productivity and income of farmers is too low or too high.

Econometric Model

In this study, we applied a linear regression model to assess the impact of *Jajar Legowo* planting system on wetland paddy productivity and income of farmers. To enrich the analysis, we also incorporated other variables that may have impacts on the response variable as control variables. Therefore, there are two models that we estimated in this study, namely the yield model (Equation 1) and the income model (Equation 2):

$$\ln productivity_i = x_i'\beta + \delta Jarwo + \varepsilon_i \qquad (1)$$

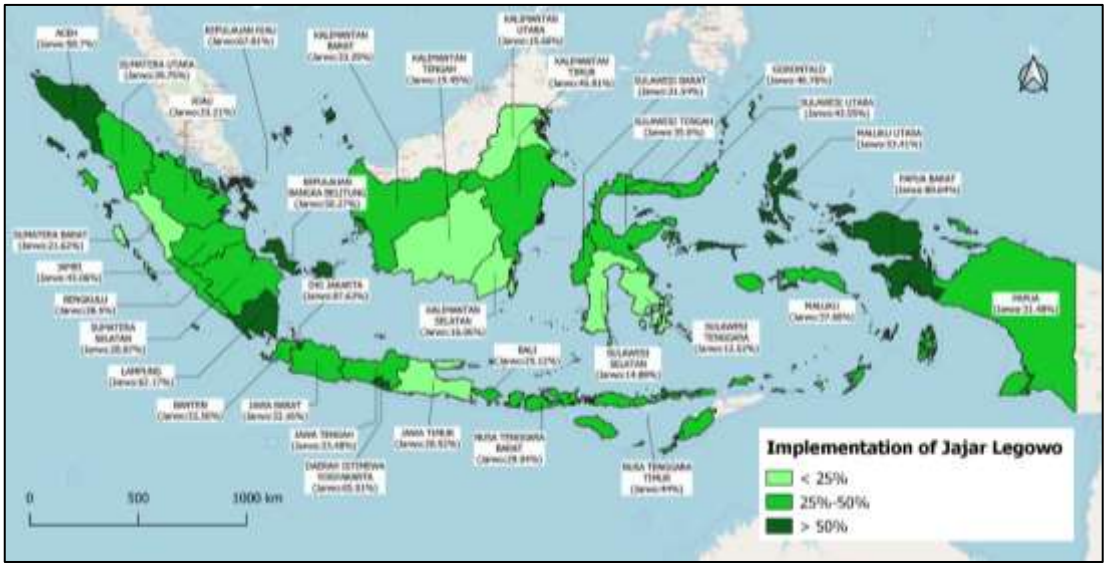
$$\ln income_i = x_i'\beta + \delta Jarwo + \varepsilon_i \qquad (2)$$

where $productivity_i$ is wetland paddy productivity (yield per hectare) for the-ith households, and $income_i$ is farmers' income for the-ith households. *Jarwo* is a dummy variable of *Jajar Legowo* planting system application utilising. Therefore, this study focuses on estimating δ, which captures the impact of the increase of productivity and farmers' income in percentages as a result of the implementation of each planting system. The use of a semilog model or logarithmic form on the response variable allows us to interpret the change in productivity and income as the impact of *jajar legowo* implementation in percentage. Also, x_i' is a vector of control variables that are considered to be able to explain productivity and farmers' income, such as farmer demographics and cultivation characteristics as detailed in Table 1. It also contains sub-district dummy variables to capture region-specific effects (sub-districts) which is constant for each unit of observation. ε_i is a regression error that is assumed to be independent and identically distributed (i.i.d).

The model is estimated by Ordinary Least Square (OLS). The robust standard error is applied in calculating standard error to overcome the issue of heteroskedasticity in the variance-covariance matrix. It is well known that the presence of heteroskedasticity leads to consistent but inefficient parameter estimates and inconsistent covariance matrix estimates. As a consequence, it will result in a faulty inference when testing statistical hypotheses. In this regard, we follow White (1980) by implementing robust standard errors to address the issue of heteroskedasticity. In our study, the survey weight is also used in estimating the regression coefficients.

RESULTS

Table 2 presents the average of farmers' income (rupiahs per hectare), productivity (ton per hectare), and the proportion of farmers by the planting system implemented. It can be seen that the average income



Source: SOUT2017, BPS (authors calculation)

Figure 2. Implementation of *Jajar Legowo* Planting System (Percentage)

of farmers not adopting *Jajar Legowo* planting system is lower than the farmers who implemented the planting system. It indicates that *Jajar Legowo* planting system gives a significant impact on farmers' income.

Table 2. Income, Productivity, and Distribution of Farmers by Planting System Adopted

Description	***Jajar Legowo***	**Non-*Jajar Legowo***
Income (000 Rp/ha)	6,871.19	5,991.68
Productivity (ton/ha)	4.73	4.33
Percentage of Farmers (%)	33.81	66.19

The same applies to the income variable. The average of wetland paddy productivity implementing *Jajar Legowo* cultivation techniques is higher than that of wetland paddy productivity with the non-*Jajar Legowo* planting system. The results of SOUT 2017 pointed out that the productivity of paddy using *Jajar Legowo* planting system reached 4.73 tons/ha on average. In comparison, the productivity of paddy cultivated with the conventional planting system was 4.33 tons/ha on average. Unfortunately, based on the results of SOUT2017, only 33.81 per cent of wetland paddy farmer households applied *Jajar Legowo* planting system. It means that there is an opportunity to boost the yield of wetland paddy in Indonesia by expanding the implementation of the *Jajar Legowo* planting technique. There are some explanations for the small portion of farmers implementing the technique so far, such as a limited number of skilled workers on *Jajar Legowo* planting technique (Santoso, et al, 2005) and the difficulty of changing conventional farmers' planting technique habits (*tegel system*) with the new one (Malahayatin, et al, 2017).

It is also shown in Figure 2 that most provinces have a percentage of the implementation of *Jajar Legowo* planting system below 50 per cent. It means that this planting system still has not been widely applied nationwide. One effort that can be done by the government to scale up the implementation of the technique is by providing regular counselling. Counselling is highly essential in order to guide and assist farmers about *Jajar Legowo* planting system as well as the benefit gained from implementing the technique. Therefore the farmers will be interested in and know how to implement *Jajar Legowo* planting system (Patil, 2017). Research shows that Field Agricultural Counseling (FCA) is a policy tool that can be used by the government to encourage agricultural development. FCA is also expected to assist farmers in solving problems they faced in applying *Jajar Legowo* planting system (Payong et al., 2018).

As mentioned earlier, we assess the impact of *Jajar Legowo* planting system on wetland paddy productivity and income of farmers using

econometric models. Table 3 shows the estimation results of OLS regression models. Without controlling for other variables affecting productivity, the estimation result pointed out that on average, the *Jajar Legowo* cultivation system can increase productivity by about 10 per cent or $(e^{0.0954} - 1) \times 100\%$. Besides, the estimation results also confirm the expected results of the positive impact of the technical implementation of *Jajar Legowo* on the farmer's income. We found that there is an increase in farmers' income of approximately 15 per cent due to the implementation of *Jajar Legowo* planting system. To enrich our analysis, we also implemented the same regression model to assess the impact of *Jajar Legowo* planting system along with other control variables on the wetland paddy productivity and income of farmers. As presented in Table 3, most of the variables included in the model are statistically significant at the 1 per cent significance level. In general, both the magnitude and signs of the regression coefficients estimated are as expected.

The estimation results pointed out that even after controlling for other variables, *Jajar Legowo* planting system still can increase productivity significantly, indicating a better efficiency than that of the conventional one. It could be explained since the plants sitting on the edge can get enough air circulation and solar radiation, and are also more comfortable to be treated and supervised (Abdulrachman et al., 2013). This condition results in a better yield. Also, according to Misran (2014), *Jajar Legowo* planting system significantly affects yield components, especially at panicle length, number of grains per panicle and grain yield so that farmers can earn more as compared to the conventional system. Besides, Melasari, Supriana, and Ginting (2013) revealed in their research that the technical implementation of *Jajar Legowo* technique requires less input than the conventional ones, such as the use of seed, fertilizer, and labour. The fertilizer needed for *Jajar Legowo* planting system is less than the conventional one because the paddy plant in *Jajar Legowo* planting system obtains more sunlight intensity. Nitrogen content will increase due to high solar radiation so that plants do not require much additional nitrogen supply from chemical fertilizers.

However, after controlling for other variables, the magnitude of *Jajar Legowo* coefficient in estimating wetland paddy productivity decreases from about 10 per cent to around 5 per cent. The same applies to the magnitude of income of farmers which declines from 15 per cent to around 12 per cent. The decrease represents the contribution to the human capital capacity that also has a significant impact on increasing the yield and farmers' income.

The estimation results also show other interesting findings. We found that there is a presence of productivity and income gap between female and male farmers even though statistically insignificant. The gap exists due to the difference between female and male farmers' capacity in doing wetland paddy cultivation. Furthermore, education variables give a significant and positive impact on increasing both wetland paddy productivity and the income of farmers. The finding is consistent with many studies on the impact of education on the yield of farmers (Paltasingh and Goyari, 2018; Oduro-Ofori et al., 2014; Narayanamoorthy, 2000). The returns to education on agriculture come to play by opening the mind of farmers to knowledge and enhancing their adoption of modern technology (Oduro-Ofori et al., 2014), including the implementation of *Jajar Legowo* planting system. Paltasingh and Goyari (2018) found that the minimum level of farmers' education has a significant impact on the decision of farmers to use a modern paddy variety so that it can increase productivity. In other words, the education level can increase the capacity of farmers in absorbing technology introduction that could increase their yield and income.

The increasing age has a significant and positive impact on productivity. It indicates that there is an experience factor that increases with age. Furthermore, government assistance also gives a significant and positive impact on enhancing the productivity of wetland paddy. Government assistance in our study includes all types of assistance given by the government, for instance, superior seeds, fertilizer, and agricultural machinery. However, it only has an impact of around 3 per cent in increasing the yield of farmers. It could be explained since some farmers who get assistance still lacked seriousness in paddy cultivation activities.

Our finding also pointed out that farmers who receive counselling could produce higher income than farmers who do not receive counselling. As mentioned earlier, counselling is essential as a

Table 3. OLS Regression Estimation Results

Variables	Productivity		Income of Farmers	
	Without Controlling Other Variables	Controlling Other Variables	Without Controlling Other Variables	Controlling Other Variables
Jajar Legowo	0.0954***	0.0478***	0.1386***	0.1130***
	(0.0097)	(0.0085)	(0.0222)	(0.0248)
Gender (Female)		-0.0072		-0.0018
		(0.0126)		(0.0356)
Elementary school		0.0172**		0.0304
		(0.0068)		(0.0225)
Junior High School		0.0446***		0.1056***
		(0.0085)		(0.0261)
Senior High School		0.0649***		0.1361***
		(0.0087)		(0.0302)
D1/D2		0.0663***		0.1646**
		(0.0237)		(0.0674)
D3		0.0827**		0.2020**
		(0.0363)		(0.0913)
D4/S1		0.0510***		0.1684***
		(0.0179)		(0.0330)
S2/S3		-0.0055		0.0880
		(0.0632)		(0.1733)
Age		-0.0037		-0.0032
		(0.0023)		(0.0061)
Age^2		0.0041*		0.0055
		(0.0023)		(0.0062)
Goverment Assistance		0.0250***		-0.0307
		(0.0078)		(0.0203)
Counselling		0.0085		0.0726***
		(0.0096)		(0.0176)
Bank access		0.0980***		0.0864
		(0.0248)		(0.0635)
Agricultural machineries		0.1321***		0.1771***
		(0.0173)		(0.0302)
Type of land		0.0811***		0.0632**
		(0.0135)		(0.0276)
Fertilizer use		0.2305***		0.2093***
		(0.0278)		(0.0608)
Constant	1.3736***		8.2954*** (0.0202)	
	(0.0117)			

Notes: Number in parantheses are standard errors. *** is significat at α = 1%; ** is significant at α = 5%, * is significant at α = 10%. Weight is used in estimation process. Number of observations = 98,165.

medium to guide and evaluate the process of paddy cultivation by farmers so it could improve their agriculture practices and management. However, our study shows that counselling does not have a significant impact on increasing productivity. It indicates that the effectiveness of counselling given in increasing rice crop productivity has not been maximized. Besides, the counselling portrayed in SOUT2017 is more general, not only specific to cultivation techniques. It could be that farmers get counselling but not related to cultivation techniques.

Moreover, our estimation results confirmed the vital role of farmers' access to the financial sector. Farmers who have access to get capital from banks on average have higher productivity of around 10 per cent than those who do not have access to loans from banks. It can be explained since farmers who have access to capital from

banks tend to have an opportunity to perform cultivation techniques that could increase the yield through the use of fertilizers, superior seeds, agricultural machinery and equipment and pest control (Prasetyo & Kadir, 2019).

In terms of mechanization, it seems that the utilization of agricultural machinery in paddy cultivation should be encouraged since this variable has a substantial impact on increasing both the yield and farmers' income (14 per cent and 19 per cent respectively). The use of agricultural machinery could lead to the possibility of farmers managing larger paddy field areas. Besides, farmers who use agricultural machinery tend to require less time in the land processing as well as require less labour which can alleviate labour costs.

Paddy is a water-intensive crop, and it consumes plenty of water (Paltasingh & Goyari, 2018). Our estimation results show that irrigated wetlands could produce higher productivity by around 8 per cent and result in higher income by 7 per cent compared to non-irrigated wetlands. It indicates that assured irrigation is quite compulsory for paddy cultivation. Similarly, fertilizer is one of the principal inputs in paddy cultivation. Our study shows that the use of fertilizer can increase wetland paddy productivity by around 26 per cent and farmers' income by approximately 23 per cent.

CONCLUSION

The results of our study confirmed that *Jajar Legowo* planting system has a significant impact in increasing the wetland paddy productivity and income of farmers. Therefore, increasing the participation of farmers in the implementation of the *Jajar Legowo* planting system should be considered a pivotal measure to boost wetland paddy productivity and income of farmers. Several ways can be taken to increase farmers' participation, such as increasing farmers' education level and providing periodic and intense agricultural counselling regarding the implementation of *Jajar Legowo* that includes training in implementation. Our study also pointed out that several measures can also be done to enhance wetland paddy productivity and farmers' income, such as increasing the capacity of farmers, bank access, machinery utilization, and ensuring the availability of fertilizer for farmers.

REFERENCES

Abdulrachman, S., Mejaya, M.J., Agustiani, N., Gunawan I., Sasmita, P., & Guswara, A. (2013). *Sistem Tanam Legowo*. Jakarta: Indonesian Agency of Agricultural Research And Development, Ministry of Agriculture.

Darmawan, M. (2016). Analysis of Legowo Row Planting System and System of Rice Intensification (Sri) of Paddy Field (Oryza Sativa L.) Toward Growth and Production. Agrotech Journal, 1(1), 14-18.

David. (1978). Non-Sampling Errors in Agricultural Surveys-Review, Current Findings and Suggestions for Future Research. The Philippine Statistician, XXVII (1&2).

Hamdani, K. K., & Murtiani, S. (2014). Application of Jajar Legowo Planting System to Increase Paddy Yield. Jurnal Pertanian Agros, 16(2), 285-291.

Malahayatin, D. M., & Cahyono, E. D. (2017). *Faktor kesesuaian dengan kebutuhan petani dalam keputusan adopsi inovasi pola tanam jajar legowo (Studi kasus petani padi di Kecamatan Widang, Kabupaten Tuban)*. Jurnal Ekonomi Pertanian dan Agribisnis, 1(1), 56-61.

Melasari, A., Supriana, T., & Ginting, R. (2013). *Analisis Komparasi Usahatani Padi Sawah melalui Sistem Tanam Jajar Legowo dengan Sistem Tanam Non Jajar Legowo (Studi Kasus: Desa Sukamandi Hilir, Kecamatan Pagar Merbau, Kabupaten Deli Serdang)*. Journal on Social Economic of Agriculture and Agribusiness, 2(8).

Narayanamoorthy, A. (2000). Farmers' education and productivity of crops: A new approach. Indian Journal of Agricultural Economics, 55(3), 511-520.

Oduro-Ofori, E., Aboagye, A. P., & Acquaye, N. A. E. (2014). Effects of education on the agricultural productivity of farmers in the Offinso Municipality. International Journal of Development Research, 4(9), 1951-1960.

Paltasingh, K.R., & P. Goyari. (2018). Impact of Farmer Education on Farm Productivity under Varying Technologies: Case of Paddy Growers in India. Agricultural and Food Economics 6:7. Accessed from https://doi.org/10.1186/s40100-018-0101-9

Payong, P., Gunawan, C.I., and Adisarwanto, T. (2018). Technology Adoption of Jajar Legowo Rice Planting System Application. Agricultural and Resource Economics: International Scientific E-Journal, 4(3), 34-43.

Prasetyo, O. R., & Kadir, K. (2019). *Teknik Penanaman Jajar Legowo untuk Peningkatan Produktivitas Padi Sawah di Jawa Tengah*. Jurnal Litbang Sukowati: Media Penelitian dan Pengembangan, 3(1), 13-13.

Santoso, P., Suryadi, A., Subagyo, H., & Latulung, B. V. (2005). *Dampak teknologi sistem usaha pertanian padi terhadap peningkatan produksi dan pendapatan usahatani di Jawa Timur*. Jurnal Pengkajian dan Pengembangan Teknologi Pertanian, 8(1), 124955.

Siriwardana, A. N., and Jayawardena, L. N. A. C. (2014). Socio-demographic factors contributing to the productivity in paddy farming: A case study. Tropical Agricultural Research, 25(3).

Susilastuti, D., Aditiameri, and Buchori, U. (2018). The Effect of Jajar Legowo Planting System on Ciherang Paddy Varieties. Agritropica: Journal of Agricultural Sciences, 1(1), 1-8.

Suyatno, A., Imelda, I., and Komariyati, K. (2018). The Effect of Tractor Utilization on Revenue and Use of Labor on Rice Farming in Sambas Regency. AGRARIS: Journal of Agribusiness and Rural Development Research, 4(2), 92-100.

Toyibah, E. S., Sujarwo, S., and Nugroho, C. P. (2016). Jajar Legowo Planting System as The Strategy on Climate Change Adaptation (Case Study in Srigading Village, Lawang District, Malang). Agricultural Socio-Economics Journal, 16(1), 25-30.

White, H. (1980). A Heteroskedasticity-consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. Econometrica, 48(4), 817-838.