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Analysis of the factors influencing the technical efficiency among oil palm smallholder farmers in Indonesia

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Abstract

Agricultural sector in Indonesia plays an important role in raising rural livelihood, as it is becoming the main source of national income. Oil palm plantation was emphasized in Master Plan for Acceleration and Expansion of Indonesia Economic Development (MP3EI) as one of the potential sectors in agriculture. Since the implementation of the plan, it had provided smallholder farmers with an opportunity to expand their resources for oil palm plantation. On the contrary, smallholders' oil palm cultivation were also facing productivity gap among farmers because of the background of farming practices. The present study aimed to investigate oil palm productivity of smallholder farmers with stochastic frontier approach to provide evidence on agricultural practices that were beneficial to enhance the productivity of oil palm. The results observed several socio-economic factors that can lead to the increasing of farmers' efficiency, such as farmers group, extension program, education level, and farm diversification. Empirical results were expected to provide better input to the government, in order to improve the policy regarding with the land expansion in oil palm sector.

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Keywords: Oil palm; smallholders; technical efficiency; stochastic frontier analysis; Indonesia

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1. Introduction

The increasing demand of oil palm has led to a rapid expansion of agro industry, with South East Asia and particularly Indonesia as the most productive countries for its plantation [18]. Master Plan for Acceleration and Expansion of Indonesia Economic Development (MP3EI) stated that oil palm is one of agricultural major sectors under focus to be developed, with Sumatera as the center for production. The aim of oil palm development is to reduce poverty in rural area by attracting its community to actively participate in agricultural sector as source of income. Given the importance of oil palm for piling up the national income and for increasing the standard of living in rural community, more attention should be given to downstream level who are called as smallholder farmers.

Accentuation of oil palm cultivation in MP3EI policy brings an opportunity for smallholder farmers. It was reported that smallholder farmers have occupied about 52% of total plantation area [8]. However, along with the tremendous trend of oil palm cultivation by smallholders, unequal agricultural practice still remains as an actual problem. Furthermore, significant gap of oil palm productivity among farmers conveyed inconsistent result to government expectation on reducing inequality of rural livelihood.

Oil palm cultivation was introduced in Riau Province in the 1980s by transmigration program, with aim to control over-populated islands by relocating inhabitants to the less populated islands. Oil palm plantations have been designated through Nucleus Estates and Smallholders (NES-scheme), in which a company operates a refinery and an estate supported by smallholding owned by trans-migrant or known as NES-Trans farmers. NES-Trans farmers were provided with technical assistance from company and divided into several group to ease the dissemination of technical information. Having learnt from NES-Trans farmers on successfully practicing oil palm plantation, local people, called as independent farmers, also followed the trend of oil palm cultivation. However, different from NES-Trans farmers, the independent farmers run their farm without contract farming system, and therefore, they were lack of guidance from formal institutions. Consequently, the independent farmers in the study area were observed to experience productivity gap that might come from the characteristic of their farming practices. Nevertheless, there was less attention on investigating the technical efficiency of oil palm farming with the case of both NES-Trans and Independent farmers, before the gap problem was increased significantly in recent years. One notable study was reported by Hasnah et al. [10], which took the case of NES-Trans farmers in West Sumatera, Indonesia.

Based on those backgrounds, this present study hypothesized that the existing of non-uniform practice in farming might affect the productivity performance. Furthermore, discussion on socio-economic characteristics of the farmers will provide better explanation on how to improve the farming practice. Hence, the main objectives of the present study were to investigate the oil palm productivity performance by analyzing the technical efficiency and to determine socio-economic characteristics of the farmers that have substantial impact to the technical efficiency. The study was expected to provide evidence on the important role of extension service and formal education to enhance oil palm productivity. Thus, the implication of the study might force the government to increase the investment on education facility, research and development as well as the extension service, in order to accelerate productivity of oil palm in smallholder's level. Other important issues were concerning the option of farm diversification and specific farm location that might sustain the future agricultural practice of smallholder farmers.

2. Data and empirical methods

2.1. Data

The primary data was formed from production performance of 271 oil palm smallholder farmers which gathered by structured questionnaire in 2013. The study sites were under Pelalawan Regency administration, Riau Province, western part of Sumatera, Indonesia. Hence, in the present study, two villages were under the NES-Trans program, namely "Makmur (MR)" and "Mekar Jaya (MJ)", and other two villages were classified as non- transmigration village for independent farmers; namely "Kiyap Jaya (KJ)"and "Lubuk Ogung (LO)". The study area holds variation of socio-economics characteristic of farmers and these 4 villages were attributed with geographical differences, particularly the characteristic of soil. Referring to the Reproduction Soil Map [13], mineral soil was covering 3 selected villages (MR, MJ and KJ) and peat land was existed in the southern part of LO village. Therefore, farm location will be introduced as one of unobserved variable in the technical efficiency and incorporated to the index of individual technical efficiency of oil palm farmers.

2.2. Literature review

Technical efficiency approach for investigating the performance level and inefficiency factors of oil palm farming has been widely applied by several studies. In West Sumatera, Hasnah et al [10] found that the mean of technical efficiency index of NES-Trans farmers using translog model was 0.66, which implied that farmers could increase the output of oil palm by using better extension service than using more input in production. They highlighted that the selection of progressive farmers was very important for future scheme since the progressive farmers had not been successful on disseminating farming guidance. Iwala et al. [12] applied stochastic frontier approach to investigate efficiency among oil palm farmers in Nigeria. They implied that the index of technical efficiencies varied among oil palm farmers, ranging between 0.463 and 0.999. The results indicated that the age of palm tree, the cost of fertilizers and agrochemicals, and the cost of harvesting and processing were positively correlated to the output. On the other hand, the use of labor had negative contribution to oil palm production due to excessive labor employment in the farming practice. Farmers' education level negatively contributed to efficiency because farmers tend to have off-farm job and delegated hired labor to operate their farm.

2.3. Analysis model

To estimate the efficient frontiers, a popular parametric method, the stochastic frontier analysis (SFA), was utilized. It has the main strength to be able to deal with the statistical noise in the data and also permits statistical testing of both the hypotheses pertaining to the production structure and the degree of inefficiency [7]. This function contains a disturbance term comprising of statistical noise and technical efficiency term (eq. 1 and 2). Technical efficiency consists of the ratio of the observed output, and the maximum feasible output is equal to 1. Therefore, inefficiency affects the model when technical efficiency score for each firm is less than 1.

$$Y = \left(\beta_0 + \sum_{n=1}^{N} \beta_0 \ln X_n + \sum_{n=1}^{N} \sum_{m=1}^{N} \beta_{nm} \ln X_n \ln X_{nm} + \left(V_i + U_i \right) \right) \tag{1}$$

$$U = \delta_0 + \delta_1 Z_{1i} + \delta_1 Z_{2i} + \cdots + \delta_n Z_{ni} \tag{2}$$

Y	=	Production per hectare
$\beta_0 - \beta_{nm}$	=	Regression coefficient including constant (β_0)
$X_0 - X_{nm}$	=	Production input per hectare
V_i	=	Random error term
U_i	=	Non-negative random variables which assumed to account for technical inefficiency
δ_0 - δ_n	=	Inefficient parameters
Z_{1i} - Z_{ni}	=	Socio-economic variables

3. Data and empirical methods

3.1. Descriptive statistics

Table 1 shows the descriptive statistics of household characteristic. There are two categories of variables: the given input of production with regard to oil palm productivity, and the unobserved variables such as socio-economic and spatial heterogeneity range for explaining inefficiency effect. In the present study, geographical variation of farm represented type of soil used for plantation and it was taken into account as a potential source of efficiency variation among farmers. There are two types of soil type that was observed: peat soil and mineral soil. Farm location was gathered from GPS point's records that were integrated with The Reproduction Soil Map [13]. The decision to introduce farm location into unobserved variable was to explain spatial heterogeneity in technical efficiency by introducing into dummy variable [1].

Table 1. Descriptive statistics of the variables of technical efficiency variables

Variable Code		Definition	Unit	Mean	Std. Dev.	Min.	Max.
Y	Yield	Oil palm fresh fruit bunch (FFB) yield	Ton/ha	19.59	6.0	4.8	46,64
Production input							
X_1	Fertilizer	Total of chemical fertilizer applied	Ton/ha	1.18	0.34	0.20	2.68
X_2	Herbicide	Total of herbicide applied	Liter/ha	3.94	1.12	1.5	7.5
X_3	Labor	Working day of hired & family labor	Man-day/ha	43.11	11.91	21	60
X_4	WPT	Weighted oil palm tree	Number/ha	0.84	0.13	0.56	1
Inefficiency variable							
Z_1	Group	1 = NES-Trans farmers; 0 = independent farmers	Dummy	0.60	-	0	1
Z_2	Education	Years of farmer education	Years	9.09	2.93	6	16
Z_3	Age	Head of households age	Years	49.15	7.44	31	84
Z_4	Divers	1 = have farm diversification; 0 = otherwise	Dummy	0.27	-	0	1
Z_5	Credit	1 = get access to credit; 0 = otherwise	Dummy	0.75	-	0	1
Z_6	Farm Location	1 = peat soil; 0 = mineral soil	Dummy	0.10	-	0	1

Note: Farm Location was recorded using GPS

As can be seen in Table 1, the yield variability was high with an average of 19.6 ton per hectare during 2012-2013. The amount of aggregated chemical fertilizer was about 1.18 ton per hectare, including urea, rock phosphate, potassium chloride, and dolomite. Farmers used herbicide 3.94 Liter per hectare in order to anticipate spreading of *Imperta cylindrica*, the most serious pest of oil palm [10]. In average, 43 man-days were needed for labor input, consisted of hired and family labors to operate oil palm farm per hectare (1 days is equal to 6 hours). The total of working days was accumulated from total activities such as weeding, crop maintenance, fertilizing, and harvesting.

To emphasize the age of tree effect toward productivity, the variable of weighted oil palm tree (WPT) was introduced. WPT was calculated by dividing the average output of oil palm fruit for each age profile with the maximum output at its peak period of the yield. Based on the yield profile, oil palm tree ages were grouped into 3 categories such as w1= 3 – 8 years, w2 = 9 – 19 years (considered as yield peak period), and w3= over 20 years [19]. Thus, WPT values for each age profile were determined as: w1PT1 = 70/125, w2PT2 = 125/125 and w3PT3 = 100/125. This approach had been applied by several researches to capture the effect of tree age in Cocoa in Ghana [15] and Vietnam's Rubber Plantation [10].

As for farmer group, 60% of NES-Trans farmer were selected. The age range of respondents was between 31 and 84 years old, with the mean age was 49 years old, implying that farmers in study area were relatively ageing. Majority of farmers gained formal education with average of 9 years, which was the level of national primary education. Around 30% of farmers have farm diversification such as crops plantation and livestock. As for credit access, 75% of oil palm farmers were facilitated by low rate interest of credit from bank. Lastly, the present study found that 10% of farmers cultivated oil palm in the large size of peat soil due to the land availability in this area, particularly in the southern part of study area.

3.2. Stochastic frontier analysis

The stochastic frontier approach, which deals with the stochastic frontier production, was applied with assumption that all deviations from frontier were associated with disturbance terms. Since oil palm farmers in study area were smallholding-family based operation, farmers tended to pay less attention to farming record system, and the production record might be inaccurate. Thus, the availability of data on productivity was likely to be subject on measurement error [7]. The main point of this section was to gain the evidence that inefficiency effect existing among oil palm smallholder farmers. As the simultaneously estimation result, analysis of production input will be discussed.

Table 2. The maximum likelihood estimation (MLE) for parameters of translog stochastic frontier for oil palm farmers

Variable	Parameter	Coefficients	Std. Error	z
Stochastic frontier				
Constant	β_0	0.20	0.06	3.30
ln(Fertilizer)	β_1	0.17**	0.08	2.18
ln(Herbicide)	β_2	-0.03	0.08	-0.35
ln(Labor)	β_3	0.14	0.11	1.23
ln(WPT)	β_4	-1.66***	0.15	-5.16
0.5([ln Fertilizer]^2)	β_{11}	-0.28	0.17	-1.62
0.5([ln Herbicide]^2)	β_{22}	-0.52	0.23	-2.25
0.5([ln Labor]^2)	β_{33}	0.94	0.62	1.52
0.5([ln WPT]^2)	β_{44}	-4.87	1.15	-4.25
[ln Fertilizer][ln Herbicide]	β_{12}	0.01	0.16	0.34
[ln Fertilizer][ln Labor]	β_{13}	0.05	0.18	0.25
[ln Fertilizer][ln WPT]	β_{14}	0.23	0.23	1.00
[ln Herbicide][ln Labor]	β_{23}	-0.07	0.18	-0.41
[ln Herbicide][ln WPT]	β_{24}	0.08	0.32	0.24
[ln Labor][ln WPT]	β_{34}	-0.05	0.38	-0.14
Variance Parameter				
Sigma-v	σ_v	0.23	0.02	
Sigma-u	σ_u	0.23	0.07	
Lamda	λ	1.01	0.09	
Log Likelihood Function		-30.33		

Note: (a) *** and ** are significant at 1% and 5% levels, respectively (b) the log-likelihood function of a stochastic frontier model is maximized by the Newton–Raphson method, and the estimated variance matrix is calculated as the inverse of the negative Hessian (second partial derivatives matrix) [17]

The coefficient of fertilizer was positive and highly significant to oil palm output, which indicated that farmers need to apply the quality and quantity of each given fertilizer, in order to achieve the higher yield. Negative and significant of WPT coefficient suggested that ageing tree might reduce the output. The result was in line with the nature of oil palm tree, which its yield-peak periods were reported in between 9 – 19 years and decreased after 20 years of planting [19]. Insignificant of labor coefficient was far from the initial expectation. It might arise from the effect of family labor that still actively involved on farming activity because oil palm was accounted as the main source of income. Furthermore, coefficient of herbicide variable, which was found negative and not significant, was consistent with the fact that the chemical herbicide should be carefully applied to the targeted pest, weed or disease. Inappropriate amount of herbicide might lead to the decreased of productivity, due to its negative effect toward trees and soil condition [16]. Thus, the roundtable on sustainable palm oil (RSPO) [16] suggested that farmers need to consider the integrated pest management by using physical methods to minimize the application of chemicals.

The inefficiency effect in oil palm productivity could be identified by examining the value of estimated lambda (λ), as it was the main point of the present study. The value of λ is larger than 1, which implied that inefficiency term contributed significantly in the analysis of oil palm productivity. Thus, the analysis of socio-economics aspect of smallholder farmers might be more suitable to explain the existing productivity gap. The result of likelihood ratio (LR) test was 52.92, which larger than critical value in 5% of significant level with 11 degrees of freedom taken from Table 2 of Kodde and Palm [12], and then, the null hypothesis of no inefficiency effect was rejected. Therefore, LR test confirmed that the inefficiency effect due to socio-economics background of farmers influenced strongly the technical efficiency among oil palm smallholder farmers in the study area. The explanation of socio-economics factors which influence the technical efficiency as the result of the maximum likelihood estimation (MLE) of inefficiency effect, will be described on the later part of this report.

Table 3. The maximum likelihood estimation (MLE) of inefficiency effect for oil palm farmers

Variable	Parameter	Coefficients	Std. error	z
Constant	δ_0	-6.69	13.88	-0.48
Group	δ_1	-1.69 ***	0.76	-2.23
Education	δ_2	-7.44 *	4.73	-1.57
Age	δ_3	4.66 **	2.30	2.03
Divers	δ_4	-2.00 *	1.08	-1.85
Credit	δ_5	-0.48	0.80	-0.60
Farm location	δ_6	1.55	1.04	1.49

Note: ***, ** and * are significant at 1%, 5%, 10% levels, respectively

3.3. Factors affecting efficiency

The result of technical inefficiency effect is presented in Table 3. The present study observed that group of oil palm farmers was negative and highly significant, indicated that NES-Trans farmers were more efficient than independent farmers. The results could be justified by the fact that NES-Trans farmers have adequate guidance from their contract company about the standard practice of farming from RSPO [10]. However, the approach on how to disseminate extension program through farmers group in this study area seemed to generate higher efficiency, in contrast with report published by Hasnah et al. [10]. NES-Trans farmers in this study area, through farmers group, tended to maintain the best management of farming practice given by the extension service. On the contrary, the role of farmer group and extension service on the farming practice of independent farmers was very low.

Negative sign of education and significant are consistent with the expectation, which implied that education level of oil palm farmers might improve the technical efficiency. Educated farmers tended to be more responsive in technology adoption and utilization. Coelli and Battese [5] found that higher year of schooling farmers achieved less inefficiency. Dummy variable of farm diversification had negative sign and significant, which suggested that if farmers had various resources of production other than oil palm cultivation (*i.e.*, crop cultivation in different plots and livestock), these other resources were likely to generate positive impact to efficiency. Coelli and Fleming [6] argued that farm diversification activities seemed to increase efficiency because the farmers might have opportunity to select several farming activities which complemented the given input of each other resources. Furthermore, the present result was interesting to be furtherly investigated in the future research. The analysis of multi output and input of production may be required to provide which combination of products is to generate higher efficiency.

Credit access has negative value and not significant, which indicated that the access of credit might not have substantial effect to increase the efficiency in this study area. One of the specific reasons was because of inappropriate utilization of credit. Farmers in the study area tended to use credit facility for expanding oil palm farmland to increase production or buying daily expenditure rather than for improving productivity in its current farmland. The shift of the existing paradigm was needed in order to encourage the farmers to get the advantages from credit facility. In line with what was reported by Binam et al. [3], if the farmers could appropriately manage the advantage of credit facility, it is likely to enhance the ability of the farmers in adopting farming technology and improving productivity. Therefore, the ability to manage the credit facility was a crucial factor for agricultural sector, as had been reported in Nigeria. The age of farmers had positive sign with the inefficiency and it was significant at 5%, younger farmers were observed to be more technically efficient than the older one. This fact was due to the tendency of younger farmers to be more activity in the current agricultural activity and their willingness to improve the farming knowledge, in accordance with that was reported by Coelli and Battese [5].

Farm location had positive, but not significant correlation to efficiency, which indicated that the farmer who cultivates oil palm in peat soil area might be less efficient. According to Funakawa et al. [9], peat soil in tropical area was generally low in nutrient supplying capacity which limiting its potential. This condition might lead to the higher effort from oil palm farmers to invest more in production input as well as in specific maintenance, in order to meet the targeted yield. However, farmers in peat soil area (LO village) might be facing difficulties to achieve the efficiency due to the fact that the farmers are lack of guidance from formal institution to maintain their farmland under peat soil condition.

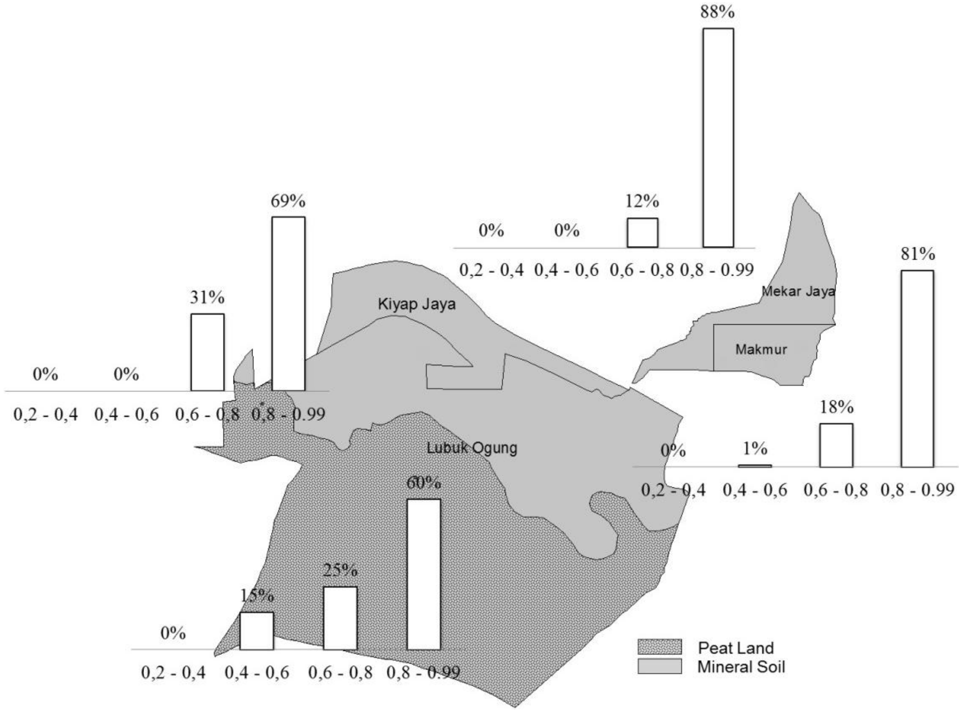

Fig. 1. Technical efficiency index of oil palm farmers in study area
Sources: (a) Self survey of farmers` plot investigation, Riau, Indonesia, 2013 (b) [13] (c) [4]

3.4. Spatial distribution of technical efficiency

Technical efficiency index for farmers in each villages are presented in Figure 1. The average technical efficiency of oil palm farmers in study area is 83%, which indicated that there was plenty of section which should be improved to get the maximum efficiency. The Spatial heterogeneity was considered as the variable which might affect to the differences in efficiency level among farmers [1]. The results, therefore, suggested that the farmers should apply appropriate farming practice based on the characteristic of their farm locations to maintain its productivity.

By referring to the score of individual technical efficiency for each location in study area, it was concluded that the lowest average of technical efficiency score is 74%, which was experienced by the independent farmers in peat land area. The present result implied that the farmers in the study area could not achieve optimum level of productivity due to the lack of knowledge on how to cultivate oil palm in peat land. Current farming guidance only supported the farmers who cultivate oil palm in mineral land. However, the interaction between geographical characteristic and farmer's ability to apply farming activity in particular area should be taken into account in the future projection of agricultural policy.

4. Concluding remarks

The main objectives of the present study were to investigate the existence of the inefficiency effect on oil palm cultivation practice among smallholder farmers in Indonesia and to determine unobserved variable that affect technical efficiency. The Inefficiency was observed to exist among smallholder farmers and the technical efficiency index discrepancy was relatively high (41%), which reflected that farmers in study area experienced non-uniform farming practice. The present study revealed several socio-economics factors which contributed to the efficiency, such as:

1. The important role of technical assistance from formal institution on farming practice and the existence of farmers group in disseminating information. As being experienced by NES-Trans farmers, dissemination of the extension material through farmer group enhanced the effectiveness of productivity. Therefore, this kind of farming practice can be introduced to the independent farmers as well.
2. The education level of the farmers might improve oil palm productivity. The farmers with higher level of education were likely to be more responsive in technology adoption and utilization. In addition, the level of education had influenced the decision to introduce the efficient approach in farming practice. Thus, young generation who has interest to work in agricultural sector should be facilitated by formal education that related to agriculture.
3. The credit facility for agriculture sector was given by government to support smallholder farmers to enhance their productivity. However, evaluation is necessary to investigating whether the credit facility has been used for improving oil palm cultivation or has been consumed for other purposes.
4. The diversification activities of farming gave the farmers opportunities to select those activities which was able to complement the input resources and had positive impact toward efficiency.
5. The index of technical efficiency of oil palm farmers who cultivate in peat soil was low, relatively compared to that of the farmers who cultivate in mineral soil, since there was no particular guidance on how to maintain farmland for peat soil. Farming in peat soil without appropriate knowledge and management might not only lead to the less performance of productivity, but also to the environmental degradation.

The present study on the technical efficiency generated the opportunities for improving the productivity performance of oil palm farming by improving socio-economic aspects of smallholder farmers. Thus, this study provided some evidences to support the improvement of rural livelihood. However, this research can still to be optimized by the investigation of farm diversification, considering the fact that the ageing of oil palm trees had lead to the decreased of productivity over time. The further analysis should be focused on the combination of agricultural activities that can provide additional source of income to the farmers at the time of oil palm production decreases.

References

1. Areal, F, J., Kelvin, B., Richard, T., Integrating Spatial Dependence into Stochastic Frontier Analysis. The Australian Journal of Agricultural and Resource Economics 2012;56:521-541.
2. Battese, G., Corra, G., Estimation of a Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia. Australian Journal of Agricultural Economics 1977;21:167-179.
3. Binam, N, J., Tonye, J., Wandji, N., Nyambi, G., Akoa, M., Factors Affecting Technical Efficiency among Smallholder Farmers in the Slash and Burn Agriculture Zone of Cameroon. Food Policy 2004;29:531-545.
4. BPS, Pelalawan in Figures, Indonesia Statistic Bereau;2012.
5. Coelli, T. J., Battese, G. E., Identification of Factors which Influence the Technical Inefficiency of Indian Farmers. Australian Journal of Agricultural Economics 1996;40:103-128.
6. Coelli, T., Fleming, E., Diversification Economies and Specialization Efficiencies in a Mixed Food and Coffee Smallholder Farming System in Papua New Guinea. Proceedings of the 25th International Conference of Agricultural Economists (IAAE);2003: 0-958-46098-12003.
7. Coelli, T.J, Rao, D.S.P., O'Donnell, C.J., Battese, G.E., An Introduction to Efficiency and Productivity Analysis. 2nd Edition:Springer; 2005.
8. Dinas Perkebunan Provinsi Riau, Riau Province Crop Estate Statistic, Crop Estate Department of Riau Province; 2010.
9. Funakawa, F., Yonebayashi, K., Shoon, J.F., Khun, E.C.O, Nutritional Environment of Tropical Peat Soils in Sarawak, Malaysia Based on Soil Solution Composition. Journal of Society of Soil Science and Plant Nutrition 1996;42(2):833-843.
10. Hasnah, Fleming, E., Coelli, T., Assessing the Performance of a Nucleus Estate and Smallholder Scheme for Oil Palm Production in West Sumatra: A Stochastic Frontier Analysis. Agricultural Systems 2004;79:17-3.
11. Hung, S.T., Coelli, T., Fleming, E., Analysis of the Technical efficiency of State Rubber Farms in Vietnam. Agricultural Economics 1993;9:183 – 201.
12. Iwala, O. S., Okunlola, J.O., Imoudu, P.B., Productivity and technical efficiency of oil palm production in Nigeria. Journal of Food, Agriculture & Environment 2006;4:181-185.
13. Kemenhut RI, Reproduction Soil Map Republic of Indonesia. Ministry of Forestry Republic of Indonesia;1989.
14. Kodde, D. A., Palm, F.C., Wald Criteria for Jointly Testing Equality and Inequality Restriction. Econometrica 1986;54(5):1243-1428.
15. Ofori-Bah, A., Ashafu-Adjaye, J., Analysis of Scope Economies and Technical Efficiency of Cocoa Agroforestry System in Ghana. Journal of Ecological Economics 2011;70:1508-1518.

16. RSPO, Principles and Criteria for Sustainable Palm Oil Production. Roundtable on Sustainability Palm Oil;2007.
17. STATA, "Stochastic Frontier Model". http://www.stata.com/manuals13/rfrontier.pdf. Accessed on July 20th 2014.
18. USDA, "Indonesia: Palm Oil Production Prospects Continue to Grow," Commodity Intelligence Report, 2007.
19. USDA, "Malaysia: Stagnating Palm Oil Yields Impede Growth", Commodity Intelligence Report, 2012.