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Yield Gaps and Factors Affecting Production Inefficiency in Smallholder Oil Palm Plantations in Muaro Jambi District Jambi Province

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Abstract. Oil palm plantations in Indonesia, including in Jambi Province, are categorized into large private plantation, state-owned plantation, and smallholder plantation. The productivity of smallholders is the lowest compared to the other 2 categories. At the district and sub-district level, the yield of smallholder oil palm is also vary, spreading from 1,675 to 6,680 kg CPO per ha per year. The large yield variation is inseparable from the plantation management among farmers. The objectives of this research are to study the yield gap and technical efficiency of production among smallholders, and to analyze the factors that affect the technical production inefficiency in smallholder oil palm plantation. The research was conducted in Muaro Jambi District as a main palm oil producing district in Jambi Province. Data was collected from a sampel of 120 independent smallholders. One way anova test was used to study the yield gap and double natural log (ln) of Cobb–Douglas stochastic frontier production function was used to analyze the technical efficiency and some factors affects its inefficiency. The results revealed that there were significant differences in yield among smallholders based on area size, level of education, and activeness in the farmer organizations. However, on average, the management of oil palm by independent smallholders is quite technically efficient. The factor that significantly affects the level of technical inefficiency are the size of the area and farmers' level of education.

Keywords: oil palm, yield gap, smallholder

1. Introduction

Indonesia is the largest palm oil producing country in the world with a harvested area of 12.1 million hectares and contributes to the world's total harvested area of 51.7% [1]. For Indonesia, oil palm is one of the economic pillars that makes a major contribution to foreign exchange earnings and job creation for the community [2]; [3] and reduces poverty among agricultural and non-agricultural households. [4]; [5]; [6]; [7].

Jambi Province is one of the centers of palm oil production in Indonesia with a contribution of around 7% to total national production [1]; [8]. Palm oil plantation in Indonesia, including in Jambi Province, is categorized into three, namely large private plantations, state owned plantations, and smallholder plantations. Nationally, in 2020 smallholder plantations contributed 54.69% to the total area, but contributed only 33.47% to the national palm oil production [8], meanwhile in Jambi Province, smallholder plantations contributed 62.98% to the total area and 50.95% to total production [8].

In line with the data above, the productivity of smallholder oil palm plantations in Jambi Province is the lowest compared to the other 2 types of plantations, namely 80.49% of state plantation productivity and 86.41% of private plantation productivity [9]. If we look at the productivity data of people's plantations in Jambi Province by district (especially production center districts), we get an illustration that the productivity of smallholder palm oil between districts is also uneven, spreading from 1,675 kg/ha to 6,680 kg/ha [9]. Likewise, if it is observed that the distribution of smallholder oil palm productivity between sub-districts in the production center districts, there is also a tendency for the same variation.

The large variation in productivity in smallholder oil palm plantations is inseparable from the existence of a production gap between farmers. This is due to several factors, including plantation management practices carried out by smallholder oil palm plantation farmers. [10] found that there is a very strong correlation between the characteristics of plantation management and economic performance, including production. Likewise, Alamsyah [11] found a significant difference between production and income earned by farmers at various levels of oil palm plantation management. While plantation management practices, plantation management is also strongly influenced by the characteristics of farmers, including age, experience, formal education [12]; [13], number of family members [12]; [13], membership in cooperatives and access to credit [13],

2. Methods

The research was conducted in Muaro Jambi District as main palm oil producing district in Jambi Province which focused on 2 sub-districts, namely Sungai Bahar sub-district and Kumpeh Ulu sub-district. Data was collected by interviewing a sampel of 120 independent smallholders. One way anova test was used to study the yield gap and double natural log (ln) of Cobb–Douglas the stochastic frontier production function was used to analyze the technical efficiency and some factors influenced its inefficiency with the analytical model as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln N_i + \beta_2 \ln P_i + \beta_3 \ln K_i + \beta_4 \ln H_i + \beta_5 \ln L_i + (v_i - u_i) \quad (1)$$

where Y is yield (kg fresh fruit bunches, FFB/ha/year), N is nitrogen fertilizer used (kg/ha/year), posphor fertilizer used (kg/ha/year), K is potasium fertilizer used (kg/ha/year), H is herbiscides and pesticides used (liters/ha/year), L is labor used (mandays/ha/year), v is the random error, u is error that reflects inefficiency, and i is observation. The fertilizers used focused on macro nutrients, i.e. nitrogen, phosphorus and potassium which were calculated based on the content of each of these nutrients in the type of fertilizer. The types of fertilizers used by farmers are urea and ZA (ammonium sulfate) as nitrogen fertilizers, SP36 and TSP as phosphorus fertilizers, KCl and ZK as potassium fertilizers, and compound fertilizers in the form of NPK Mutiara and NPK Ponska.

The technical efficiency (TEi) of the i-th farmer is predicted using the expected value of ui according to the i-th random variable. Thus, the conditions must be met, where:

$$TEi = Exp(-ui) \text{ sehingga } 0 \leq TEi \leq 1 \quad (2)$$

where TE is technical efficiency. Technical inefficiency is determined by various variables with the following general model:

$$\ln ui = \delta 0 + \delta 1 \, PAi + \delta 2 \, EDi + \delta 3 \, AOi + wi \quad (3)$$

where ui is technical inefficiency, PA is plantation area (ha), ED is farmers’s education (year), and AO is farmers activeness in the farmer organization. The stochastic frontier production determined by Equation (1) and the technical inefficiency model determined by Equation (3) are estimated together using the maximum likelihood method.

3. Result and Discussion

The results showed that there was a yield gap among oil palm farmers in the study area where yields ranged from 11,608 to 21,794 kg of Fresh Fruit Bunches (FFB) per hectare per year with an average of 15,261 kg of Fresh Fruit Bunches (FFB) per hectare per year. The large yield gap that occurs is caused by variations in plant age, land area and input used by farmers. Table 1 shows the distribution of yield data, plant age, input use and farmer characteristics.

Table 1 shows variations in plant age, use of production inputs, area, and formal education of farmers which are suspected of causing yield gaps among farmers. The use of nitrogen, phosphorus and potassium fertilizers vary greatly with the average usage still below the recommendations, namely 64.19, 53.55 and 71.79 kg per hectare per year. While the recommended dose for each of these fertilizers is 155 kg N, 110 kg P and 170 K, calculated on average for plant ages over 8 years based on [14]. The land area and the formal education attended also varies which can affect crop management. Likewise, the activeness of farmers in farmer group activities will also affect crop management abilities. Of the 120 sample farmers, 70 of them were active while 50 were not active.

Tabel 1. Description of the yield, plant age, use of production inputs and farmers' education.

Variables	Minimum	Maximum	Mean	Std. Deviation
Yield (kg FFB/ha/yr)	11608.00	21794.00	15261.57	2477.99
Plant age (yr)	8.00	24.00	17.32	3.83
N-Fertilizer (kg/ha/yr)	19.20	147.56	64.19	29.10
P-Fertilizer (kg/ha/yr)	8.00	114.00	53.55	22.84
K-Fertilizer (kg/ha/yr)	16.00	246.50	71.79	41.36
Pesticide (l/ha/yr)	1.88	15.00	7.75	1.99
Labor (Man days/ha/yr)	66.00	134.00	86.33	14.22
Land area (ha)	2.00	9.00	3.62	1.17
Education (yr)	6.00	18.00	9.10	3.51

The yield gap based on land area was studied by grouping the respondent farmers into 4 groups, namely L1 (2-3 hectares, n=22), L2 (> 3 to 4 hectares, n=43), L3 (> 4 to 5 hectares, n=38), and L4 (> 5 hectares, n=17). The yield distribution according to the group is presented in Figure 1 and the comparison test of the yield is presented in Table 2.

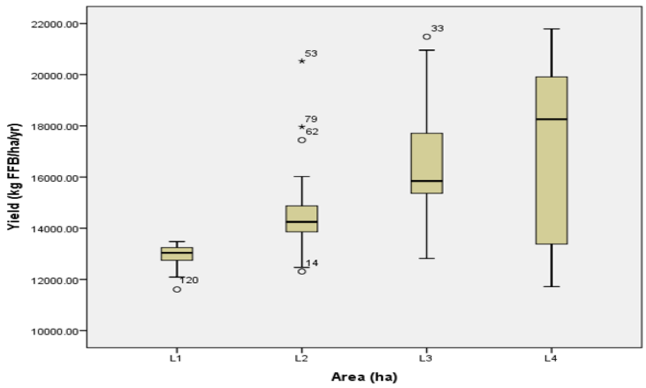

Figure 1. Distribution of yield according to land area

Tabel 2. Multiple comparisons of yield according to land size (area)

	(I) Area (ha)	(J) Area (ha)	Mean Difference (I-J)	Std. Error	Sig.
Tukey HSD	L1	L2	-1559.24101*	513.76553	.016
		L3	-3697.05742*	525.08105	.000
		L4	-4346.40107*	632.92224	.000
	L2	L1	1559.24101*	513.76553	.016
		L3	-2137.81640*	436.38553	.000
		L4	-2787.16005*	561.52719	.000
	L3	L1	3697.05742*	525.08105	.000
		L2	2137.81640*	436.38553	.000
		L4	-649.34365	571.89848	.668

*) The mean difference is significant at the 0.05 level

Figure 1 and Tabel 2 show that the larger the land size, the higher the yield obtained. The result is in line with [15] and [16] that the land size has positive and significant influence to palm oil production and productivity. But, there is no significant yield difference between L3 and L4 indicating that the addition of land size of more than 5 hectares does not provide much additional to yield. Meaning that with the availability of other existing resources to farmers, the maximal land size for smallholder oil palm plantation in research area is 5 hectares.

The yield gap based on farmers' formal education was also studied by grouping farmers into 4 groups, namely Elementary school (length of study ≤ 6 years, n=55), Junior high school (6 < length of study ≤ 9 years, n=26), Senior high school (9 < length of study ≤ 12 years, n=24), and Higher education (length of study > 12 years, n=15). The yield distribution according to the education group is presented in Figure 2 and the comparison test of the yield is presented in Table 3.

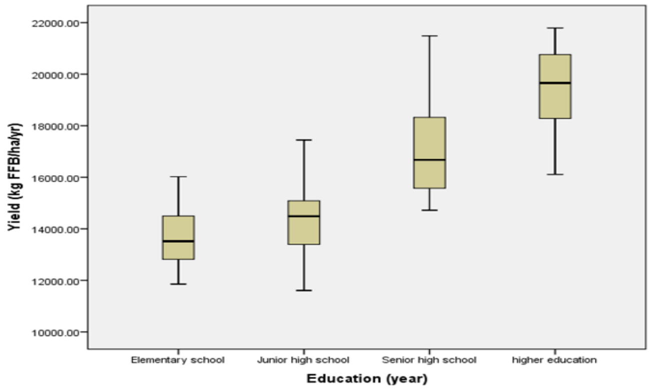

Figure 2. Distribution of yield according to farmers'education

Figure 2 also shows that there are quite large yield variations in each educational group and there is a tendency that the longer the farmers attended formal school, the higher the yield they obtained. A very sharp difference in yield occurs after farmers pass senior high school.

Tabel 3. Multiple comparisons of yield according to farmers' education

(I) Farmers' education	(J) Farmers' education	Mean Difference (I-J)	Std. Error	Sig.
Elementary School	Junior High School	-755.59720	336.46675	.117
	Senior High School	-3533.27348*	345.85515	.000
	Higher Education	-5681.44848*	411.80319	.000
Junior High School	Senior High School	-2777.67628*	400.18460	.000
	Higher Education	-4925.85128*	458.38172	.000
Senior High School	Higher Education	-2148.17500*	465.31678	.000

*) The mean difference is significant at the 0.05 level

Table 3 proves that the higher the farmers' education, the higher the yield. But, and there is no significant yield difference between junior high school educated farmers and farmers with elementary school education. This result is in line with [12], [13] and [17] that education will affect the managerial ability of farmers so that it has a positive effect on yield.

The activeness of farmers in farmer groups also tends to lead to yield gaps. Based on their activeness, the respondent farmers were grouped into 2 groups, namely active farmers (n=70) and inactive farmers (n=50). Yield distribution according to farmer activity is presented in Figure 3 and yield comparison test is presented in Table 4.

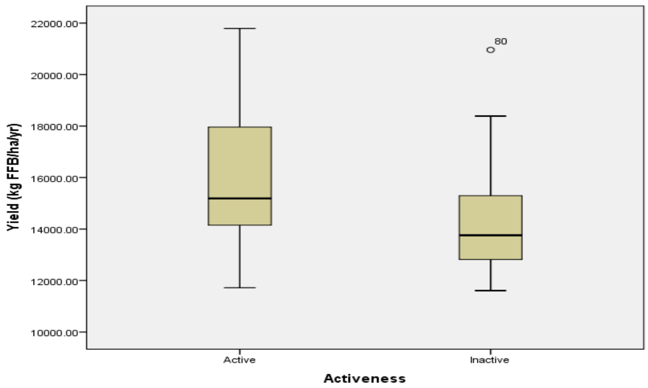

Figure 3. Distribution of yield according to farmers' activeness

Figure 3 shows the distribution of yield according to the activity of farmers in the organization. Although the average yield of farmers who are active in organizations is higher than farmers who are not active, the distribution of yields is wider than farmers who are inactive in organizations. Table 4 proves that there is a significant average yield difference between the two groups where farmers who are active in organization have a higher average yield than farmers who are inactive.

Tabel 4. Comparisons of yield according to farmers' activeness

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Yield (kg FFB/ha/yr)	Equal variances assumed	7.067	.009	4.000	118	.000	1728.3828
	Equal variances not assumed			4.214	117.959	.000	1728.3828

The relatively large yield gap among farmers was apparently not caused by inefficiency components but by external factors outside of farmers' control. This can be seen in the gamma coefficient in Table 5, where the coefficient is not statistically significant. On average, the technical efficiency of farmers is quite high, ranging from 89 to 98 percents. However, factors that can affect inefficiency in smallholder oil palm plantations are the size of plantation area and the farmers' education.

Tabel 5. The final MLE estimates using Cobb Douglas stochastic frontier production function

Parameters	**Coefficient**	**Standard-error**	**t-ratio**
β_0	8.2966	0.2478	33.4790
β_1 (Plant age)	-0.0479	0.0195	-2.4541**
β_2 (N-fertilizers)	0.0809	0.0278	2.9111***
β_3 (P-fertilizers)	0.1138	0.0180	6.3323***
β_4 (K-fertilizers)	0.0513	0.0172	2.9753***
β_5 (Pesticides)	-0.0033	0.0151	-0.2212
β_6 (Labor)	0.1187	0.0526	2.2568**
δ_0	0.1901	0.1501	1.2670
δ_0 (Area)	-0.0306	0.0180	-1.7003*
δ_0 (Education)	-0.0496	0.0182	-2.7241***
δ_0 (Activeness)	0.0002	0.0006	0.3958
sigma-squared	0.0018	0.0002	7.4509***
gamma	0.0000	0.0000	0.0413

log likelihood function = 208.88   *) significant at α = 10%
LR test of the one-sided error = 13.75   **) significant at α = 5%
with number of restrictions = 5   ***) significant at α = 1%

Partial estimation results show that plant age has a significant and negative effect on yield with an elasticity coefficient of -0.0479. It means that the yield decrease as the plant age getting older. While nitrogen fertilizer, phosphorus fertilizer, potassium fertilizer and the use of labors have significant and positive effects on yield. It means that the yield could be increased by increasing the use of those inputs. These results are in accordance with several previous studies related to the variables that affect the oil palm yield gap [14], [17], [18]. There are still opportunities to increase oil palm yield by increasing input use to optimal levels, renewing old planting and increasing the intensity of labor use in plant maintenance.

4. Conclussion

The study concluded that various plantation management practiced by oil palm smallholder marked by the use of very diverse inputs has caused yield gap between farmers. There is a tendency for the larger the land area, the higher the level of farmers' education and the more active farmers in organization, the higher the yield produced. Although technically there is a large yield variation among farmers, the variation is not caused by technical inefficiency components. The technical efficiency of smallholder oil palm plantation is quite high. However, inefficiency problems can occur and the significant factor influences it is the area of plantations and the level of farmer education.

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