Research Article

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Palm oil plantation and cultivation: Prosperity and productivity of smallholders

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Abstract: Indonesia developed the Smallholder Plantation Scheme (PIR) in the early 1980s, making smallholders an important part of the national scale. Increasing smallholder yields is an important instrument for increasing local income and livelihoods. However, small-scale oil palm expansion has problems with low productivity and quality of production. Therefore, to increase their productivity and improve their cultivation, this study measures the importance of planting behavior and specific treatment of farmers' prosperity and productivity. To measure the possible significant differences between and within groups, a statistical approach, ANOVA, has been used while Spearman's correlation matrix also has been used to measure the correlation between variables. This study finds that good seed treatment and adequate doses of fertilizer are important for farmers' prosperity and productivity. Smallholder farmers have the least expenditure but the highest average production and income with the most extended growing age when compared with the other two groups of smallholder farmers. Even though the number of seeds used was the smallest, the success rate of smallholder planting was the highest. The optimal use of fertilizer and seed care alone is not significant enough to increase yields. It is a combination of other factors such as planting management practices, drainage capacity and soil substrate properties, climate characteristics, rainfall distribution, nutrient supply, and prevention of plant diseases and also determining maximum yield.

1 Introduction

Palm oil is a vegetable oil which has high productivity and low production with a productivity of 5 tons/ha (Hashim et al. 2017). However, the area that is the main supply of oil palm cultivation is the area around the equator or the latitude of ten degrees north and south (Dubos et al. 2019). Some tropical regions, such as Indonesia, Malaysia, and Brazil, have fulfilled the global supply of palm oil (Zabid and Abidin 2015). Nevertheless, the area of oil palm plantations is minimal. It cannot be done intensively because the equatorial region is a tropical rain forest region as a forest with the nickname of the world's lung source. Therefore, ways are needed to increase the productivity by minimizing the expansion of cultivation areas that can threaten these lands, which are important for biodiversity (Dubos et al. 2019). In addition to being limited in the area for growth, oil palm cultivation is only profitable in developing countries where labor is cheap and readily available, with a sustainable standard of living in developing countries. It will be difficult for palm oil to remain competitive without significant reductions in demand for relevant labor and costs (Gupta 2012).

Indonesia has 1,43,26,350 ha palm oil plantations in 2018, with 55.09% large private companies, 40.62% smallholder plantations, and 4.29% state large estates (Directorate General Plantation 2019). Around 20–25% CPO produced in Indonesia is used for domestic consumption, and the rest was exported (GAPKI 2018); the demand for CPO will increase every year through an increase of domestic and export demand for Indonesia CPO (Sheil et al. 2009; Khatiwada et al. 2018). But to achieve that demand, the palm oil industry in Indonesia still relies more on extensification than intensification to increase palm oil productivity (Varkkey et al. 2018). The palm oil industry in Indonesia gives large revenues to

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the government, develops the rural area, and improves local people and smallholders income with the consequences some vast forest in Sumatra, Kalimantan, and Papua has been changing the function (Casson 2000; Sheil *et al.* 2009; Feintrenie *et al.* 2010; Euler *et al.* 2017). Therefore, this article focus on subject of productivity increment and cultivation process.

A policy that benefits a community and encourages the smallholders prosperity realization stimulates a plantation development by smallholders to increase their financial needs (Yanita *et al.* 2019). The income of oil palm farmers can reach up to more than 5,000 US \$ per year so that it can support the acceleration of people's economic development and help reduce poverty in rural areas and one of the efforts to reduce poverty (Syahza 2011). Palm oil also contributed around USD 21 billion to Indonesia's export revenues on 11 million ha of plantation land in 2015 (Purnomo *et al.* 2018). The economic development of people, especially farmer's cause by the growth of palm oil plantation, makes the palm oil industry vital, including Jambi Province (Krishna *et al.* 2017; Adiprasetyo *et al.* 2019).

Palm oil development in Jambi has been encouraged by a partnership scheme between smallholders and company (Sheil *et al.* 2009; Feintrenie *et al.* 2010; Cramb *et al.* 2016; Euler *et al.* 2016a,b; Krishna *et al.* 2017). As in other provinces, the history of palm oil production in Jambi is marked by the emergence of the PIRTrans scheme and the emergence of state-owned and private companies. Smallholders began to enter the palm oil production process through government support to be included in the core area (Baudoin *et al.* 2017). They account for 63.14% of plantation when compared with 34.92% plantation managed by large private companies (Directorate General Plantation 2019). Under this scheme, smallholders, also called core smallholders, receive financial and technical support for their cultivation and distribute their harvest to the companies (Krishna *et al.* 2017). Other smallholders not attached to the company/core are known as common smallholders or self-subsistent smallholders (Saadun *et al.* 2018). Although smallholders enter into a partnership scheme with the company, the results obtained depend on the quality of planting material, adequate plot management, technical support, and how farmers are treated by the company (Zen *et al.* 2005).

Roundtable on Sustainable Palm Oil (RSPO) certification is a global sustainable certification that is voluntary and improves palm oil industry standards based on sustainability principles (Ivancic and Koh 2016; Rival *et al.* 2016). Other than RSPO, the Palm oil industry

in Indonesia also uses ISPO certification which is a mandatory certification since 2009. According to the core smallholder scheme in the RSPO guideline: (i) self-subsistent smallholders have their own decision to manage their land, organize themselves, and manage themselves including their finance. They cannot be bound by a contract of the credit agreement or any planning with certain factories or certain associations, but they can receive government supports; (ii) smallholder schemes characterized structurally by contracts, credit agreements, or partnerships to specific factories/companies. Scheme farmers can cultivate using plantation or large factory practices, where they are bound or using their own practices. The RSPO also regulates the total area planted with oil palm, which is under 50 hectares per farmer, while ISPO sets the area of oil palm cultivation under 25 ha per farmer.

The development and expansion of Indonesia's oil palm plantations by large estates and communities from year to year continue to increase rapidly, even very astonishing. That also followed by an increase in Fresh Fruit Bunches (FFB) and Crude Palm Oil (CPO) production. Increasing production through area expansion is still needed as long as the potential is available and feasible. However, the most important thing is to increase the productivity and quality of production (Mawardati and Khalil 2018). Although CPO productions can reach 9 tons/hectare/year, the average of Indonesia's productivity is still around 3.4 tons/hectare/year (Daemeter Consulting 2013). Given the important role of smallholders, increasing their harvest yields has a vital factor in increasing income and local livelihoods (Euler *et al.* 2016a,b). The low productivity causes the low overall productivity of palm oil by smallholder plantations (Mawardati and Khalil 2018). And smallholders in Indonesia still have the least productivity than the company (Jelsma *et al.* 2019). They have financial, knowledge, and supply chain barrier which make their productivity low (Schoneveld *et al.* 2019; Innocenti and Oosterveer 2020). These barriers should be evaluated to help them find ways to improve the smallholder productivity.

The management and cultivation process of palm oil plantations determines the harvest and income results (Corley and Tinker 2016). In terms of comparative productivity and sustainability, oil palm requires a smaller area of land to produce the target amount of oil (Basiron 2007). Other than that, palm oil plantations are also influenced by the type of land, fertilizers, good management practice, and care of seeds. Fertilizer application is an important factor in the cultivation process, which impacts plantation productivity (Daemeter Consulting 2013; Clough *et al.* 2016; Darras *et al.* 2019)

because fertilizer provides nutrients, which is a vital factor in the physiology and anatomy's plant growth (Darras et al. 2019). The specific purpose of fertilization is not to limit yields and deplete soil reserves if nutrient input is lower than crop requirements and to avoid excessive amounts, which adversely affect the environment (Dubos et al. 2019). Good management practices can increase smallholder productivity, which can increase the CPO productivity around 2.3 tons per hectare per year (Daemeter Consulting 2013; Adiprasetyo et al. 2019). Planted oil palm on dry lands has different capabilities (soil structure, soil fertility, and other conditions) than wetlands (swamps) so that they will affect the requirements and use of inputs and productivity (Lifianthi and Husin 2012). Seed care is the main control for the growth and production of each plant (Rahim et al. 2019). Seedlings are raised in nurseries for about 12 months before they are ready for planting. Ground cover is quickly formed by planting cover crops to prevent soil erosion and weed growth. After 30 months, oil palm may have produced fruit bunches of sufficient size and quantity to start the harvesting process (Basiron 2007). Advances in oil palm cultivation technology are directed at increasing yields and reducing costs. In most situations, adequate and balanced fertilization is essential to realize genetic growth and the potential for palm oil (Ng and Thong 1985). Yields can also be increased through better quality seeds that have been developed through research (Basiron 2007).

However, the smallholder cultivation process in Indonesia is still poor. Some of them cultivate their plantation with limited GAP implementation and limited fertilizer application since they do not have the capability to get good quality seed and to provide a fertilizer continuously (Jelsma et al. 2019; Woittiez et al. 2019). Because of that, through help smallholders improve their cultivation process, it can improve their

productivity and overall productivity of palm oil. In this article, the farmer's planting behavior is analyzed by analyzing how it can affect farmers' welfare and productivity through a statistical approach, namely, ANOVA and the correlation matrix. This article also measures how soil characteristics and fertilizer use affect palm oil productivity.

2 Method

2.1 Study area and sample selection

Data in this study were collected from 400 oil palm farmer respondents from five districts in Jambi province, Indonesia. A total of 80 samples were taken from five districts in Jambi, namely, Merangin, Muaro Jambi, Sarolangun, Tanjabar, and Tebo, representing the population of oil palm farmers in Jambi. The method of collecting sample responses is selectively based on farmers who own and process palm oil that meets the requirements in the survey. The requirements of this survey are smallholders who live in Jambi province and own the landfields themselves. Data collected in the form of farmers planting behavior can affect farmers' welfare and productivity, soil characteristics, and fertilizer use that affects palm oil productivity (Table 1). In this article, the sample (smallholders) is divided into two types of groups, but most of the analysis will be divided through smallholder groups. First, it is targeted at smallholder groups and producers of planting seeds. These smallholder groups are as follows: (1) Core Smallholders, (2) Self-subsistent Smallholders, and (3) Common Smallholders. The Self-subsistent Smallholders

Table 1: Summary statistics of respondents'

No.	Types of smallholders	Indicators			
		Expenditure per capita (USD/Day)	The income per capita (USD/Day)	Local govt support (%)	Harvest quantities (Tons)
1	Core smallholders	8.22	15.86	0	0.83333333
2	Common smallholders	7.78	16.43	13	0.93591837
3	Self-subsistent smallholders	7.67	18.16	9	1.09875
4	Total (all smallholders)	7.84	16.67	22	0.94925

Key indicators: expenditure and income per capita, local government support exposure, and harvest quantities on each group of smallholders. Source: Survey data, calculated by the author. The value of 1 USD is Rp14,037, as of average value in October 2019.

group more dominates the number of respondents. The types of seeds planted are Marihat and Scofindo.

2.2 Data analysis

Variables in the data related to cultivation are processed through statistical methods, both chemical and physical approaches. To analyze the data, ANOVA has been used to measure possible significant differences between smallholder groups and other geographical aggregations. The presented data are stated in ANOVA tables along with analytical explanations of which significant differences have been occurred on. The average amount of output harvested by smallholders is analyzed through one-way and two-way ANOVA. It divides the sample into two types of grouping categories: farmer groups and seed producers. One-way and two-way ANOVA analyses were conducted to detect differences, whether significant or not, between smallholder groups, seed producers, and other control variables. ANOVA was also used to confirm the relationship between the amount and dosage of fertilizer use and soil types of each smallholder group.

To test the significant difference of one variable between groups, one-way ANOVA method is used by the following hypothesis:

$$H_0 : \mu_1 = \mu_2 = \mu_3,$$

$$H_A : \mu_1 \neq \mu_2 \neq \mu_3.$$

To test the significant differences between the two variables between groups, the two-way ANOVA method is used by the following hypothesis:

$$H_0: \mu_1 = \mu_2 = \mu_3,$$

$$H_A: \mu_1 \neq \mu_2 \neq \mu_3,$$

$$H_0: \mu_a = \mu_b = \mu_c = \mu_d = \mu_e,$$

$$H_A: \mu_a \neq \mu_b \neq \mu_c \neq \mu_d \neq \mu_e.$$

To test a significant difference between two variables by detecting a detailed relationship between variables, the two-way ANOVA method that interacts is used by the following hypothesis:

H_0 : There is no significant difference between the two variable.

H_A : There is a significant difference between the two variable.

Experimental designs like this can show the role of specific treatments in planting oil palm seeds carried out

by farmers, which can influence yields and prosperity through land conditions and other socio-economic factors.

3 Results

3.1 Smallholders' socio-economic characteristics

Socio-economic characteristics defined as how smallholders' economic conditions, appropriateness of living, and living standard are measured by quantitative variables in the survey. Quantitative variables that have been used to approximate smallholders' socio-economic conditions (prosperity and economic status) are the income and expenditure per capita, harvest outputs, and governmental supports exposure.

Table 1 shows the different types of harvest, income, and expenditure of each smallholder type and support from local government to each smallholder. Core smallholders have the most expenditure per capita while self-subsistent smallholders have the most income per capita and harvest quantity. The difference in core smallholders' expenditure is around 0.44 USD per day with common smallholders and around 0.55 USD with self-subsistent smallholders. The difference in the expenditure of 0.44–0.55 USD per day has a large enough value if it is calculated for 1 month, which is around 14.24 USD. The self-subsistent smallholders have the highest income, which is supported by high yields. The core smallholders have the lowest yields and the lowest income when compared with the other two smallholder groups. The average harvest of core smallholders and common smallholders only reach around 0.8 and 0.9 ton, fall behind from harvest quantities achieved by self-subsistent smallholders with average harvest quantities 1.1 ton. Then from the indicators local government support, the percentage of smallholders who received a local government support is below 25%, which is just 22% of smallholders has received the local government support. It can be concluded that there are some barriers that the smallholders cannot receive more local government support. Common smallholders have the highest percentage support from the local government, which is 13% of smallholders has been supported by the local government. Moreover, 0% core smallholders got the support from the local government.

3.2 Seeds and planting

Table 2 lists the differences between the type of smallholders regarding their planting process and the seed each type smallholder used.

Table 2 lists that in the Jambi region, with respondents, selected, the average palm planting period is 16 years. Self-subsistent smallholders have the most extended average planting period of 23 years. The average difference in the life span of self-subsistent smallholders to core smallholders and common smallholders is around 6 years and 10 years. From the indicator of the number seed unit per hectare, core smallholders have the greatest needs, reaching 138 units/ha when compared with self-subsistent smallholders and common smallholders with 130 unit/ha and 131 unit/ha,

respectively. On the other hand, the success of planting core smallholders is around 1.4% and 0.5% smaller than self-subsistent smallholders and common smallholders, respectively. There are two types of seeds used, Marihat and Scofindo. Marihat seedlings are dominantly used by self-subsistent smallholders and common smallholders, while core smallholders use Marihat and Scofindo in relatively equal amounts. The core smallholders do not have a choice to get their seed other than buying it. Different from self-subsistent smallholders and common smallholders, they still can get their seeds from the help of their farmer groups. After the seeds are obtained, the core smallholders still have to treat the seeds, self smallholders use the seeds directly, while the common smallholders can choose either to treat the seed first or directly used.

Table 2: Summary statistics of variables related to seeds and planting. Source: survey data, calculated by the author

No.	Indicators	Types of smallholders			Total (all smallholders)
		Core smallholders	Common smallholders	Self-subsistent smallholders	
1	Plantation age (years)				
	Mean	17.506667	13.259184	23.375	16.07875
	Std. dev.	2.6578458	4.2217197	4.7584036	5.7123551
	Freq.	75	245	80	400
2	Number of seeds (units/Ha)				
	Mean	138	131.39918	129.98718	132.37121
	Std. dev.	0	3.5128335	1.9102838	3.9988707
	Freq.	75	243	78	396
3	Seeds' success ratio (%)				
	Mean	95	95.657143	96.4625	95.695
	Std. dev.	0	1.2367329	1.4921207	1.259341
	Freq.	75	245	80	400
4	Seeds				
	Marihat	45	205	66	316
	Scofindo	30	32	13	75
	N/A	0	8	0	8
	Total	75	245	79	399
5	Source of seeds				
	Given by farming association	0	150	70	220
	Buying on my own	75	81	10	166
	Mixed (given and bought myself)	0	14	0	14
	Total	75	245	80	400
6	Seed treatment				
	No	0	120	80	200
	Yes	75	125	0	200
	Total	75	245	80	400

Table 3: Summary statistics of land and fertilizer

No.	Indicators	Types of smallholders			Total (all smallholders)
		Core smallholders	Common smallholders	Self-subsistent smallholders	
1	Fertilizer dosage (L/Ha)				
	Mean	1.7	2.2046	2.3	2.1616
	Std. dev.	0.2419	0.4319	0.4025	0.4436
	Freq.	45	226	80	351
2	Usage of fertilizer per hectares (<i>n</i> times)				
	Mean	2.1352	2.2046	2.3	2.2138
	Std. dev.	0.4508	0.4319	0.4025	0.4309
	Freq.	61	226	80	367
3	Land types				
	Peat	0	40	40	80
	Mineral	75	205	40	320
	Total	75	245	80	400

3.3 Land and fertilizer

Other than the seed and planting process, land and fertilization also affect the productivity. Table 3 lists the different land and fertilizer process by each smallholder.

Self-subsistent smallholders provide the biggest dose of fertilizer and usage of fertilizer per hectares compared to core smallholders and self-subsistent smallholders. The average dose of fertilizer given by self-subsistent smallholders is 2.3 L/Ha, which is 0.1 L/Ha greater than common fertilizer and 0.6 L/Ha higher than core fertilizer. From the indicator usage of fertilizer per hectares, core smallholders use 2.1 times, common smallholders 2.2 times, and self-subsistent smallholders 2.3 times. Among the common smallholders, the largest composition of land used is mineral soils compared to peatlands. While in self-subsistent smallholders, they cultivate land in the same composition. While in core smallholders, they cultivate plant on mineral soils.

which are less competitive in the global market because they are endowed with various advantages. Then, to increase that productivity, the following activities can be carried out: expanding the planting area, rehabilitating the existing plantations, and intensification. Efforts to intensify and expand the area planted for oil palm plantations are difficult because of land limitations and allocation. Recently, there has been a lot of pressure to stop the expansion of oil palm plantations, especially on peatlands (Hendri 2019). With the development of the existing conditions, the development of oil palm plantations from the beginning was strictly adhered to by the principle of compliance with applicable regulations. However, it was only carried out in corridors that were indeed permitted, namely in other use areas (APL) and in conversion forests in a planned and systematic manner. However, ongoing accusations still portray the development of oil palm as damaging natural resources and the environment.

The perpetrators of oil palm farming in Indonesia consist of large private plantation companies, state plantations, and community plantations. A partnership model generally manages the community oil palm plantation business with large private companies and state plantations (nucleus-plasma). Specifically for smallholder oil palm plantations, common problems faced include low productivity and quality of production. The productivity of the people's oil palm plantations averaged 16 tons of FFB per hectare, while the production potential when using superior palm seedlings could reach 30 tons of FFB/ha. CPO productivity of smallholder plantations only reaches an average of 2.5 tons of CPO

4 Discussion

4.1 Smallholders' socio-economic characteristics

Palm oil is an important plantation crop-producing food oil, industrial oil, and biofuels. Indonesia needs to increase the national productivity to achieve the demand. The rapid increase in CPO productivity over the past decade is a challenge to other vegetable oils,

per hectare and 0.33 tons of palm kernel oil (PKO) per hectare. In comparison, state plantations produce an average of 4.82 tons of CPO per hectare and 0.91 tons of PKO per hectare, and private plantations, on average, produce 3.48 tons of CPO per hectare and 0.57 tons of PKO per hectare.

One of the causes of the low productivity of community oil palm plantations is that the production technology applied is still relatively simple, from seeding to harvesting. With the application of appropriate cultivation technologies, the palm oil production can be increased. They are as follows: long exposure to the sun for oil palm between 5 and 7 h/day; this plant requires an annual rainfall of 1,500–4,000 mm or minimum rainfall requirements of 2,000 mm per year, which is distributed evenly throughout the year (minimum 100 mm per month) (Gupta 2012); the optimal temperature of palm oil is 24–28°C or minimum average temperature above 20°C and maximum between 28 and 34°C with at least radiation around 15 MJ/m²/day and irradiating around 1,800 h per year (Gupta 2012); the ideal height for oil palm is between 1 and 500 m above the sea level (above sea level) and the optimum humidity for oil palm plants is around 80–90% and wind speeds of 5–6 km/h to help the pollination process.

The long history of oil palm development in Indonesia records that oil palm began to be commercialized in 1911. Its exploitation until the end of the 1970 s is still the only plantation crop that is only cultivated as a large plantation business. While other plantation crops, which include around 126 species of plants, are mostly cultivated as smallholder plantations. At that time, the big national development agenda was poverty alleviation and employment opportunities, and the need for cooking oil raw materials was still based on coconuts.

By 2050 global demand for cooking oil is estimated to reach around 240 million tons, almost double the consumption in 2008. To meet this additional demand, it is a gift for palm oil, because it is the lowest production cost when compared with other vegetable oils. Advances in research and technology and increasing awareness of environmental sustainability are believed to make the future of Indonesian palm oil more prospective. Oil palm plantation companies will be increasingly encouraged to apply the latest technology in developing palm oil production while increasing their commitment to protecting the environment.

Small-scale oil palm plantations are also a highlight in efforts to meet global demand in various consumption needs made from oil palm. In this case, the productivity and quality of production of small-scale oil palm farmers

must also be strived to be stable and maximum to meet the demand in the future. Smallholder production is generally more biodiversity-friendly than large-scale oil palm plantation production and can support better conservation outcomes (Azhar et al. 2017). Core smallholders have higher expenditures when compared with self-subsistent smallholders and common smallholders. The factor that enables the expenditure of core smallholders is higher than the other two smallholders is the total production input production, which allocates total expenditure for production. The difference amount of expenditure has a large enough value if it is calculated for one month, which is around 24 USD (Table 1). This amount of money can reduce farmers' expenses and support fertilization, nursery or disinfection, and other medicines, which are believed to be the basis for increasing yields from oil palm cultivation (Lee et al. 2014).

Higher expenditure on core smallholders does not guarantee a higher income. That can be seen from how the self-subsistent smallholders with the lowest expenditure had the highest income, whereas the core smallholders who had the highest expenditure had the lowest income (Table 1). Supposedly, if expenditures are high, productivity will be maximized, and income will be relatively high (Papenfus 2005; Lee et al. 2014). The differences in income of common smallholders and core smallholders and self-subsistent smallholders are relatively significant for the level of oil palm farmers in the region. High income and low expenditure will make common smallholders more potential to have greater savings and an adequate level of welfare of farmers when compared with core smallholders and self-subsistent smallholders. In Jambi, smallholders income reach 10 million rupiahs per month (van Reemst 2015).

The average harvest of self-subsistent smallholders can reach more than 1 ton. In contrast, the average harvest of core smallholders and common smallholders only reach around 0.8 and 0.9 tons (Table 1). This average harvest is less than half the average global production of palm oil, which is 3.96 tons of oil per hectare per year (Novindra et al. 2019). When the amount of harvest is large and abundant, the scarcity of common smallholders is the smallest compared to market needs. Therefore, common smallholders need help and the role of the government as a very significant alternative to support their palm oil farming. Unfortunately, support from the Regional Government is largely given to the types of common smallholders when compared with core smallholders and self-subsistent smallholders (Table 1). Entirely, the self-subsistent smallholders' oil palm

plantations have received more attention from the Indonesian government and international organizations (Lee *et al.* 2014). In fact, despite having the most support from the Regional Government, common smallholders have per capita expenditures that are close to the average expenditure of smallholders as a whole. The average harvest yields are not more than one ton (Table 1). Supported smallholders usually have relatively better performance when compared with independent smallholders so that the smallholders' oil palm system has great potential for increasing productivity. Its only needs are increasing farmers' awareness of changes in oil palm management requirements over the plantation life cycle (Euler *et al.* 2016a,b). Government support is not only limited to meeting the farmers' financial needs in running plantations but also on the instrument of deforestation policies. That must reflect environmental indicators for sustainable palm oil production while still safeguarding local communities who still depend on the forest ecosystem (Suwarno *et al.* 2016).

One other effort made by the government to support the sustainability of oil palm is the pattern of core people's production relations (PIR). In the government's conception, the PIR pattern is interpreted as a form of mutually beneficial cooperation between agricultural industry companies as a guide and surrounding farmers as the core. The primary impetus for core plantations is the development of smallholders, including high yield management and technology, as well as services that involve land clearing and planting, input supply, and processing. In the late 1970s, the government's efforts were to provide subsidized capital and land access for plantation development (Zen *et al.* 2005). The pattern of core peoples' production relations (PIR) can be classified into types of businesses that use contracts (contract farming). PIR production patterns are expected to encourage increased agricultural productivity managed by the people, aim to increase farmers' incomes and welfare, expand employment opportunities, open access to technology transfer, involve private capital in agricultural development, increase exports, and enlarge the country's foreign exchange (Chotim 2016). Oil palm plantations are believed to be a guaranteed asset and can improve living standards. However, the development of oil palm plantations in forested areas also takes on many important values because of the loss of ecosystem services (Acosta and Curt 2019). The empowerment of oil palm plantations managed by smallholders enables benefits for local communities (Suwarno *et al.* 2016). Palm oil yields from smallholders can usually reduce poverty among rural farmers (Azhar *et al.* 2017).

However, we found the phenomenon of low core smallholders' income despite receiving assistance, contrary to the positive expectations and probabilities offered in the PIR pattern, which indicates the failure that failed to be achieved in the contract farming concept.

The failure to apply the PIR pattern is likely to occur because the company failed to suppress labor conflicts, which in the end disrupted the deposit of farmers' production to the company. Thus, it can be said that the company failed to regulate farmers to comply with the agreement contained in the contract. Eventually, events that continue to occur will accumulate and can have an impact on economic costs and high social costs, which companies have tried to avoid from the beginning by entering into a contract farming system. In this case, the PIR pattern is also not able to increase farmers' income and welfare. The problem probably originated in the company's unpreparedness to function as a core party. The company is deemed unable to open the market for core smallholder products while failing to supply the funds, technology, and counseling promised in the initial agreement according to the contract, even though these are not the only determinants of failure or the successful implementation of the Food PIR pattern. However, it can be said that the company has a large tendency in the failure to apply the PIR pattern. The readiness of the core company to conduct the program outreach process is very influential on the success or failure of the PIR system (Chotim 2016).

The productivity and cultural practices of core smallholders are generally higher than self-subsistent smallholders due to management assistance and company standards. Transfer of agricultural skills is proving difficult, especially with people from non-agricultural backgrounds. It often takes years for these settlers to competently handle their territories, especially with harvesting and other operations that require much expertise. When management is accustomed to dealing with hired workers and ignores the training problem, the results are undoubtedly wrong. However, when an appropriate and sympathetic extension is institutionalized, the results are often very good, increasing net profit for all parties. Bank Indonesia is also considered often slow in its payments to commercial banks that manage loans, while the latter banks are poorly coordinated with both the department and plantation companies, which results in months or even years of delay in land clearing and planting, leading to higher spending to support core smallholders. Smallholders and self-subsistent smallholders are usually residents,

which means they can access land without a large fee, which often applies to plantations and other outsiders (Zen et al. 2005).

On the other hand, the government and company assistance can cause conflict. A lack of transparency almost entirely causes conflicts between communities and companies and the government, unequal distribution of benefits, and lack of clear land rights (Rist et al. 2010).

4.2 Seeds and planting

Seed selection and planting methods are the main supporting factors for the amount of oil palm harvest. Self-subsistent smallholders have the most extended average planting period of 23 years. The average difference in the life span of self-subsistent smallholders to core smallholders and common smallholders is around 6 years and 10 years (Table 2). The average age of oil palm plantations ranges from 7 to 16 years for smallholders (Merten et al. 2016), but it does not rule out the age of oil palms over. Palm oil is a long-lived plant, and the stand can reach more than 30 years (Smith et al. 2012).

When viewed from the need for seeds to be used later, core smallholders have the greatest needs, reaching 138 units/ha compared to self-subsistent smallholders and common smallholders (Table 2). The success of the whole seed is significantly influenced by the distance between rows, concluding that less optimal distances give low yields per hectare. In contrast, optimal distances give high yields per hectare (State 2018). By comparing the number of seeds with plantation age, it can be observed that self-subsistent smallholders have the highest ratio up to 10.1 when compared with core smallholders (8.1) or common smallholders (5.6) (Table 2). Referring to the needs of seedlings, it can be recommended that the types of self-subsistent have the highest productivity when compared with core smallholders and common smallholders. Instead, traced from the planting period and harvest quantity, the best recommendations are produced by the type of farmers who are self-subsistent smallholders. The need for seeds per unit/ha is also relatively small so that its productivity is high.

The following discussion explains the types of seeds used. There are two types of seeds used, Marihat and Scofindo. After the seeds are obtained, the core smallholders still have to treat the seeds, while the

common smallholders or self-subsistent smallholders use the seeds directly (Table 2). Generally, there are three techniques that can be carried out to improve seed quality, namely, the provision of hydration treatment, seed conditioning, and coating technology (Rahim et al. 2019).

4.3 Land and fertilizer

The amount of oil palm harvest is highly determined by the treatment of planting seeds and the type of land for planting oil palms. Land type and fertilizer treatment can increase land productivity. The average dose of fertilizer given by self-subsistent smallholders is 2.3 L/Ha, which is 0.1 L/Ha greater than common fertilizer and 0.6 L/Ha higher than core fertilizer (Table 3). Fertilizer application usually contributes a relatively large portion of the production cost of oil palm plantations, reaching around 31–35% of oil palm plantations for up to 10 years and around 50–60% over more than 10 years of age (Lifianthi and Husin 2012). If related to the previous Table 2 findings, taking into account the planting period of self-subsistent smallholders which can reach 23 years, this use is still relatively normal and balanced. Although not too aggressive in spurring land productivity because there is only a small difference in fertilizer dosages between common smallholders and self-subsistent smallholders, the yield of self-subsistent is relatively higher when compared with common smallholders. The application of fertilizers in palm oil cultivation boosts crop production to the maximum since they provide mineral nutrients (Daemeter Consulting 2013). The dose of fertilizer is a significant determinant of yield gaps in addition to the length of time of harvest and crop mortality (Euler et al. 2016a). In addition to the dose of fertilization, the use of fertilizer must also be done at the right time. The application of fertilizer can improve the physical, biological, and chemical properties of the soil and provide the availability of nutrients to increase growth and yield (Sudradjat et al. 2018). The important role of fertilizers in the production and maintenance of large and sustainable fruit bunches results has led to efforts to develop methods that provide a scientific basis for estimating oil palm fertilizer needs (Fairhurst and Mutert 1999). Table 3 lists that fertilizer application can boost productivity, even though the palm oil plantation not in their productive periods. Moreover, fertilizer application can boost productivity but the application should be

appropriate, because inappropriate fertilizer application can give an impact on the environment and in the end will affect productivity (Woittiez *et al.* 2019). The efficiency of fertilizer application is essential to increase the yield, minimizes the negative impact on the environment, and reduces operational costs (Jelsma *et al.* 2019). Because of that, the appropriate fertilizer application will increase the yield plantation and having beneficial income gains. If this approach can be extended to traditional smallholders, it will mark significant progress.

On the other hand, the use of fertilizers needs to pay attention to the composition of substances present in fertilizers, which must continue to be sought. Thus, more use of environmentally friendly materials and low in chemicals will be sought. Guidance and direction in helping farmers practice proper oil palm cultivation and without damaging the environment can also be provided by the government and other institutions (Lifianthi and Husin 2012). Organic fertilizer is feasible as an environmentally friendly alternative source of nutrition for oil palm plantations even though it does not provide maximum results (Lee *et al.* 2014). Oil palm plantations must apply properly in both wetland and dryland plantations, environmentally friendly agricultural methods and practices to support sustainable development (Lifianthi and Husin 2012). When viewed from an environmental perspective, the palm oil sector must be a concern when developing rapidly in areas with weak environmental law enforcement. The increase of productivity which is focused on extensification leads to deforestation, and palm oil production will tend to cause large-scale loss of biodiversity (Azhar *et al.* 2017). Recently, there is a research that proves that the oil palm economy has a very large-added value only to those who participate in the production chain. Moreover, it tends to be disincentive or less useful for those out of the chain, especially if deforestation is due to oil palm plantation expansion (Purnomo *et al.* 2018). New alternatives in the use of agrochemicals and plant protection are believed to contribute significantly to biodiesel production's environmental impact, reaching 50% (Siregar *et al.* 2015). If environmental standards can be raised, and policy interventions targeted broader social impacts of land development, oil palm expansion in Indonesia has significant benefits for many rural smallholders (Rist *et al.* 2010). Expansion of oil palm plantations on suitable land increased productivity and extraction of palm oil must be encouraged to reduce environmental impact (Silalertruksa *et al.* 2017).

Another factor that can trigger large amounts of land productivity is the type of land cultivated by each farmer. Not only productivity, age of planting, and soil type will affect production costs. Among the common, the largest composition of land used is mineral soils when compared with peatlands. Self-subsistent smallholders cultivate land in the same composition, while core smallholders plant on mineral soils (Table 3). The existence of soil management practices assumes that soil carbon stocks on mineral soils do not increase or decrease with the cultivation of oil palm (Khasanah *et al.* 2015).

Oil palm plantations in wetlands are more prospectively based on performance. Based on the current performance, significant differences in productivity and income earned by farmers in both regions suggest that wetland oil palm plantations are more prospective (Lifianthi and Husin 2012). When viewed from farmers' incomes, with the same amount of land, peatland farmers have lower income than farmers on mineral land (van Reemst 2015). Developing good oil palm on peatlands requires water management considerations to minimize peat oxidation and subsidence (Othman *et al.* 2011). In addition, Central Kalimantan, Indonesia, has proven that more than 40% of the peatlands converted for oil palm plantations will release carbon dioxide of 93 to 217 megatons (MtCO_2e) over the next 25 years (Dohong *et al.* 2018). Therefore, choosing the right land can optimize productivity even without looking at which groups of farmers plant oil palm. Spatial arrangement and selection of appropriate land capabilities are needed to control the productivity of oil palm plantations (Muhjad 2016).

Palm oil can grow on Podzolik, Latosol, Hydromorphic Gray, Alluvial or Regosol soils, saprik peat soils, coastal plains, and river mouths. The optimal acidity (pH) for oil palm is 5.05. Palm oil requires loose, fertile, flat, and well-drained (irrigated) soil and has a deep layer of solum (80 cm) without layers. The slope of oil palm plantations should not be more than 15° (Palm Oil Cultivation Technology, Innovation Book Series, BBPPTP 2008).

Table 4 lists the differences in average yields among smallholder groups are significant, but based on survey results, there are no significant differences between seed producers in influencing yields. The two-way ANOVA test results detected that the yields also did not differ significantly between the use of seedlings or seed producers in Marihat and Scofindo (Table 4). The ANOVA test results indicate that the quality of seeds

Table 4: Two-way ANOVA of harvest output differences among farming groups and seeds planted

Number of obs	400	<i>R</i> -squared	0.4293
Root MSE	0.1550	Adj <i>R</i> ²	0.4235

Source	Partial SS	Df	MS	<i>F</i>	Prob > <i>F</i>
Model	2.8040	3	0.9346	26.92	0.0000
Farming groups	2.8025	2	1.4012	40.37	0.0000
Seeds	0.0470	1	0.0470	1.36	0.2450
Residual	13.7123	395	0.0347		
Total	16.5164	398	0.0415		

from the producers did not differ at a significant level of 5% and did not reject the hypothesis of 0. This result also confirms previous findings related to significant differences in output between farmer groups. That is, the use of fertilizers and optimal seed care alone is not significant enough to increase yields, but other combinations of factors are also needed to build maximum yields. Another factor can be in the form of planting management practices. Under proper management, oil palm is very responsive to fertilizers (Fairhurst and Mutert 1999). Better planting management can increase palm oil yields from an average of 4 tons/ha to 5–6 tons/ha, or as much as 8 tons/ha in good years (Pauli et al. 2015). Failure of management practices is the main factor that can reduce crop yields (Rhebergen et al. 2018). In addition, the location and condition of oil palm plantations also affect production results because they are related to land drainage capacity, planting depth, and the nature of the substrate contained in the land (Veloo et al. 2015). Factors limiting and determining the growth of oil palm (radiation reception, planting material, climate classification, rain distribution, and nutrient supply), pests and diseases, and plantation management determine the harvest results (Obikihe and Sc 2016; Stomph 2017; Rhebergen et al. 2018).

Investing in palm oil planting and cultivation management on smallholder plantations and improving the access for smallholders can increase palm oil productivity without adding to planted areas (Rhebergen et al. 2018). Policymakers must focus to improve the policy that offers benefits to smallholders and every short-term action needs to be complemented by initiatives to improving the quality and availability of planting material (Euler et al. 2016b). An increase in palm oil productivity can be achieved not only by extensification, which can put pressure to forest resources but also by improving the planting and cultivation methods and management. Increasing the

smallholders productivity offers the improvement smallholders livelihoods, local community development, and improve overall palm oil sectors.

5 Conclusion

Self-subsistent smallholders can achieve the highest average production and income with less expenditure than the other two smallholders. They have the most extended planting period with the fewest amount of seed use and the highest success rate of common smallholder planting. That high success can be triggered because the provision of fertilizer doses by self-subsistent is higher than that of core smallholders and common smallholders, even though their plantation period has been passing the productive period. Support from the local government is mostly given to the types of common smallholders when compared with core smallholders and self-subsistent. Even though they have received the most support from the local government and have the shortest plantation period but their harvest quantity does not reach one ton. It means that the support from local governments does not yet have a significant impact on the production process of smallholder, especially smallholders in Jambi. Moreover, the optimal use of fertilizer and seed care alone is not significant enough to increase yields. So to increase the smallholder productivity still need a combination of other factors such as planting management practices, drainage capacity and soil substrate properties, climate characteristics, rainfall distribution, nutrient supply, and prevention of plant diseases. Good planting management is also one of the keys to success in increasing palm oil productivity. In addition, support from all parties is also needed to assist smallholders in increasing crop yields that give a positive impact on smallholder livelihoods and local community development. In a greater aspect, the results of this study can be used as information to improve smallholder cultivation technic and increase smallholder productivity since their productivity and cultivation have been fallen behind from the other stakeholders. This study was carried out on one province and from indicator harvest, seed, and fertilizer that smallholders applied in their cultivation and planting process. Moreover, to improve their productivity and cultivation is a complicated process, and many factors that can influence that issue. So, it is recommended to analyze other indicators that influence the productivity and cultivation of smallholders either in Jambi or other

provinces in Indonesia to increase the overall palm oil productivity of smallholders.

Abbreviations

%	percentage
\$	dollar
μ	indicator
°C	degree celcius
ANOVA	analysis of variances
CPO	crude palm oil
CO ₂	carbon dioxide
Df	degree of freedom
FFB	fresh fruit bunch
Freq.	frequencies
GMP	good management practice
GAP	good agriculture practice
H	hypothesis
Ha	hectares
ISPO	Indonesian sustainable palm oil
kg	kilogram
L	liters
m	meter
m ²	square meters
MJ	metrics joules
MS	mean square
MSE	mean square error
Mt	metrics tons
N/A	no available
PIR	perkebunan inti rakyat/plasma program
PIRTrans	Perkebunan inti rakyat transmigrasi/plasma transmigration program
RSPO	roundtable on sustainable palm oil
RP	rupiahs
Std.Dev.	standard deviation
SS	some of square
US	United States
USD	United States dollar

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