pISSN : 2301 – 8968
JEKT ♦ 14 [1] : 59-73 eISSN : 2303 – 0186

The Characteristics and Technical Efficiency of Independent Oil Palm Smallolders in Indonesia

Firna Varina
Sri Hartoyo
Nunung Kusnadi
Amzul Rifin

STIP Graha Karya
IPB University

ABSTRAK

Studi ini bertujuan untuk mengetahui efisiensi teknis dan menganalisis sumber inefisiensi produksi pekebun kelapa sawit mandiri dengan mengggunakan pendekatan stokastik frontier. Hasil studi menunjukkan bahwa semua variabel input berpengaruh positif terhadap produksi kelapa sawit. Pekebun mempunyai nilai rata-rata efisiensi teknis 0.6583, namun lebih dari 54 % yang mempunyai efisiensi lebih dari 0,70. Faktor-faktor seperti umur pekebun, pendidikan, penyuluhan, keanggotaan kelompok tani, kepemilikan lahan dan pembiayaan berpengaruh positif terhadap efisiensi teknis. Diharapkan dengan perbaikan faktor-faktor seperti penggunaan input, peningkatan pendidikan, penyuluhan budidaya kelapa sawit yang baik dan kemudahan akses perkreditan akan dapat meningkatkan produktivitas dan efisiensi teknis produksi kelapa sawit pekebun mandiri. Pekebun yang mempunyai tanaman kelapa sawit dengan umur lebih dari 31 tahun, dimana tanaman kelapa sawit mempunyai produktivitas dan TE terendah, harus mulai memikirkan peremajaan perkebunannya.

Kata Kunci: *Pekebun mandiri, stokastik frontier, efisiensi teknis*

Klasifikasi JEL: *C51, D24, Q15*

ABSTRACT

This study aims to determine technical efficiency and analyze the sources of inefficiency in palm oil production by independent smallholders using a stochastic frontier approach. The study results indicated that all input variables had positive effects on palm oil production. Farmers had an average technical efficiency value of 0.6583, but more than 54% had efficiency values above 0.70. Factors such as farmer's age, education, extension services, farmer group membership, land ownership, and financing had positive and significant effects on technical efficiency. It is suggested that the improvement of factors such as inputs, increased education, proper extension service of oil palm cultivation, and easy access to credit will increase the productivity and technical efficiency of independent oil palm smallholders. Farmers having oil palm trees at the age of more than 31 years (at which oil palm has the lowest productivity and TE) should start thinking about replanting.

Keywords: Independent farmers, stochastic frontier, technical efficiency

JEL Classification: C51, D24, Q15

INTRODUCTION

The Indonesian government has been developing oil palm as a driver of economic development in rural areas for four decades. The expansion of oil palm plantations, which began in the 1980s, went on a large scale, which initially involved smallholders with contractual ties to large state-owned companies. It then continued with large private companies, known as PIR, Perkebunan Inti Rakyat. Over time, the improvement in most PIR farmers' welfare made oil palm cultivation more attractive to independent smallholders. Smallholders having completed contracts with large companies (getting experience in palm oil cultivation and increased welfare through previous agreements) will quickly adopt independent palm oil plantation development (Gatto *et al.*, 2017).

The expansion of oil palm plantations by farmers has created jobs in the Indonesian economy (Jelsma *et al.*, 2017). In 2018, oil palm smallholder plantations' total area reached 5.81 million hectares or 45.54% of Indonesia's entire oil palm land (BPS 2019). Thus, more than 2.6 million households depend on this commodity (Ditjenbun, 2018). Of these smallholder plantations, about 79% are controlled and cultivated by independent smallholders. Thus, independent oil palm farmers will become key players for developing the Indonesian oil palm industry in the future.

In terms of intensification, independent oil palm farmers still face significant challenges in how to increase production. The productivity of smallholder oil palm plantations, especially independent farmers, are lower than large plantations. In 2018, the productivity of sizeable private palm oil plantations reached 3.85 tons of CPO/Ha, while smallholder productivity was only 3.06 tons of CPO/Ha (BPS 2019). The low use of fertilizers by smallholders and the lack of access to fertilizers and pesticides, the use of low-quality seeds, and the application of poor production practices are the reasons for the low oil palm production of independent farmers (Lee *et al*., 2014; Euler *et al*., 2016; Jelsma *et al*., 2017).

The increase in production is not only determined by the adoption of technology but also the rise in the smallholders' technical efficiency. According to Coelli *et al*. (2005), technical efficiency shows smallholders' ability to achieve maximum output using existing production inputs. This aspect drives the need for technical efficiency analysis of production to help formulate policies for the development of independent oil palm smallholders, especially in increasing smallholders' ability to manage their farms. Consequently, this study will describe the characteristics of independent oil palm smallholders and analyze the technical efficiency of independent oil palm smallholders in Indonesia.

MATERIALS AND METHODS

The data used in this study are secondary in the form of a cross-section data from the 2014 estate cultivation household survey (ST2013 SKB) conducted by BPS-Statistics Indonesia. The analysis was carried out on 18,003 selected farmers with several limitations, namely the farmers having plantation in one area with the same plant age, monoculture planting system, and plant age in the 3-31 years production period.

The stochastic frontier production model is used in the analysis of the production function. It was developed by Aigner *et al*. (1977) and Meeusen and van Den Broeck (1977) through the following model:

$$Y_i = f(X_i, \beta) e^{v_i - u_i}, \quad i = 1, 2, \ldots N \quad (1)$$

where Y_i is the output of the i-th farmer and $f(X_i, \beta)$ represents the corresponding production function. X_i is the farmer's input variable vector; β corresponds to the parameter vector to be estimated; v_i is a noise effect that cannot be controlled by the farmers and is assumed to be independent and identically distributed iid~N $(0;\sigma^2_v)$. u_i is a technical inefficiency in a model with and assumed to be iid and truncated $(u_i \sim N^+(\mu(Z_i),\sigma^2_u))$. Zi showed socioeconomic variables of farmers.

The technical efficiency (TEi) is measured by calculating it from the ratio of the observed output to the maximum output (frontier).

$$TE_i = \frac{Y_i}{f(X_i\ \beta)\exp(v_i)} = \exp(-u_i) \quad (2)$$

The stochastic frontier model's application requires a suitable functional form specification, where in many pieces of literature, the Cobb-Douglas (CD) and transcendental logarithmic (TL) forms are used. In this study, the functional form that fits the data is TL. The TL model was modified to accommodate a value of 0 on the use of chemical fertilizers by some farmers according to the Battese (1997) method. Thus, the model specifications are as follows:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{2} \alpha D_{ji} \sum_{j=1}^{3} \beta_j \ln X_{ji} + \frac{1}{2} \sum_{j=1}^{3} \sum_{k=1}^{3} \beta_{jk} \ln X_{ji} \ln X_{ki} + (v_i - u_i) \quad (3)$$

where ln is the natural logarithm; Yi is the fresh fruit bunch (FFB) production of the i-th farmer (kg); α and β are the parameter coefficients to be estimated; D1 is the dummy variable for the chemical fertilizer used where the value is 1 if the farmer uses fertilizer and 0 if not; D2 is the dummy variable for the use of certified seed where the value is 1 if the farmer uses certified seedlings and 0 if not; X1 is the weighted variable number of productive trees by considering the effect of plant age on production (LPN). The LPN is calculated by dividing the average FFB output for each age profile by average FFB output in the peak period. The age profile is classified according to Euler *et al*. (2016), namely u1= 3-7 years (when potential yield begins to increase), u2 = 8-16 years (as the peak yield period), and u3= 17-25 years (when yield begins to decrease until economic life) and u4= > 25 years (exceed the economic life of oil palm). The LPN values for each age profile are 91.6/112.4; 112.4/112.4; 110.7/112.4; 88.6/112.4, respectively. A similar approach has been applied in previous studies in capturing the effects of age and number of trees on the production of oil palm (Alwarittzi *et al*., 2015) and cacao (Ofori-bah and Adjaye, 2011); X2 is number of workers (man days), and X3 is total use of chemical fertilizers (Kg).

Technical efficiency is obtained through Battese and Coelli (1995) approach, where the estimation of production function parameters and inefficiency functions is carried out simultaneously. The technical inefficiency function uses the following equation:

$$u_i = \delta_0 + \sum_{j=1}^{8} \delta_j Z_{ji} \quad (4)$$

where Zj shows the socio-economic variable of the smallholders; Z1 Age of a farmer (years); Z2 length of formal education (years); Z3 dummy received extension service (1-received 0- not received); Z4 dummy membership of farmer group (1-member of farmer group 0-non-member); Z5 dummy land ownership status (1-own land 0-not owned); Z6 dummy tractor as tool of land processing used (1- use tractor 0-not use); Z7 dummy source of farm financing source (1 receive loan 0- self expense); Z8 dummy assistant recipients (1-received assistance 0- not received).

RESULTS AND DISCUSSION

Characteristics of Independent Oil Palm Smallholders

Independent oil palm smallholder plantations are located in almost all Indonesian islands. Based on the study results, the independent palm oil farmers are 47.1 years old on average, meaning that they are relatively old with an education level of 6.97 years or equivalent to grade 1 junior high school. They also have average household members of 4 (Table 1).

In terms of farming characteristics, the average area of plantations owned by farmers was 1.62 hectares, and more than 79% of farmers had fewer than two hectares. The farmland is generally self-owned. In the land processing, smallholders are more dominant in using human labor than tractor cultivators. In general, farmers use their capital to finance their farming. This aspect shows that the independent oil palm smallholders are generally small farmers, cultivating their land traditionally and finance their own farming.

The average age of oil palm trees is 8.84 years, meaning that the plant's age is in the peak production according to the age category proposed by Euler *et al*. (2016). However, the productivity of oil palm is still far below the productivity potential issued by Indonesian Oil Palm Research Institute. The average potential of palm

Table 1. Characteristics of Independent Oil Palm Farmers in Indonesia

Variables	Values	
Characteristic of Household		
Age of oil palm farmers (years)	47.11	
Education (years of schooling)	6.97	
Household size	4.21	
Characteristic of farming		
Area cultivated (Ha)	1.62	
Age of oil palm plant (years)	8.84	
Productivity of FFB (kg/tree)	106.70	
Chemical fertilizer used (kg/tree)	3.60	
Certified variety seed used	35.25	%
Land ownership	97.94	%
Tractor as tool of land processing used	0.65	%
Self financing	91.06	%
Receiving assistance	22.55	%
Characteristic of farmers institution		
Receiving extension services	5.28	%
Member of farmer group	19.57	%
Distribution of oil palm production		
- Traders	89.94	%
- Plantation company/ Industry	5.46	%
- Village/ plantation cooperative	3.97	%

Source: BPS (data processed)

oil in S2 land was 189 kg FFB/tree, while the study results only reached 106.70 kg/tree or 56.41% of the potential productivity

In terms of inputs, only 37.25% of the independent farmers used certified seed. Smallholders will get low productivity using uncertified seedlings where the maximum FFB production level is only 50%, and the maximum CPO yield is 18% (Ditjenbun, 2014). Apart from the low use of certified seeds, the dosage of plant fertilization is also relatively low. The average chemical fertilization rate is only 3.60 kg per tree per year, which is lower than the recommended standard dose of 5-10 kg per tree (Ditjenbun, 2014).

More than 80% of the farmers were not members of farmer groups and 94.72% did not receive extension service in terms of institutional characteristics. The smallholders do not join the farmer group because there is no such institution in their place of residence. For this reason, the role of the government through extension institutions in disseminating information on agricultural technology to farmers through farmer groups should pay attention to areas where palm oil plantations are concentrated. In terms of FFB marketing, the role of intermediate traders is very dominant. Almost 90% of the independent farmers sell FFB to traders, 5.46% to plantation companies/industry (PKS), and 3.97% to village cooperatives.

Stochastic Frontier Production and Technical Inefficiency Effect Model

The results of the maximum likelihood estimation (MLE) of the stochastic frontier production function and the inefficiency effect model of independent oil palm farmers, specified in equations (3) and (4), are presented in Table 2. The inefficiency effect in the model can be identified through the lambda value. The values of σ_u, σ_v and lambda are significant at the 1% level. A lambda value greater than 1 implies that there is inefficiency effect in analyzing production function of independent oil palm farmers.

Table 2 shows that the use of certified seed has a significant effect on FFB production. All production inputs had positive and significant impacts on oil palm production from the partial production elasticity calculation. All inputs in the production function are inelastic, indicating that an increase of 1% in each input will cause an increase FFB production of less than 1%. Of all the model inputs, the number of weighted productive trees is most responsive to oil palm production, because it has the most significant effect on FFB production with a production elasticity of 0.7104. This result implies that an increase in the number of productive palm oil tree by 1% will increase FFB production by 0.71%, ceteris paribus. This finding is consistent with previous studies proposed by Hasnah *et al*. (2004), Adar

Table 2: Maximum likelihood estimation of independent oil palm production

Variable	Coefficient		Std Err
Frontier			
Constant	5.1049	***	0.0718
ln weigted productive trees (ln X1)	0.8904	***	0.0274
ln labor (ln X2)	0.0668	***	0.0221
ln chemical fertilizer (ln X3)	0.0351	***	0.0035
0,5 x $(\ln X1)^2$	-0.0257	***	0.0075
0,5 x $(\ln X2)^2$	0.0519	***	0.0044
0,5 x $(\ln X3)^2$	0.0068	***	0.0004
ln X1 x ln X2	-0.0144	***	0.0046
ln X1 x ln X3	0.0039	***	0.0006
ln X2 x ln X3	-0.0053	***	0.0006
Dummy seed	0.0205	***	0.0070
Dummy chemical fertilizer	0.0189		0.0241
Variance and other model statistics			
sigma_u	2.3966	***	0.3638
sigma_v	0.2702	***	0.0043
Lambda	8.8701	***	0.3620
Log-likelihood	- 13,460		
Output Elasticities			
Productive trees	0.7104	***	
Labor	0.2122	***	
Chemical fertilizer	0.0451	***	

Notes: ** significant at 5%, *** significant at 1%

(2011), Ofori-bah and Adjaye (2011), and Juyaeng *et al*. (2018), where the number of productive plants has a significant effect on crop output.

The next highest elasticity is labor, with a production elasticity of 0.2122. An increase in the number of workers by 1% will increase palm oil FFB by 0.21%, ceteris paribus. The results of this study are in line with those of the research by Hasnah *et al*. (2004), Ofori-bah and Asafu-Adjaye (2011), and Onumah *et al*. (2013). Based on the chemical fertilizer variable, the production elasticity is 0.0450, meaning that an increase in fertilizer use of 1% causes an increase of

Table 3: Frequency distribution of technical efficiency

TE Level	Frequency	Percentage
≤ 0.10	104	0.58
0.11-0.20	581	3.23
0.21-0.30	777	4.32
0.31-0.40	1,011	5.62
0.41-0.50	1,346	7.48
0.51-0.60	1,819	10.1
0.61-0.70	2,591	14.39
0.71-0.80	4,384	24.35
0.81-0.90	4,962	27.56
0.91-1.00	428	2.38

0.05% in the production of oil palm FFB, ceteris paribus. Hasnah *et al.* (2004) and Alwarritzi *et al*. (2015) also showed the positive effect of fertilizers on oil palm production

Table 3 presents frequency distribution of the technical efficiency (TE) for independent oil palm smallholders in Indonesia. The TE value range for independent oil palm smallholders is 0.0319-0.9546 with an average TE of 0.6583. However, most smallholders (54.29%) are efficient because they have a technical efficiency value of > 0.70. This figure is not different from the results of the study by Hasnah *et al*. (2004) on NES farmers in West Sumatra (TE 0.66). The average TE value shows that there is still an enormous opportunity (34.17 %) for independent farmers to improve technical efficiency by using existing technology and resources.

Of the eight variables thought to affect the technical inefficiency of independent oil palm smallholders, six have been identified as having a significant effect on technical inefficiency (Table 4), namely the age of the farmers, education, extension service, membership of farmer group, land ownership and funding sources. The use of tractors and assistance does not contribute to technical inefficiency.

The older a worker is, the lower his workability will affect efficiency. This study's results indicate the opposite, where the sign of the coefficient value is negative with a significant effect on technical inefficiency, meaning that older farmers are relatively more efficient than younger ones. When viewed from farmers' distribution, most of the efficient farmers were farmers over 46 years of age (54.72%). This aspect is

Table 4: Estimates of inefficiency effect model

Variable	Coefficient		Std Err
Constant	-5.4228	**	2.2241
Age of oil palm farmers	-0.0429	***	0.0154
Education	-0.1037	***	0.0391
Extension services	-1.0331	*	0.5759
Membership of farmer group	-0.7904	**	0.3546
Ownership of farmland	-1.7119	**	0.7573
Tractor	1.4509		1.1762
Funding sources	-1.5414	***	0.5960
Assistant	-0.2748		0.2521

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

thought to be related to plantation management and not merely physical factors. Older farmers certainly had more extended experience than young ones, so that their managerial ability to make decisions about managing their plantations became better. The results of the study by Onumah et al. (2013), Adar (2011), and Wongnaa et al. (2019) revealed similar results of age affecting efficiency.

Education variable is significant with a negative sign, meaning that farmers having a higher education will be more efficient than those with low education. The majority of independent smallholders have primary education; a maximum of 60.32% completed Elementary school/equivalent. Farmers who did not complete primary school had an average TE of 0.6462 at the lowest, while farmers with higher education had an average TE of 0.6590. With higher education, farmers have broader insights and can read new information, making them more efficient in farming. It is essential to pay attention to the government to guide and foster highly educated young people to become farmers and re-brand the agricultural sector that the estate sector is not inferior to the industrial sector, providing better hope for the future. The results of the study by Binam *et al.* (2008) and Fadwiwati *et al*. (2014) also revealed the positive effect of education on the technical efficiency of farmers.

The coefficient extension service variable was negative, meaning that farmers who received extension (TE 0.6913) were more efficient than those who did not (TE 0.6564). Smallholders can improve their technical efficiency through extension services by applying innovations in cultivation techniques and using an optimal input. The results of previous studies identified the significant effect of extension service on technical efficiency, among others, Binam *et al.* (2008), Ofori-bah and Asafu-Adjaye (2011), Adar (2011), Onumah *et al.* (2013), and Wongnaa *et al.* (2019).

In line with extension service, the coefficient of farmer group membership is negative and significant, meaning that farmers who are members of farmer groups (TE 0.6748) are relatively more efficient than non-members (TE 0.6542). Farmer groups are groups of smallholders formed based on shared interests, similar environmental conditions, and familiarity to improve and develop members' businesses (SK Mentan No. 273/Kpts/OT.160/4/2007). Through farmer groups, the mass extension is provided by PPLs, independent extension agents, partner companies, related agencies, universities, and individuals. The positive effect of farmer group membership on technical efficiency is consistent with the results of a study by Adar (2011) in the highlands of NTT and Fadwiwati *et al.* (2014).

Land ownership will improve the technical efficiency of farming, as evidenced by the negative and significant coefficient value. As many as 97.36 % of the farmers cultivating their land had an average TE value of 0.6592, while the farmers working on the land that did not belong to them had an average TE of 0.6127. It is suspected that a sense of belonging strengthens the smallholders in managing their plantations efficiently. The results of previous studies showing the positive effect of land ownership on technical efficiency include

Asravor *et al*. (2019) in the forest-savannah transition zone of Ghana

Table 5: Mean TEs of independent oil palm smallholder and productivities by the age of trees

Age of plant (Year)	Number of Sample (%)	Mean TE	Mean of productivity (Kg/tree/year)
3-7	54.10	0.6332	91.61
8-16	36.05	0.6878	112.43
17-25	8.59	0.6921	110.75
26-30	1.18	0.6725	91.60
31	0.08	0.4700	46.30
Total	100	0.6583	106.70

The source of financing for smallholders in managing their plantations generally comes from their own funds. The study results indicated that a loan in farm financing has a significant effect on-farm efficiency. Independent oil palm farmers are small farmers having limited capital. Thus, they need capital assistance from financial institutions to carry out their farming activities. Farmers having loans from financial institutions had an average TE of 0.6859, while self-financed farmers had an average TE of 0.6556. This description can be used as information for related parties to assess the benefits of liquidity assistance for smallholders with less than 2 hectares of land allocating funds for plantation management. This aspect will lead to efficiency and facilitate access to credit for smallholders. The results of previous studies showing the positive effect of credit on technical efficiency included Binam *et al*. (2008), Onumah *et al*. (2013), Fadwiwati *et al*. (2014), Alwarritzi *et al*. (2015), and Wongnaa *et al*. (2019).

Various TE values were obtained when viewed from age group of oil palm plants (Table 5). When plant age in potential productivity increases before reaching a peak (3–7 years), the average TE is 0.6332. The average TE increases when the potential productivity reaches its peak (8-16 years), i.e., 0.6878. Until the palm oil trees reach economic age (25 years), the average TE is still high at 0.6921. The average TE begins to decline after passing the economic life and had the lowest TE when the oil palm reaches 31 years old. The lowest average TE is 0.4700, and the lowest average productivity is 46.30 kg FFB/tree/year. Older plants with increased height and low productivity require high harvesting labor costs, causing inefficient farming. For this reason, smallholders need to anticipate the existence of their farming by replanting palm oil trees when the plants reach 30 years of age.

CONCLUSIONS

Independent oil palm farmers are traditional small-scale farmers who generally have land with less than 2 hectares, where production facilities and technology are still low. The smallholders' institutions were not well developed, as evidenced by the minimum membership of farmer groups and only a small proportion of farmers who received extension services. Generally, FFB marketing is predominantly carried out through collecting traders. The average technical efficiency of independent palm oil plantations is 0.6583. However, more than 54% of the farmers had technical efficiency that is more than 0.70. Factors influencing technical efficiency are the age of the farmers, education, extension services, membership of farmer groups, land ownership status, and financing sources.

Increasing the technical efficiency of independent oil palm farmers can be done by (1) improving the knowledge and skills of young smallholders in managing palm oil plantations by increasing the intensity of extension and skills through training and apprenticeship, (2) expanding the role of extension agencies in expanding the capacity of farmers. In terms of farming techniques and disseminating the latest and appropriate technology information, (3) smallholders' access to financial institutions and land ownership should be facilitated.

REFERENCES

Adar, D. (2011). *Keragaan Usahatani dan Efisiensi Produksi Jeruk Keprok Soe berdasarkan Zona Agroklimat di Provinsi Nusa Tenggara Timur*. PhD: Institut Pertanian Bogor.

Aigner, D.J., Lovell, C.A.K. and Schmidt, P. (1977). Formulation And Estimation Of Stochastic Frontier Production Function Models. *Journal of Econometrics*, 6(1), pp. 21–37.

Alwarritzi, W., Nanseki, T. and Chomei, Y. (2015). Analysis of The Factors Influencing The Technical Efficiency Among Oil Palm Smallholder Farmers in Indonesia. *Procedia Environmental Sciences,* 28, pp. 630-638.

Asravor, J., Wiredu, A.N., Siddig, K. and Onumah, E.E. (2019). Evaluating the Environmental-Technology Gaps of Rice Farms in Distinct Agro-Ecological Zones of Ghana. *Sustainability* 11(7), pp. 1-16.

Battese, G.E. (1997). A Note on The Estimation of Cobb-Douglas Production Function When Some Explanatory Variables Have Zero Values. *Journal of Agricultural Economics*, 48(2), pp. 250–252.

Battese, G.E. and Coelli, T.J. (1995). A Model for Technical Inefficiency Effects in A Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, 20(2), pp. 325–332.

Binam, J.N., Gockowski, J. and Nkamleu, G.B. (2008). Technical Efficiency and Productivity Potential of Cocoa Farmers in West African Countries. *Developing Economics*, 46(3), pp. 242–263.

Badan Pusat Statistik. (2019). *Statistik Kelapa Sawit Indonesia 2018*. Jakarta: BPS.

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J. and Battese G.E. (2005). *An Introduction to Efficiency and Productivity Analysis*. 2nd ed. New York: Springer Science+Business Media, Inc.

Direktorat Jenderal Perkebunan. (2014). *Pedoman Budidaya Kelapa Sawit (Elais guineensis) yang Baik.* Jakarta: Ditjenbun.

Direktorat Jenderal Perkebunan. (2018). *Statistik Perkebunan Indonesia 2017 - 2019: Kelapa Sawit*. Jakarta: Ditjenbun.

Euler, M., Hofman, M.P., Fathoni, Z. and Schwarze, S. (2016). Exploring Yield Gaps in Smallholder Oil Palm Production Systems in Eastern Sumatra, Indonesia. *Agricultural System,* 146, pp. 111-119.

Fadwiwati, A.Y., Hartoyo, S., Kuncoro, S.U. dan Rusastra, I.W. (2014). Analisis Efisiensi Teknis, Efisiensi Alokatif dan Efisiensi Usahatani Jagung Berdasarkan Varietas di Provinsi Gorontalo. *Jurnal Agro Ekonomi,* 32(1), pp. 1-12.

Gatto, M., Wollni, M., Asnawi, R. and Qaim, M. (2017). Oil Palm Boom, Contract Farming, and Rural Economic Development: Village-Level Evidence From Indonesia. *World Development,* 95, pp. 127–140.

Hasnah, Fleming, E. and Coelli, T. (2004). Assessing The Performance of A Nucleus Estate and Smalholder Scheme For Oil Palm Production in West Sumatra: A Stochastic Frontier Analysis. *Agricultural Systems,* 79(1), pp. 17-30.

Jelsma, I., Slingerland, M., Giller, K.E. and Bijman, J. (2017). Collective Action in A Smallholder Oil Palm Production System in Indonesia: The Key To Sustainable and Inclusive

Smallholder Palm Oil?. *Journal of Rural Studies*, 54, pp. 198 -210.

Juyjaeng, C., Suwanmaneepong, S. and Mankeb, P. (2018). Technical Efficiency of Oil Pam Production Under A Large Agricultural Plot Scheme in Thailand. *Asian Journal of Scientific Research*, 11(4), pp. 472-479.

Lee, J,S,H,, Ghazoul, J., Obidzinski, K. and Koh, L.P. (2014). Oil Palm Smallholder Yields and Incomes Constrained by Harvesting Practices and Type of Smallholder Management in Indonesia. *Agronomy for Sustainable Development,* 34, pp. 501–513.

Meeusen, W. and van den Broeck, J. (1977). Efficiency estimation from Cobb–Douglas production functions with composed error. *International Economic Review,* 18, pp. 435–444.

Ofori-bah, A. and Asafu-Adjaye, J. (2011). Analysis Scope Economies and Technical Efficiency of Cocoa Agroforestry Systems in Ghana. *Ecological Economics*, 70, pp. 1508-1518.

Onumah, J.A., Onumah, E.E., Al-Hassan, R,M. and Brümmer B. (2013). Meta-Frontier Analysis of Organic And Conventional Cocoa Production in Ghana. *Agricultural Economics*, 59(6), pp. 271-280.

Wongnaa, C.A. and Awunyo-Vitor, D. (2019). Scale Efficiency of Maize Farmers in Four Agro Ecological Zones of Ghana: A Parametric Approach. *Journal of the Saudi Society of Agricultural Sciences*, 18, pp. 275-287.