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Technical Efficiency of Rice Production Using the Stochastic Frontier Analysis Approach: Case in East Java Province

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ABSTRACT

The aim of this study is to evaluate the efficiency of East Java rice production in 2018. This study uses a model for measuring the efficiency of stochastic frontier analysis (SFA). Empirical results of these findings indicate that the efficiency of rice production in East Java in 2018 was said to be very efficient in several districts and towns affected by the variable dry milled grain / GKG and irrigation variables, although there are still some districts and towns that cannot be said to be productive. Additionally, the explanatory variable of population growth affects the technical inefficiency of East Java rice production in 2018. Based on the results of this study's review, the practical implications for the government must continue to work to increase the scale and impact of efficiency on rice production, particularly on adding irrigated land to rice commodities, so that rice production can increase to the maximum and domestic food needs can be satisfied. Since the population of Indonesia continues to rise significantly, and rice is in fact a staple food for the people of Indonesia, rice production needs to be increased to ensure national social security. For this reason, it is necessary for the government to pay more attention to policies regarding the use and addition of paddy fields in order to keep optimum domestic rice production.

1. Introduction

Indonesia is the world 's largest archipelagic country with different kinds of ethnicity, race, customs and culture including a variety of staple foods. One of the Indonesian people's staple foods is rice because rice is that type of food commodity that is so much needed. The preference of Indonesian people for rice is very high so that rice demand in Indonesia continues to rise every year.

Indonesia is an agricultural country that has become one of the world's largest rice-producing countries. Indonesia is still unable to meet its people's food needs, due to the extent of agricultural land and abundant harvests. One strategy of the government to maintain national food security is therefore to import rice from many neighboring countries (Statistics Indonesia, 2019). Indonesia imported rice from Thailand, Japan, India, Taiwan, Malaysia, Vietnam, the Philippines, Singapore, Oman, Qatar, Pakistan and Korea over the span of five years in a row namely from 2015 to 2019. Increased demand for rice that is not met by a production increase demands that Indonesia import rice annually. This import operation aims to cover the lack of domestic demand for rice.

Referring to data from the Indonesian Central Statistics Agency, a year 's total rice consumption is higher than a year 's total rice production. High total consumption and not offset by increased production will lead to increased demand for rice and a risk to national food handling. The government has therefore taken measures to import rice from many neighboring countries. The number of rice imports in Indonesia has increased each year. However, Indonesia's rice import figures dropped markedly in 2017, from 997.7 thousand tons in 2016 to 127.2 tons in 2017. In 2018, different conditions jumped sharply with a total import of 1,801,576, 4 tons of rice.

Indonesia faces a major challenge in stabilizing national food security. To meet domestic food needs, the government must import rice from several neighboring countries. However, it will have an impact on the welfare of Indonesian farmers with rice imports continuing and increasing each year. Because farmers are the main livelihood source for most of Indonesia's population (BPS, 2019). For this purpose, to increase yields, it is important to evaluate the output and productivity of domestic rice production, both in terms of labor, seed use, paddy fields, fertilizer, and the technology used. To increase productivity in production, the degree of efficiency, and inefficiency in the inputs and outputs used is very important to identify (Bhattacharyya & Mandal, 2016).

As well as meeting basic food needs and enhancing national food security, increased rice production is also capable of improving farmers' welfare and generating employment and affecting food prices (Schneider & Gugerty, 2011). Based on the findings of Gollin & Rogerson (2014), it is reported that a 10 percent increase in output would have an impact on the improvement of farmers' welfare, which is important in proportion to the effect of a 62 percent increase in consumption.

East Java is one of Indonesia's provinces with the highest crop yield among 33 additional provinces. In 2017 East Java produced 13.60 million tons of rice produced in total and became Indonesia's largest food buffet. The following year, however, witnessed a very dramatic decline to 10.53 million tons of rice, which was produced successfully. As well as experiencing a decline in East Java, most other provinces also experienced a decline. This needs to be studied in greater depth on the causes of the decline in rice production, particularly in the East Java Province which is Indonesia's largest rice barn.

As we know the agricultural sector is the main source of livelihood for the majority of the population, particularly in rural areas of East Java. Growth in agricultural productivity, especially rice commodities, can be a transformation of the rural economy. Furthermore, it is one of the ways to help reduce rural poverty. That has been proven on the basis of classical economic development theories and the results of the latest empirical findings. Increased productivity in the agricultural sector is the main factor behind the great expansion of agriculture (Wickramasinghe, 2018). In line with Abro et al., (2014) findings, which state that increasing productivity of farmers is beneficial in improving the

welfare of farm households. McArthur & McCord, (2017) also state that increasing rice production plays a significant role as a driver of structural economic change.

Over time, land narrowing, particularly in East Java, can not be avoided every year, due to the conversion of land from farming to non-farming. Though the land area is one of the important variable components that affect the improvement of rice production technical performance. Nevertheless, it is still possible to increase rice production by raising the degree of technological productivity in the agricultural sector. Since, based on the results of the (Tinaprilla et al., 2013) report, the level of technical efficiency in rice production in Java was 74.22 percent with the most sensitive land variables affecting rice production. Additionally, research conducted by Kusnadi et al., (2016), Nwaru & Iheke (2010), and studies conducted by Yoko et al., (2017), states that land is an elastic variable in influencing rice production.

Certain relevant variables besides land that has a major impact on the technical efficiency of rice production based on research carried out by Anik et al., (2017) are the variables of natural resources, labor and technology. Another case with a study by Fuglie et al., (2017) notes that the key drivers of increased rice production are funding and development assistance from the government and the institutions concerned. Whereas research by Suphannachart (2016) notes that the positive determinant of rice production is the superior seed variable or the adoption of superior rice varieties.

Increasing production by means of technical efficiency is very important to further research in order to find out other variables that influence the technical efficiency of raising rice production. In addition, the land conversion will affect changes in the value of rice production, particularly in East Java, for the variable land area for rice commodities.

This study will address and explore the technical and efficiency of rice production in East Java in greater depth. This study will analyze the technical efficiency of rice production referring to data reports and publications from the East Java Province, Central Statistical Office, the Ministry of Agriculture, and other institutions associated with the cases discussed in this paper. This study aims to evaluate and determine the factors of efficiency and inefficiency in farming by measuring the input-output used, particularly in rice production. In this case, it is necessary to know what factors are influential so that it can be assessed in order to improve the efficiency of rice production in Indonesia, especially in East Java. So that other province that needs increasing rice production may later be used as an example. It can also be used as a reference for the government to take steps to formulate policies, especially in the food sector, particularly for domestic rice production.

2. Literature Review

The importance of rice commodities for most countries around the world, particularly those that make rice as Indonesia 's main staple food. Make a lot of people do research related to rice and its production, especially from the world of education. Various models, goals, and research literature from different countries have been carried out, including work on productivity and inefficiency in rice and rice processing. In addition to the model used in this study, the objective is to predict and analyze factors that determine productivity in the agricultural sector, particularly rice fields that can be used later to evaluate rice production (Fuglie et al., 2017). So that the results of this study's significant findings will be used to suggest policy formulation and appropriate solutions increase rice production in Indonesia.

The agricultural sector is one of Indonesia's leading sectors, especially rice commodities that can be fairly efficient in the economy (Kusnadi et al., 2016). The agricultural sector in Indonesia becomes one of the sectors which contributes significantly to the Gross Domestic Product (GDP) annually (BPS, 2019). Given the importance of rice commodities, recent observational studies have been conducted by several researchers in rice production through technological efficiency, as well as

factors affecting rice production using various models of the process. Regardless of the model used, the aim of this study is to analyze the determinants which affect the level of rice production's technical performance.

This section will include a brief overview of results from recent studies based on an analysis of the rice production's technical performance. In an overview of rice farmer efficiency studies, Mazumder (2013) reported that the average technical output in the Assam region was 69 percent, indicating that technical efficiency has a major impact on growing growth. This appears to be affected by the technicality of the proportion of land used to grow rice while age and labor education are factors influencing inefficiency. Seok et al., (2018) conducted another study on rice farming in Korea, which examined the efficiency and determinants of farm productivity. His results indicate that the technical efficiency of rice production is negatively influenced by age, schooling, labor, property, and property.

Other results from Nguyen et al., (2019) in Hanoi, Vietnam suggested that the technical efficiency of rice production in 2018 was generally relatively good technical performance. The output is explained by several factors, namely the characteristics of farmers, including age, education, gender, and external factors such as Gross Domestic Product which have an effect on technical inefficiency. In their report, Sari & Winahju (2016) reported that the predictor variables influencing rice production in East Java in 2014 were only land area variables, whereas other predictor variables such as fertilizer usage and pesticides did not affect rice production in East Java in a significant way.

Ishaq et al., (2017) said in 2014 that land area and rainfall had a major effect on East Java rice production. Puspitasari et al., (2019) indicated that irrigation had an impact and could increase food crop productivity, especially rice. In line with the findings of a Muzdalifah (2014) study, which also notes that irrigation has a major impact on rice farming production.

Not only variables affect the level of technical efficiency, which requires attention. But it is also very important to note important variables that affect technical inefficiency. The quality and ability of the workforce are still poor and causes a reduction in agricultural productivity, especially in rice commodities (Mantiri et al., n.d.). However, defective irrigation canals do need to be addressed, as they have a real effect on the technological efficiency of production (Prabandari et al., 2013).

Referring to literature and studies conducted by researchers in different parts of the world, this paper examines and tests the efficiency and uses a frontier stochastic analysis model to determine the productivity factors for rice production in Indonesia. In this study, researchers used the latest data collected from different sources regarding the problem to be studied.

3. Research Method

SFA Model / Technical Efficiency

This study focuses on measuring the level of efficiency in rice production and determining the factors that form productivity. Affiliated with the border output feature of the East Java Province consisting of 38 City Regencies referring to the Central Statistics Office, the Ministry of Agriculture, the East Java Province Regional Growth Planning Board, and other related research institutions. The government's orientation in this study is to strengthen national food security by increasing the output of rice production from the use of certain inputs. Hence the performance calculation in this analysis is an output-oriented.

The model for measuring efficiency that will be used in this study is stochastic frontier analysis (SFA). SFA is a parametric method in which the output function assumptions are defined, and can be statistically estimated. The benefit of this model is that the hypothesis can be statistically checked, and a proven type of operation follows the relationship between input and output. Additionally, SFA is

used simultaneously to estimate the technical effectiveness and the effective model of the technical inefficiency of a company (Song & Chen, 2019).

In this analysis, the application of SFA is focused on models of Battese and Coelli, using panel data, if mathematically depicted:

$$\ln y_{it} = \beta_o + \sum_{n=1}^{N} \beta_n \ln x_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{n=1}^{N} \beta_{nk} \ln x_{nit} \ln x_{kit} + \beta_t t + \frac{1}{2}\beta_{it} t^2 + \sum_{n=1}^{N} \beta_{nt} \ln x_{nit} t + v_{it} - u_{it}$$

$$u_{it} = \delta_o + \sum_{k=1}^{K} \delta_k Zk_{it} + w_{it}$$

Where y is output in this study, x_n is input, t is the time trend variable, $z_k$is an exogenous variable, β_0 intercepts the production function, δ_0 is estimated as the ineffective intercept function, β and δ is estimated as the parameters. Subscript notation I show analyzed DMU (Decision Making Unit), subscript notation t shows observation time, v_{it} is a stochastic error component, u_{it} is a technical inefficiency and w_{it} is an inefficiency component.

Frontier production function parameters and inefficiency effects are estimated simultaneously using the maximum likelihood method based on assuming that the error components v_{it} and u_{it} are distributed appropriately.

$\sigma s2 = \sigma s2 + \sigma s2$ and $y = \sigma 2/\sigma s2$

With values from 0 to 1 y is a variance parameter correlated with an inefficiency effect of u_{it}. If y = 0, the inefficiency function exogenous variable can go directly to the output boundary .

Technical efficiency can be predicted on the basis of conditional expectations, adapted to the model assumptions.

$$ET = \frac{y_{it}}{y *_{it}} = \exp(-u_{it}) = \exp(-Zk_{it} - w_{it})$$

Where ET is technical efficiency, y_{it} is the performance of the output and $y *_{it}$ is the maximum potential of the output. The technical efficiency values range from 0 to 1. DMU that reaches the value 1 means it was efficient, and if the achievement is less than 1 then the coefficient.

The selection stage of the model is carried out in accordance with the observations following the above steps. By using the generalized LR-test defined by a mathematical formula:

$$\lambda = -2\{\log[Likelihood(H_0)] - \log[Likelihood(H_1)]\}$$

The "mixed" X^2 distribution is used to test whether there is an effect of inefficiency on the production function, where if the LR test value is less than the mixed X^2, then H_0 or the no-inefficiency model is rejected and H_1 is accepted as the translog model (Song & Chen, 2019).

As for the formulation of the Cobb Douglas model:

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_{ni} + v_i - u_i$$

For the Hick Neutral formula:

$$\text{In } y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n \text{ In } X_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{n=1}^{N} \beta_{nk} \text{ In X}_{nit} \text{In X}_{kit} + \beta_t t + \frac{1}{2}\beta_{it} t^2 + v_{it} - u_{it}$$

For model formula No Technological Progress:

$$\text{In } y_{it} + \beta_0 + \sum_{n=1}^{N} \beta_n \text{In } X_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{n=1}^{N} \beta_{nk} \text{ In } X_{nit} \text{In } X_{kit} + v_{it} - u_{it}$$

And for the Inefficiency Effect:

$$\text{In } y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n \text{In} X_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{n=1}^{N} \beta_{nk} \text{In } X_{nit} \text{In } X_{kit} + v_{it}$$

Efficiency studies usually use the techniques of data envelopment (DEA) and stochastic frontier analysis (SFA). There are advantages and disadvantages of each method, but, of general, SFA can be used to perform research using large samples, and thus, output calculation can be achieved. On the other hand, SFA is often commonly used to evaluate the efficiency of the production system, so this technique is appropriate for the analysis of production processes, in particular in the agricultural sector (Nguyen et al., 2019).

We tend to use the SFA approach in this analysis because this approach is superior to other approaches. The SFA methodology uses mathematical programming methods that remove the association of input, output, and other exogenous variables that influence estimates of effectiveness. In particular, the SFA method is commonly used by researchers to evaluate the degree of technical performance measurement.

Data and Variable Selection

The data used in this study are secondary data from an agricultural sector survey conducted by the Ministry of Agriculture of the Republic of Indonesia and the Indonesian Statistics (BPS) Agricultural Census, and publishing data from institutions related to this research. The data we use are data from 2018 since rice production has decreased this year due to inadequate input or output factors. In order to find out which factors cause inefficiencies in rice production in East Java in 2018, it, therefore, needs to be studied more deeply. Table 1 provides a description of the variables used in the analysis.

Table 1. Definition and measurement of output/input on rice production

Variable	Description	Unit
Rice Production (y)	Total production of rice in a year	Ton
Milled Dry Grain/GKG (x1)	Total GKG in a year	Ton
Labour/Lb (x2)	Total Labour/farmers used for rice plants	Unit of person
Land/L (x3)	Total land use for rice plants	Ha
Irrigation/I (x4)	Total broad irrigation in a year	Ha
GDP/PDRB (z1)	Gross Domestic Product at current prices (East Java)	Bilion (IDR)
Population (z2)	Total population per sub-district in East Java	Unit of person

4. Results and Discussion

Rice Production Frontiers in East Java

The Cobb-Douglas production function is selected on the basis of the model selection analysis and is implemented accordingly in this report. The results of the Maximum Likelihood Estimation (MLE) estimate illustrate the effect of research inputs on output in East Java in 2018. The results of these estimates were summarized and shown in table 2.

Table 2. SFA Production Frontiers of Rice Farms in East Java 2018

Variables	Coefficient	t-ratio
Constant	2.118	5.955
Milled Dry Grain/GKG (x1)	0.574*	0.588
Labour/Lb (x2)	-0.223	-0.152
Land/L (x3)	-0.245	-0.142
Irrigation/I (x4)	0.939*	0.162
Sigma-squared	0.312	
Gamma	0.999	
Log-likelihood function MLE	-0.585	
LR test of the one-sides error	0.734**	

Notes: indicate significant differences at *p<0.01 and **p<0.05 respectively

Source : Stochastic Frontier Analysis

The main indicators of the results of the MLE estimation are the *sigma square* and *gamma* values, and it is known in Table 2 that the *sigma square* value is relatively small, so it can be said that the *error term* is normally distributed in this study. The *error term* comes from the 0.999 inefficiency or gamma effect, which supports the analysis of factors associated with this research. Then for the *LR-test* value is also greater than the Kodde and Palm table values with a confidence level of 95%, which means that the rice production value is influenced by efficiency factors and technical inefficiency factors.

In this estimate result, the variable Milles Dry Grain / GKG and the variable Irrigation have a positive effect on the value of rice production in East Java in 2018. Both of these variables have a significant impact on rice production to a confidence level of 99% (α 0.01). The irrigation variable elasticity value is the highest compared to other variables, meaning that if the input variable decreases, the value of rice production in East Java will increase by 9.4%, *cateris paribus.* The rise in the input is considered to be very sensitive to the yields of grain and is an addition to the output of rice. This is consistent with research conducted by Bhattacharyya & Mandal (2016), which states that the irrigation input on rice production has a significant positive in effect order to increase the value of rice production by adding or expanding irrigation land inputs. Whereas research by Suppannachart (2013) notes that the positive determinant of rice production is the superior seed variable or the adoption of superior rice varieties. Ishaq et al., (2017) said in 2014 that land area and rainfall had a major impact on East Java rice production. Puspitasari et al., (2019) indicated that irrigation has an impact and can increase food crop production, particularly rice. In line with the findings of research carried out by Muzdalifah (2014) which also notes that irrigation has a major impact on lowland rice production.

Unlike the case of the variable Labor and Land which actually has a negative effect. This shows that labor and land adversely affected the technological efficiency of rice production in East Java in 2018, triggering a decline in the rice production value that year. This problem is caused by many factors, including the shrinking of agricultural land (paddy fields) in East Java, which initially covered an area of 2,285,232 ha in 2017 to 1,828,700 ha in 2018 (BPS, 2018). This land narrowing is due to changes in land use such as being used as an integrated industrial area, expansion of the manufacturing and extractive industries, the property industry, etc. It is stated on the basis of the results of the MLE output that the labor variable also has a negative effect, indicating that the increase in labor in 2018 actually reduces the level of technical efficiency of the value of rice production in East Java.

Such findings are not proportionate to the results of the work carried out by Tinaprilla et al., (2013) report, the level of technical efficiency in rice production in Java was 74.22 percent with the most sensitive land variables affecting rice production. Additionally, research conducted by Kusnadi et al., (2016), Nwaru & Iheke (2010), and studies conducted by Yoko et al., (2017) states that land is

an elastic variable in influencing rice production. Research conducted by Anik et al., (2017)The variable natural capital, labor, and technology is the main drivers in increasing the technical efficiency of rice production.

Rice production level of technical efficiency in East Java in 2018

It is said that sub-districts which are capable of producing maximum output from a number of inputs used during the production process were technically efficient. Table 3. Summarizes the output distribution obtained by each sub-district in the East Java Province in 2018.

Table 3. Distribution of Production Efficiency of Rice Farms in East Java 2018

Efficiency range	Frequency (sub-district)	Percentage (%)
0.10 – 0.19	13	34.21
0.20 – 0.29	3	7.89
0.30 – 0.39	4	10.53
0.40 – 0.49	7	18.42
0.50 – 0.69	3	7.89
0.70 – 0.89	6	15.79
0.90 – 0.99	2	5.26
Total	38	100
Mean	0.267	
Maximum	0.999	
Minimum	0.102	

Source: Stochastic Frontier Analysis

Table 2. The highest efficiency level is shown to be 0.999, and the lowest efficiency level is 0.102. Up to 53.63 percent of sub-districts in East Java Province or 20 sub-districts have low-efficiency levels (0.5). The average output level value in East Java is 0.267, this value shows that there was no even distribution of the average technological efficiency in rice production.

Low technical efficiency in the process chain of rice production influences national food security and freedom on food (Kurnia & Iskandar, 2019). Low technical efficiency indicates that over 50 percent of sub-districts in East Java Province were unable to appropriately allocate resources or inputs to produce maximum output. For that in 2018, the trigger for the decline in the value of rice production in East Java can be used as an evaluation material for each sub-district so that the self-sufficiency of domestic rice is growing and can produce with the full quantity without having to import from abroad again.

Factors affecting rice production in the East Java Province

Based on the results of the SFA estimate, it is known that rice production in East Java Province is still less productive on average. Therefore, each sub-district always has the potential to enhance its performance by taking into account certain factors that affect the technical efficiency. These factors are all things related to internal as well as external production management. Table 4. The output results of estimating the technical inefficiencies of the stochastic frontier production function are presented in short.

Table 4. SFA production frontiers of rice farms in East Java 2018

Estimator of the Technical Inefficiency Effects of the Stochastic Frontier Production Function		
Variable	Coefficient	t-ratio
Constant	-0.109	0.15
GDP/PDRB *(z1)*	0.209**	0.111
Population *(z2)*	-0.409	-0.553
*Notes: indicate significant differences at *p<0.01 and **p<0.05 respectively.*		

source : Stochastic Frontier Analysis

For this analysis, there are two *z* variables used, and only population variables affecting the efficiency of rice production for East Java in 2018. This indicates that each year in East Java, along with growing population growth, would cause technical inefficiencies in the rice production cycle. This indicates that population growth is highly influential in community rice demand and rice consumption. Thus the population growth that increases annually must be balanced by an increase in rice production. This information can be used as a reference for evaluating manufacturing actors in order to improve technical efficiency in order to obtain maximum output and for the government to make policies that will be applied for years to come.

5. Conclusion

The results of this study are known to predict the Milles Dry Grain / MPD variable based on research using the SFA model and the irrigation variable has a positive and significant effect on the value of rice production in East Java in 2018. This is because the more rice fields get an optimum flow of irrigation, the amount and quality of grain will be made. Hence rice production is also going to increase. The variable land area used, however, has a negative impact on rising rice production. Since paddy fields have been turned to non-paddy fields or dry land. This resulted in a decline in rice production in East Java in 2018. Whereas the explanatory variable for population growth has an impact on East Java's technical inefficiency in rice production in 2018. And the empirical findings for explanatory variables are just population growth that influenced East Java's technological inefficiency in rice production in 2018.

There are still some drawbacks to this report. This analysis only tests the degree of technological efficiency with only the role of output and analyzes only from the side of certain variables. In addition to this research, the cost function was not used to calculate the level of technical efficiency of rice production in East Java. Also, the period under review is still tight. Future researchers are therefore expected to be able to incorporate more variables related to the calculation of the technological efficiency of rice production. And researchers can then gain new findings and generate new information for the public at large.

References

Abro, Z. A., Alemu, B. A., & Hanjra, M. A. (2014). Policies for Agricultural Productivity Growth and Poverty Reduction in Rural Ethiopia. *World Development*, *59*, 461–474.

Anik, A. R., Rahman, S., & Sarker, J. R. (2017). Agricultural Productivity Growth and the Role of Capital in South Asia (1980–2013). *Sustainability*, *9*(3), 470.

Bhattacharyya, A., & Mandal, R. (2016). A Generalized Stochastic Production Frontier Analysis of Technical Efficiency of Rice Farming: A Case Study from ASSAM, India. *Indian Growth and Development Review*, *9*(2), 114–128. https://doi.org/10.1108/IGDR-10-2015-0041

Fuglie, K., Clancy, M., Heisey, P., & MacDonald, J. (2017). Research, Productivity, and Output Growth in US Agriculture. *Journal of Agricultural and Applied Economics*, *49*(4), 514–554.

Gollin, D., & Rogerson, R. (2014). Productivity, Transport Costs and subsistence Agriculture. *Journal of Development Economics*, *107*, 38–48.

Ishaq, M., Rumiati, A. T., & Permatasari, E. O. (2017). Analisis Faktor-Faktor yang Mempengaruhi Produksi Padi di Provinsi Jawa Timur Menggunakan Regresi Semiparametrik Spline. *Jurnal Sains Dan Seni ITS*, *6*(1). https://doi.org/10.12962/j23373520.v6i1.22451

Kurnia, L. A., & Iskandar, D. D. (2019). Determinants self Sufficiency of Rice in Supporting Food Independence. *Ekuilibrium : Jurnal Ilmiah Bidang Ilmu Ekonomi*, *14*(2), 152–166.

Kusnadi, N., Tinaprilla, N., Susilowati, S. H., & Purwoto, A. (2016). Analisis efisiensi Usaha Tani Padi di beberapa Sentra Produksi Padi di Indonesia. *Jurnal Agro Ekonomi*, *29*(1), 25–48.

Mantiri, R. I. K. A., Rotinsulu, D. C., & Murni, S. (n.d.). *Analisis faktor-faktor yang mempengaruhi produksi padi sawah di kecamatan dumoga*.

Mazumder, R. (2013). Technical Efficiency and its Determinants in Backward Agriculture: The Case of Paddy Farmers in Hailakandi District of Assam. *Journal of Regional Development and Planning*, *2*, 35–53.

McArthur, J. W., & McCord, G. C. (2017). Fertilizing growth: Agricultural inputs and their effects in economic development. *Journal of Development Economics*, *127*, 133–152.

Muzdalifah. (2014). *Sawah di Desa Sidera Kecamatan Sigi Biromaru An effect of Irrigation about Farm Enterprises Production of Rice Plant Field in Sidera Village Sigi Biromaru sub district bahwa Kecamatan Sigi Biromaru Desa Sidera*. *2*(1), 76–84.

Nguyen, H. D., Ngo, T., Le, T. D. Q., Ho, H., & Nguyen, H. T. H. (2019). The role of knowledge in sustainable agriculture: Evidence from rice farms' technical efficiency in Hanoi, Vietnam. *Sustainability (Switzerland)*, *11*(9). https://doi.org/10.3390/su11092472

Nwaru, J. C., & Iheke, O. R. (2010). Comparative Analysis Of Resource Use Efficiency In Rice Production Systems In Abia State Of Nigeria. *Journal of American Science*, *6*(11), 396–408.

Prabandari, A. C., Sudarma, M., & Wijayanti, P. U. (2013). Analisis Faktor-faktor yang Mempengaruhi Produksi Padi Sawah pada Daerah Tengah dan Hilir Aliran Sungai Ayung (Studi Kasus Subak Mambal, Kabupaten Badung dan Subak Pagutan, Kota Denpasar). *Journal of Agribusiness and Agritourism*, 44946.

Puspitasari, O. D., Susanto, H., Arif, S., Unila, F., Prof, J., No, S. B., E-mail, B. L., & Publish, O. (2019). *Pengaruh Irigasi Terhadap Pertanian di Pringsewu Masa Penjajahan Belanda Tahun 1930-1936*. *01*.

Sari, A. D. P., & Winahju, S. (2016). Pemodelan Faktor-Faktor yang Memengaruhi Produksi Padi di Jawa Timur. *Jurnal Sains Dan Seni ITS*, *5*(2), 414–419.

Schneider, K., & Gugerty, M. K. (2011). Agricultural Productivity and Poverty Reduction: Linkages and pathways. *Libraries Test Journal*, *1*(1), 56–74.

Seok, J. H., Moon, H., Kim, G., & Reed, M. R. (2018). Is Aging the Important Factor for Sustainable Agricultural Development in Korea? Evidence from the Relationship between Aging and Farm Technical Efficiency. *Sustainability*, *10*(7), 2137.

Song, J., & Chen, X. (2019). Eco-efficiency of Grain Production in China Based on Water Footprints: A Stochastic Frontier Approach. *Journal of Cleaner Production*, *236*, 117685. https://doi.org/10.1016/j.jclepro.2019.117685.

Suphannachart, W. (2013). Total Factor Productivity of Main and Second Rice Production in Thailand. *Applied Economics Journal*, *20*(1), 1–22. https://doi.org/10.14456/aej.2013.1

Tinaprilla, N., Kusnadi, N., Sanim, B., & Hakim, D. B. (2013). Analisis Efisiensi Teknis Usahatani Padi Di Jawa Barat Indonesia. *Agribusiness Journal*, *7*(1), 15–34. https://doi.org/10.15408/aj.v7i1.5168

Wickramasinghe, G. A. U. (2018). Fostering Productivity in the Rural and Agricultural Sector for Inclusive Growth in Asia and the Pacific. *Asia-Pacific Development Journal*, *24*(2), 1–22.

Yoko, B., Syaukat, Y., & Fariyanti, A. (2017). Analisis Efisiensi Usahatani Padi di Kabupaten Lampung Tengah. *Jurnal Agribisnis Indonesia*, *2*(2), 127. https://doi.org/10.29244/jai.2014.2.2.127-140.