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Resource Utilization in Integrated Oil Palm - Bali Cattle Farms in Paser Regency East Kalimantan

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Abstract
A study on oil palm-Bali cattle integration aimed to identify the level of utilization of farmer resources, and the technical efficiency at the individual level compared to its best potential achievement (frontier production). A survey was carried out in Paser Regency, East Kalimantan. The sample as much 152 farmers as a decision unit was randomly selected in two stages: firstly, choosing farmer groups in the location studied, which covered the district area of Long Ikis, Long Kali, Paser Belengkong, and Kuaro; Second, choosing sample farmers from the selected group. Regression analysis is used to describe the output-input relationship of the system being studied. The causal relationship is modeled by the Cobb-Douglas production function. The results show that cattle production is at constant returns to scale, meaning that a twofold increase in livestock output is obtained by a twofold increase in all the resources used. The number of cattle ownership and labor are two factors that significantly increase farm output. Stochastic frontier analysis to estimate farm-level technical efficiency results in as much as 46.7 percent of farmers achieving the first and second grades of technical efficiency with an inefficiency index range is 0.7-0.9. The rest or 53.3 percent have an index range of below 0.7. Meaning that there is still a large chance for this sector to use resources more efficiently by increasing the number of cattle. Bali cattle are reproducible and transferable capital assets, making them relatively practical and affordable for smallholders to be raised. While the productivity of oil palm trees decreases with age, integrating Bali-oil cattle into their farm will strengthen the livelihoods and income of the farmers.
Keywords: constant return to scale, frontier, inefficiency index

Pemanfaatan Sumber Daya Terpadu Perkebunan Kelapa Sawit - Peternakan Sapi Bali di Kabupaten Paser Kalimantan Timur

Abstrak
Kajian integrasi kelapa sawit-sapi Bali bertujuan untuk mengidentifikasi tingkat pemanfaatan sumber daya petani, dan efisiensi teknis pada tingkat individu dibandingkan dengan potensi pencapaian terbaiknya (produksi frontier). Survei dilakukan di Kabupaten Paser, Kalimantan Timur. Sampel sebanyak 152 petani sebagai unit keputusan dipilih secara acak dengan dua tahap yaitu pertama, memilih kelompok tani di lokasi penelitian yang meliputi wilayah Kecamatan Long Ikis, Long Kali, Paser Belengkong, dan Kuaro; Kedua, memilih petani sampel dari kelompok terpilih. Analisis regresi digunakan untuk menggambarkan hubungan output-input dari sistem yang dipelajari. Hubungan sebab akibat dimodelkan oleh fungsi produksi Cobb-Douglas. Hasil penelitian menunjukkan bahwa produksi ternak berada pada skala pengembalian konstan, yang berarti bahwa peningkatan hasil ternak dua kali lipat diperoleh dengan peningkatan dua kali lipat dalam semua sumber daya yang digunakan. Jumlah kepemilikan ternak dan tenaga kerja merupakan dua faktor yang secara signifikan meningkatkan hasil peternakan. Analisis stochastic frontier untuk mengestimasi efisiensi teknis tingkat petani menghasilkan sebanyak 46,7 persen petani mencapai tingkat efisiensi teknis tingkat satu dan dua dengan kisaran indeks inefisiensi 0,7-0,9. Selebihnya atau 53,3 persen memiliki kisaran indeks di bawah 0,7. Artinya masih ada peluang besar bagi sektor ini untuk menggunakan sumber daya secara lebih efisien dengan meningkatkan jumlah ternak. Sapi Bali adalah aset modal yang dapat direproduksi dan dialihkan, membuatnya relatif praktis dan terjangkau untuk dipelihara oleh petani kecil. Sementara produktivitas pohon kelapa sawit menurun seiring bertambahnya usia, mengintegrasikan sapi bali ke dalam peternakan mereka akan memperkuat mata pencaharian dan pendapatan petani.
Kata kunci: skala hasil konstan, frontier, indeks inefisiensi

Introduction

Maintaining sustainable livestock production requires adequate resources, such as land, environment, capital, and human resources. The farmers as decision-makers are a key factor in the success and sustainability of production. Oil palm plantations have potential resources that farmers can use for livestock, especially ruminants. It provides sufficient space and environment for animals to graze and meet their forage needs. Indonesia is the world's leading palm oil producer, and both large companies and smallholders are involved in the sector (Euler et al., 2016). However, this potential has not been utilized optimally to produce livestock to meet the local's needs

(Hanun, 2018). Integrating livestock into oil palm plantations can optimize the resources, the planted area endows wild grass and weeds that could be eaten by the cattle. It makes the cost of feed free. Grazing cattle can be a strategy to reduce chemical herbicides that have an impact on the environment friendly, and also the success of livestock production can promote food security (Azhar et al., 2021). The benefits of crop-livestock diversification will overcome losses to farmers by balancing the trade-off between maximizing profits and reducing risk (Bell et al., 2021).

Oil palm farmers who integrate beef cattle into their plantations which are managed in semi-extensive farming have the advantage of obtaining forage without additional agricultural land (Bremer, et al., 2022), in contrast, farmers in other regions or islands face limited land resources, and they have to pay for this resource. Raising animals with minimum feed costs is the best choice for oil-palm farmer livelihood. Even though farmers have income from their contract farming, oil palm smallholders remain vulnerable to poverty (Cahyadi & Waibel, 2015). In general, the integration system can reduce the impact of deforestation, and reduce the use of herbicides, by releasing the animal into the plantation area, the cattle will reduce weeds under the palm oil trees (Grinnell, et al., 2022)

An integrated crop-livestock system (ICLS) combines several components for economic, social, and environmental purposes. The integration process requires a holistic approach, dynamic, interactive, and multidisciplinary to support more efficient natural resources management. The integration of crops and livestock provides a synergistic effect that results in a greater added value impact compared to specialized production and intensive farming (Devendra, 2011). ICLS is socially and economically beneficial and contributes to food security, this system has been recommended for development in various countries, both developed and developing countries (Sekaran et al., 2021).

Bali cattle is a type of cattle that is preferred by farmers to be reared in palm oil plantation areas. It is estimated that a quarter of the local cattle population that is growing spread across various islands in Indonesia is a type of Balinese cattle (Lisson et al., 2010). Generally, farmers keep them to free-graze or in a semi-extensive manner. Various plants and types of grass and other wild plants that grow around the palm trees are a source of feed for Bali cattle. Bali cattle is a local breed that can survive in a tropical environment and utilizes low-nutrient feed sources. Besides eating grass, Bali cattle can also eat parasitic plants such as ferns that grow on palm tree trunks, or palm fronds that fall (cut) when the palm fruit is harvested. Bali cattle are known to adapt easily to various environmental conditions, these cattle eat agricultural waste, leaves, and weeds without requiring special handling. In the integrated system of Bali cattle and crop, feeding with agricultural waste supplemented by a kg rice bran can achieve a body weight daily gain of 0.55-0.56 kg (Mastika et al., 2017).

Over the last two decades, several palm oil-producing regions have been developing a Cattle-Palm Oil Integration System (SISKA) which has become the platform for several local government policies to encourage growth in the development of this sector. The policy of the central government of the Republic of Indonesia is contained in Ministerial Regulation No.105/Permentan/PD.300/8/2014, concerning the Integration of Oil Palm Plantations with Beef production. The three commodities resulting from the integration system have economic value, namely oil palm fresh fruit bunches (*Tandan Buah Segar*), by-products of palm oil processing, and beef cattle as complementary products. The cattle release organic matter needed by the soil and plants, and the farmers get grass and weeds for their cattle feed freely. In post-harvesting, the oil processing unit produces by-products that can be used as animal feed, such as palm kernel expeller, palm oil sludge, palm pressed fiber, oil palm fronds, and oil palm trunks (Kum & Zahari, 2011), although there is no standard of biomass processing produced by the industry (Silalahi et al., 2018)

To develop the integration system, the local government supports the SISKA program by distributing Bali cattle to the farmers and organizing their collective activities in farmers' groups. Paser Regency is one of the two regencies in West Borneo with the highest beef cattle population. The Central Statistics Agency for Paser Regency reports that the cattle population in 2020 is 18,977 heads. The total acreage of the plantation area is 192,500 hectares planted by oil palm, rubber, coconuts, and others. Hence the cattle-plantation ratio is

0.10, or on average 10.1 hectares of plantation area for one cattle. The oil palm plantation area is 175,042 hectares whereas smallholders occupy 42.8% of the planted area, and the remainder is managed by private companies and government estate (BPS, 2021).

To develop the SISKA program, local governments prioritize the smallholder. They are decision management units (DMU) as the key actor that has an important role to achieve the success of the program. This study aims to examine the achievement of the farmers to utilize their potential resources to raise cattle and increase whole-farm production. The analytical model used in this study identify technical efficiency at the farm level and compares the performance of each farm to the fully efficient farm (the best achievement). The results can identify which categories of farmers are inefficient and need improvement to increase their performance and productivity in using farm resources.

Materials and Methods

This study used a survey method in four sub-districts in Paser Regency, East Kalimantan. The locations studied cover the sub-districts of Long Ikis, Long Kali, Paser Belengkong, and Kuaro. The unit of observation is the selected farm that manages oil palm plantations and raises Bali cattle. The selected farmers were determined randomly by multi-stage random sampling. The first stage was to determine the farmer group sample, and the next stage, determine the farmer sample as the decision management unit (DMU) that will be analyzed. Second, we chose farmers from the selected group. Data collection regarding farm output and utilization of farm resources used interview techniques based on a list of questions prepared. The interview took place at the farm location.

Farm outputs consist of oil palm fresh fruit bunches (FFB) and beef cattle. The yield of palm oil is measured by the FFB sold in tons for one year. The yield of beef cattle is measured based on the number of young cattle yielded over a year. The unit of measurement of cattle used standard of livestock units (LSU), with conversion: adult cow or bull = 1 LSU, young cattle (0.5-1.5 years) = 0.8 LSU, and calves (<0.5 years) = 0.25 LSU.

Farm resources or factors of production comprise the acreage of plantation land (hectares), the number of broodstock (livestock units), farm labor, and capital assets such as cattle sheds and farm equipment. Farm labor was measured by using a standard of the workday unit. One of the workday units is equivalent to 8 hours of work for an adult. In the case of children or women are works, their workday unit is weighted by a factor of 0.5 and 0.75, respectively.

Models of Resource Utilization

The relationship between resource utilization and output was explained by the regression model, the first model explains the effect of resource availability on livestock production. The second model uses the combination of livestock and palm oil (total farm output) as the dependent variable. The individual output is represented by aggregated both, oil palm fresh fruit bunches and cattle yields (IDR per year) in a particular year (Perchova & Simpach, 2019). The *Maximum Likelihood Estimation* (MLE) was used to obtain the technical efficiency index resulting in the second model.

Production with a single output of cattle yield

The Causal relationship between resource utilization in livestock production was simplified by the Cobb-Douglas (CD) equation model. It is a set of observed variables that establishes a relationship between single output and several agricultural resources or factors of production. The relationship between variables in the integrated system of Bali cattle and oil palm is related to natural phenomena in which each treatment or event produces uncertain results. Hence, in this study, we identified the causality in stochastic mathematical equations. It is necessary to explain natural science facing large uncertainty (Renard et al., 2013).

The Cobb-Douglas production function in a logarithmic form is expressed as the following equation:

$$ln\, y_i = ln\, \alpha + \sum \beta_k \; ln\, x_{ki} + \delta D_i + u_i \quad (1)$$

$y =$ young cattle yielded, both those that are still kept and have been sold by farmers (heads/year)
$x_1 =$ cows and bulls (head)
$x_2 =$ household labor of farmers (man hour per day),
$x_3 =$ capital (IDR-million rupiah), and
$D =$ business orientation, measured by binary number:

D = 0 for breeding cattle, and
D = 1 for both, breeding and rearing commercial calves
$u_i =$ statistical disturbances

From the CD equation above, at least two production response parameters can be explained: (1) the exponential coefficient of each input which describes the output response to each resource use, and (2) the homogeneity of the function, namely the sum of the exponential coefficients $(\sum \beta_k)$ which explains total production elasticity, it measures the percentage increase in farm output from an increase of all resources proportionally (return to scale).

The below t-statistic is used to test $H_0\!:\sum \beta_k = 1$, with a level of significant 0.05. The H_0 accepted, if the $|\text{t} - \text{critical}|<$ t-statistic (Gujarati & Porter, 2009).

$$t = \frac{\sum\widehat{\beta_k} - 1}{se\,(\sum\widehat{\beta_k})} \text{ ; and } se\,(\sum\widehat{\beta_\iota}) = \sqrt{\left(\sum\widehat{\beta_k}\right)^2} \qquad (2)$$

$\widehat{\beta_k}$ is the estimated coefficient for each resource or independent variable.

Farms Performance and Inefficiency Index

Measuring a farm's performance as a decision management unit (DMU) uses the technical inefficiency index (TE). The index ranges between zero to one. The farmer has an index value of one for the success of achieving fully efficient in using their resources, and the others (most of the farmers) are those who get an index <1, meaning they relatively face an in-efficiency problem. Maximum likelihood was used to estimate the in-efficiency index, and one should have modified the Cobb-Douglass equation into equation (3) explained below (Kumbhakar *et al.*, 2018).

The stochastic CD production model is modified and expressed in the form of an equation with a u_i negative sign, as follows:

$$ln\, y_i = ln\, \alpha + \sum \beta_k\ ln\, x_{ki} - u_i \qquad (3)$$

in a matrix form:

$$\boldsymbol{Y_i} = exp\,(\boldsymbol{x'}\,\boldsymbol{\beta} - \boldsymbol{u_i}) \qquad (4)$$

$\boldsymbol{Y_i}$ is a vector of the logarithm of total output (mixed yield of cattle and oil palm) on the individual farmers. The right side of the equation above is the exponential of $(\boldsymbol{x'}\,\boldsymbol{\beta} - \boldsymbol{u_i})$, $\boldsymbol{x'}$ is a row vector of the logarithm-dependent variables and $\boldsymbol{\beta}$ is the column vector of the regression coefficient to be estimated. In this deterministic model, $\boldsymbol{u_i}$ is a non-negative random variable representing the technical inefficiency effect on each farmer.

The achievement of the level of technical efficiency (TE) is an index of the ratio between the two conditions, namely the ratio between the output based on the results of observations on the farmer and the (Y_i) the potential output that should have been produced (Y_i^*):

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{(exp\,(x'\beta - u_i)}{exp\,(x'\beta)} \qquad (5)$$

because:

$$exp\ (u_i) = \frac{1}{exp\,(u_i)}\ ;\ where\ u_i\ (non\ negatif)$$

then, the TE_i index will have a value ranging from zero (the lowest value) to one (the highest value). Most farmers have an index below one and some (if any) reach one (full efficiency), this explains most of the farmers are performing below full efficiency. The determination of TE will be calculated using the stochastic frontier analysis (SFA) method for cross-section data based on the following production function equation:

$$ln\, Y_i = ln\, \beta_0 + \sum \beta_k\, ln\, x_{ki} + \varepsilon_i \qquad (6)$$

Where ε_i is a combination of two random variables, $(\varepsilon_i = -u_i + v_i)$ each of which is the impact of inefficiency with a $(u_i\ )$ semi-normal and non-negative distribution, as well as a random variable with (v_i) respect to statistical errors which are normally distributed so that the value can be negative or positive. The variance of the two random variables was estimated using the maximum likelihood estimation method. Statistical tool STATA v.17 was used to estimate the coefficients of the production function specified (Belloti et al., 2013).

Results and Discussion

Resources used in integrated Bali Cattle and Palm-Oil

Land is the main resource for plantation farmers even though they are small farmers. The farmers we studied, as previously prepared, are those who cultivate oil palm. Land and oil palm plantations were originally physical assets that they owned. Over two decades, particularly since the SISKA program has been launching for two decades, they have also been raising Bali cattle. The average area of land owned by farmers is 3.59 hectares, and most (83.01%) of the land is planted by oil palm. They manage their crops under a partnership scheme between smallholders and plantation companies (in the scheme of plasm-nucleus estate). The age of the date palm ranges from 4 to 41 years (average 29.84 years) with average productivity of 2.38 tons of fresh fruit bunches per month. In A study of smallholder palm oil, farmers had to use less plantation labor and seek other economic activities to reduce household economic risks (Mehraban et al., 2021).

In the region of study, farmers raise cattle by grazing under oil palm trees, so feed intake by the cattle depends on the availability of edible forage in the plantation area and the movement of animals. Cattle is the second major productive asset after oil palm, even more, many farmers with their current scale of ownership, argue that beef cattle contribute cash income to farmer households more compared to oil palm. Bali cattle are the type of cattle preferred by most integrated farmers, as are commonly found in various oil palm plantation areas in Indonesia (Sil18). This type of livestock spreads and reaches about a quarter of the local cattle population, its role as a very reliable source of livelihood for small farmers (Lisson et al., 2010).

The ability of Bali cattle to survive in areas with minimal feed quality makes it possible to be reared in oil palm plantations both extensively and semi-extensive. This system benefits farmers by obtaining roughage feed freely and minimizing labor costs. In the region under study, the farmer on average hold 5.02 head of cow, approximately 65% of the total population was brood stock, and the rests are young cattle and calves. The average number of cattle is larger than livestock ownership in other integrated agroecosystems. In a study in integrated food crop-cattle farming (Mastika et al., 2017), with an average cultivation area of 0.5 hectares, breeders can raise a maximum of 4 Bali cattle which are integrated into the crop.

Integrated agricultural products are a combination of livestock products and oil palm fresh fruit bunches (FFB). The aggregate value is obtained by dividing the combined output value by the price of one ton of FFB. More a half of the farmers acquired less than 3 hectares of land or an average of 1.81 hectares. The cattle ownership varied ranging from 1-29 heads, around 61,2% of farmers are the smallest holder category, they keep 3-5 heads of cattle. Having a large acreage of plantation (over 6 hectares) did not cause farmers to increase the cattle-land ratio, farmers face many obstacles to optimally using their resources by increasing the number of cattle. Additional inputs are needed to increase herd sizes, such as working capital, appropriate technology, markets, and farmer skills (Wulandari, 2021). Technically, extensive rearing allows to use of plantation areas for cattle grazing, however, the acreage land cultivated by the farmer is not the main factor in determining the number of cattle reared.

Most farmers applied the natural mating system to mate their livestock, however, the local government of livestock service in Paser District has also facilitated artificial insemination services. Natural mating was widely practiced because, in an extensive rearing system, the application of this system is more practical where farmers do not need to take the time to observe the reproductive cycle of their cows. Although the nutritional adequacy of feed for livestock reared extensively is lower, livestock raised extensively yields higher profitability than intensive rearing. Millions of smallholder farmers in Indonesia raise Bali cattle in plantation areas. Farmers release these animals to graze under planted trees. These animals live with low intake and survive under tropical environmental pressures (Martoyo, 2011).

Output response to the resource utilization

Function of production that describe causality between farm resources and the cattle yielded, is expressed in Cobb Douglass equation model below. The second equation model (7) is constrained by $\sum \beta_k = 1$, meaning that the relationship at the constant return to scale.

$$Y = 0{,}777\, x_1^{0.600} x_2^{0.233} x_3^{0.059} x_4^{0.025}\, e^{0.948D} \qquad (7)$$

$$Y = 0{,}697\, x_1^{0{,}611} x_2^{0{,}261} x_3^{0{,}097} x_4^{0{,}031} e^{0.933D} \qquad (8)$$

The coefficient of determination (R^2) is 0.53, it means that 53% of the variation of Y is explained by the variables inside the regression model and the rest is explained by other factors outside the model. Statistic-F is 33,38 with probability p < 0,05. As a result, we cannot accept the null hypothesis of the identified model effect. T-test the constant RTS ($H_0: \sum \beta_k = 1$) is applied to the first model or equation (7), and results in t-critical (t = 0,094) with probability p>0,05, therefore we accept the hypothesis null above. Based on this result, we construct a restricted equation model (8) that explicitly expresses the sum of β_k is equal to one (Table 2).

Partially, the cattle yield is significantly influenced by the number of broodstock (x_1) and the business orientation (D). In the restricted model, land acreage (x_4) influences the yield significantly. From the two models, the total elasticity ($\sum \beta_k$) statistically is equal to 1, so it can be stated that resource use is in a constant return to scale condition (constant RTS), This means that every fourth increase in resources simultaneously causes an increase in output by the same proportion, or doubling all factors results in doubling output. In this condition, the increase of farmer income will be determined by the price ratio of output and input (Hadiana *et al.*, 2018). In the cases where farmers get labor and forage freely, it is better to add their livestock to get more yield and income.

All resources positively affect agricultural yields, meaning that an increase in available agricultural resources increases yields. The Cobb-Douglas production function model allows us to interpret the coefficients of each independent variable as a measure of the elasticity or responsiveness of inputs, namely the percentage increase in output for a one percent increase in the related input. The partial response of the resources or factor of production is 0.611, meaning that the ownership number of cattle is relatively elastic to the increase in livestock yield, and doubling the number of cattle increases yield by 61.1%. This response is relatively high compared to other resources such as labor and capital.

The difference in business orientation categories into two groups of farmers, hence we measure the variable using a binary scale. We mark zero for farmers keeping only brood stock, and one for farmers also raising commercial cattle. Business orientation has a significant effect on livestock yields. As many as 16% of farmers manage their business both in breeding and raising young cattle commercially. They also buy calves to raise for months and sell the reared cattle when they reach a commercial weight and/or when demand and market prices are high.

Inefficiency index

The results of the stochastic frontier analysis using the maximum likelihood estimation, produce a model as shown in Table 3. Overall, the technical inefficiency achieved by the farmer on average is 0.66 compared to 1 (the full efficiency). Overall, the variation in technical inefficiency ranges from 0.28 to 0.90. The farmer who is relatively efficient or those who have an efficiency index >0.80 reach 19%. More than half or 53.3% of farmers have an inefficiency index below 0.7.

The distribution pattern of technical efficiency achieved by farmers fulfills the assumption of approaching a half-normal distribution, those who achieve relatively high efficiency (TE index close to one) are graphically centered to the right (Figure 1). However, the overall achievement of these farmers is still low compared to their potential, meaning that existing resources, technically, can still be improved to achieve the most efficient conditions.

Technical inefficiency is related to plant productivity in producing fresh fruit bunches. The main factor causing the decrease in total output is thought to be oil palm productivity. Most of the crop yields have started to decline due to aging. In the area under study, the average age of the plants is more than 22 years. Oil palm planted in Paser Regency has an average age of 34 years. It is entering a phase of decline in production, the older the plant, the lower the productivity of the plant, resulting in a decrease in the income earned from the oil palm plantation (Mariyah et al., 2018)

The distance between the two conditions, the actual achievements, and the potential that can be achieved show that there is still room for farmers to increase their productivity (Ojo et al., 2009). The productivity of oil palm plants decreases with age, so farmers rely on livestock assets as an additional source of income. In the cattle-palm oil integration system. Cattle is a flexible asset because gathering and raising cattle is relatively short and easy compared to planting palm oil trees.

The various achievements of DMU in the utilization of agriculture (Table 3), raised issues or further questions related to the effects of inefficiencies. For policy purposes, we often need to know what factors, both internal and external, influence the success of farmers in managing their resources. A study of mixed-crop farming in different geographical agriculture (Ahmed et al., 2020), showed that farm size, environment or plantation location, and technology were determining factors contributing to inefficiency. In the case of external factors influencing farm productivity and technical efficiency, developing SISKA program requires organizational and institutional support to create marketing opportunities (Sekaran et al., 2021).

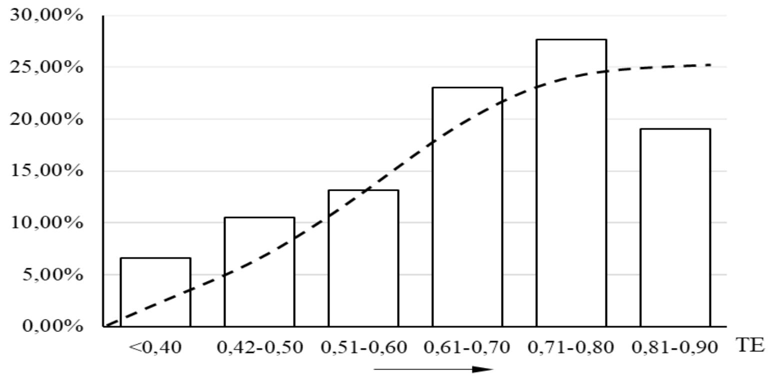

Figure 1.
Distribution of technical efficiency at the farm level

Table 1. Average farm output and resources

Farm output and resources		Land size category			Total average
		<3 ha	3-6 ha	>6 ha	
Total farm output	Eq. ton FFB	35,28	48,06	61,99	43,40
Cattle yield	(head)	4,29	4,89	7,72	5,08
Broodstock (animal asset)	(head)	4,42	4,36	7,34	4,94
Labor	(man-hour/day)	6,13	6,54	9,62	6,87
Capital	(IDR million)	3,02	3,24	3,22	3,11
Land	(hectare)	1,81	3,72	8,62	3,54
Farmer/cattle trader	(percent)	12,8%	15,8%	25,0%	15,8%
Number of households.	(n)	86	38	28	152

Table 2. The results of the regression analysis of the estimation model of cattle production

Variable	Regression without constraints		Regression with restricted ($\sum \beta_k = 1$)	
	(β_k)	P	(β_k)	P
Constant	-0.252	0.310	-0.361	0.000
Broodstock	0.600	0.000	0.611	0.013
Labor	0.233	0.052	0.261	0.253
Capital	0.059	0.609	0.097	0.704
Land	0.025	0.762	0.031	0.000
Business Orientation	0.948	0.000	0.933	0.000

The number of obs.	= 152	R-squared	= 0.533
F(5,146)	= 33.38	Adj R-squared	= 0.517
Prob > F	= 0.000	Root MSE	= 0.634

Table 3. Stochastic frontier analysis results for estimating technical efficiency at the farm level

Variable	coef.	P>|z|		
Constant	0.323	0.001		
Broodstock	0.176	0.470		
Labor	0.064	0.009		
Capital	0.219	0.000		
Land	0.273	0.000		
Average Technical Efficiency (n=152):	0.66			
Efficiency Range:	<0.40	Freq:	10	6.58%
	0.41-0.50		16	10.53%
	0.51-0.60		20	13.16%
	0.61-0.70		35	23.03%
	0.71-0.80		42	27.63%
	0.81-0.90		29	19.08%

Log likelihood = -101.59292
Number of obs = 152
Wald $chi^2(4)$ = 56.53
Prob > chi^2 = 0.0000

Conclusion

The cattle production integrated into oil palm plantations is in constant return to scale, meaning that a two-fold increase in all farm resources results in cattle yield two-fold. The number of cattle and farm labor are two factors that significantly increase cattle yield. The use of resources to produce total output (combination of fresh fruit bunches and cattle yielded), on average is still low compared to its best potential achievement (fully efficient). As much as 46.7 percent of farmers are in the first and second grades of technical efficiency (efficiency index range is 0.7-0.9), the rest, or 53.3 percent below the third grade or at the indexes range of below 0.7. This means that there is still a large space for this sector to use resources more efficiently by increasing brood stock ownership, considering the area of plantations owned by farmers is still quite large.

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