Research Article

Determinants of Adopting Oil Palm Frond Utilization Technology as Alternative Feed Among Beef Cattle Farmers in South Kalimantan, Indonesia

Fathin Imaduddin Hilmi[1], Muhammad Yasin Syihabuddin[2], Abidah Thorifatus Alya[1], Ahmad Romadhoni Surya Putra[1*]

[1]Department of Livestock Socio-Economics, Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia; [2]Department of Animal Science, Faculty of Agriculture, Universitas Lambung Mangkurat, Banjarbaru, 70714, Indonesia.

Abstract | The oil palm–cattle integration system in Indonesia creates opportunities to use oil palm fronds (OPF) as an alternative feed resource for beef cattle. However, adoption among smallholder farmers remains uneven, particularly in South Kalimantan. This study aimed to analyse the factors influencing farmers' adoption of OPF utilization as an alternative feed in Satui District, Tanah Bumbu Regency, South Kalimantan, Indonesia. Primary data were collected in May 2024 through structured face-to-face interviews with 119 beef cattle farmers selected purposively. Adoption was analysed as a binary outcome using binary logistic regression. The model showed acceptable performance, with a non-significant Hosmer-Lemeshow test ($p = 0.783$), Nagelkerke R^2 of 0.514, and classification accuracy of 83.2%. Livestock management system, participation in extension activities, and farmer group membership significantly influenced OPF adoption. Farmers operating semi-intensive or semi-extensive systems and those participating in extension were more likely to adopt OPF utilization, whereas farmer group membership was negatively associated with adoption. OPF utilization under SISKA is shaped more by practical farm management and extension exposure than by formal group affiliation. Strengthening field-based extension and improving the functional role of farmer groups are necessary to accelerate adoption of OPF as an alternative feed resource.

Keywords: beef cattle, Indonesia, oil palm fronds, SISKA, technology adoption, extension services.

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***Correspondence** | Ahmad Romadhoni Surya Putra, Department of Livestock Socio-Economics, Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia; **Emal:** ahmadromadhoni@ugm.ac.id
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INTRODUCTION

Indonesia is one of the world's leading palm oil producers, and the sector plays an important role in the national economy (Sukmaya, 2017). Alongside its economic contribution, oil palm cultivation generates large quantities of biomass residues, particularly oil palm fronds (OPF), which are produced continuously through pruning during harvesting and maintenance activities (Ooi *et al.*, 2017). OPF has attracted attention as a potential feed resource for ruminants because it is widely available in plantation areas and contains fibre and other nutritional components that can support cattle feeding when properly utilized (Hong *et al.*, 2012; Imsya and Yaqub, 2022). This potential is especially relevant in Indonesia, where feed scarcity remains a major constraint in beef cattle production and feed costs account for a large share of total production expenses (Ominski *et al.*, 2021; Begna and Masho, 2024). The use of OPF as an alternative feed may therefore help improve feed availability, reduce dependence on external

forage sources, and support more efficient livestock production systems.

This opportunity is particularly relevant in regions where oil palm and cattle production coexist, such as South Kalimantan. In this province, oil palm plantation area reached 424,754 ha in 2021 (BPS-Statistics, 2022). South Kalimantan is also one of the implementation areas of Sistem Integrasi Sapi-Kelapa Sawit (SISKA), or the oil palm-cattle integration system, which integrates beef cattle production with oil palm plantations. Previous studies have shown that oil palm-cattle integration can generate multiple benefits, including better use of plantation biomass, reduced weed control costs, improved soil fertility, and greater farm efficiency (Sirait *et al*., 2015; Bremer *et al*., 2022; Álvarez *et al*., 2024). Within this integrated system, OPF can serve as a locally available feed resource that supports both livestock production and plantation waste utilization.

Despite this potential, the use of OPF as cattle feed is not automatically adopted by farmers. Adoption depends not only on resource availability but also on farmer characteristics, farm conditions, and institutional support. Previous studies have shown that technology adoption in livestock and integrated farming systems can be influenced by factors such as education, farming experience, access to extension, perceptions of benefits, and the role of farmer organizations (Luthfi and Azizah, 2019; Yuhendra *et al*., 2022; Gabdo *et al*., 2013). In Satui District, Tanah Bumbu Regency, which is one of the important oil palm areas in South Kalimantan, many cattle farmers still rely on conventional feeding practices and may have limited access to practical support for OPF utilization. As a result, the technical potential of OPF does not automatically translate into widespread adoption at farm level.

Studies on oil palm-cattle integration in Indonesia have largely focused on technical feasibility, production potential, or general integration benefits, whereas empirical evidence on the determinants of OPF adoption at farmer level remains limited, especially in South Kalimantan. The novelty of this study lies in its specific focus on the behavioural and farm-level determinants of OPF utilization as an alternative feed within the SISKA context. Therefore, this study aimed to analyse the factors influencing beef cattle farmers' adoption of OPF utilization as an alternative feed in Satui District, Tanah Bumbu Regency, South Kalimantan, Indonesia.

MATERIALS AND METHODS

Study area and study period

This study was conducted in Satui District, Tanah Bumbu Regency, South Kalimantan Province, Indonesia, in May 2024 (Figure 1). The study area was selected purposively because Satui is one of the important oil palm plantation areas in South Kalimantan and represents a relevant setting for the implementation of Sistem Integrasi Sapi-Kelapa Sawit (SISKA), or the oil palm-cattle integration system. The coexistence of oil palm plantations and smallholder beef cattle farming in this area provides favourable conditions for examining the use of oil palm fronds (OPF) as an alternative feed resource.

Research design respondents, and sampling

This study used a cross-sectional survey design. Primary data were collected from beef cattle farmers through direct face-to-face interviews using a structured questionnaire. Respondents were selected purposively based on the following criteria: they were actively engaged in beef cattle farming, operated in the oil palm plantation area or its surrounding environment, and had the opportunity to access or utilize OPF as a feed resource.

The minimum sample size was determined using the Lemeshow formula (Pagano *et al*., 2022), which is commonly applied when the population size is unknown or large:

$$n = z2p\,(1 - p) / d2$$

where n is the minimum sample size, Z is the standard normal value at the 95% confidence level (1.96), p is the assumed population proportion (0.5), and d is the margin of error (0.10). Based on this formula, the minimum required sample size was 96 respondents. To improve the robustness of the survey and reduce potential non-sampling error, the number of respondents was increased by approximately 20%, resulting in a final sample of 119 farmers. Before the main survey, the questionnaire was reviewed and pre-tested on a small number of farmers to ensure clarity and field applicability.

Questionnaire and variable measurement

Data were collected using a structured questionnaire consisting of three sections: (1) farmer characteristics, (2) enterprise characteristics, and (3) adoption of OPF utilization as an alternative feed. The questionnaire was designed to obtain information on socio-demographic conditions, cattle farming practices, institutional support, and the respondent's adoption status. The operational definitions and measurement scales of all variables are presented in Table 1.

The dependent variable was adoption status, coded as 1 for farmers who had adopted OPF utilization as an alternative feed and 0 for farmers who had not adopted it. The independent variables included farmer characteristics,

namely age, formal education, farming experience, livestock ownership, and household dependents, as well as farm and institutional variables, including cattle-farming land area, oil palm plantation area, land ownership, livestock management system, partnership scheme, main occupation, feed processing cost, manure management, participation in extension activities, farmer group membership, and assistance received.

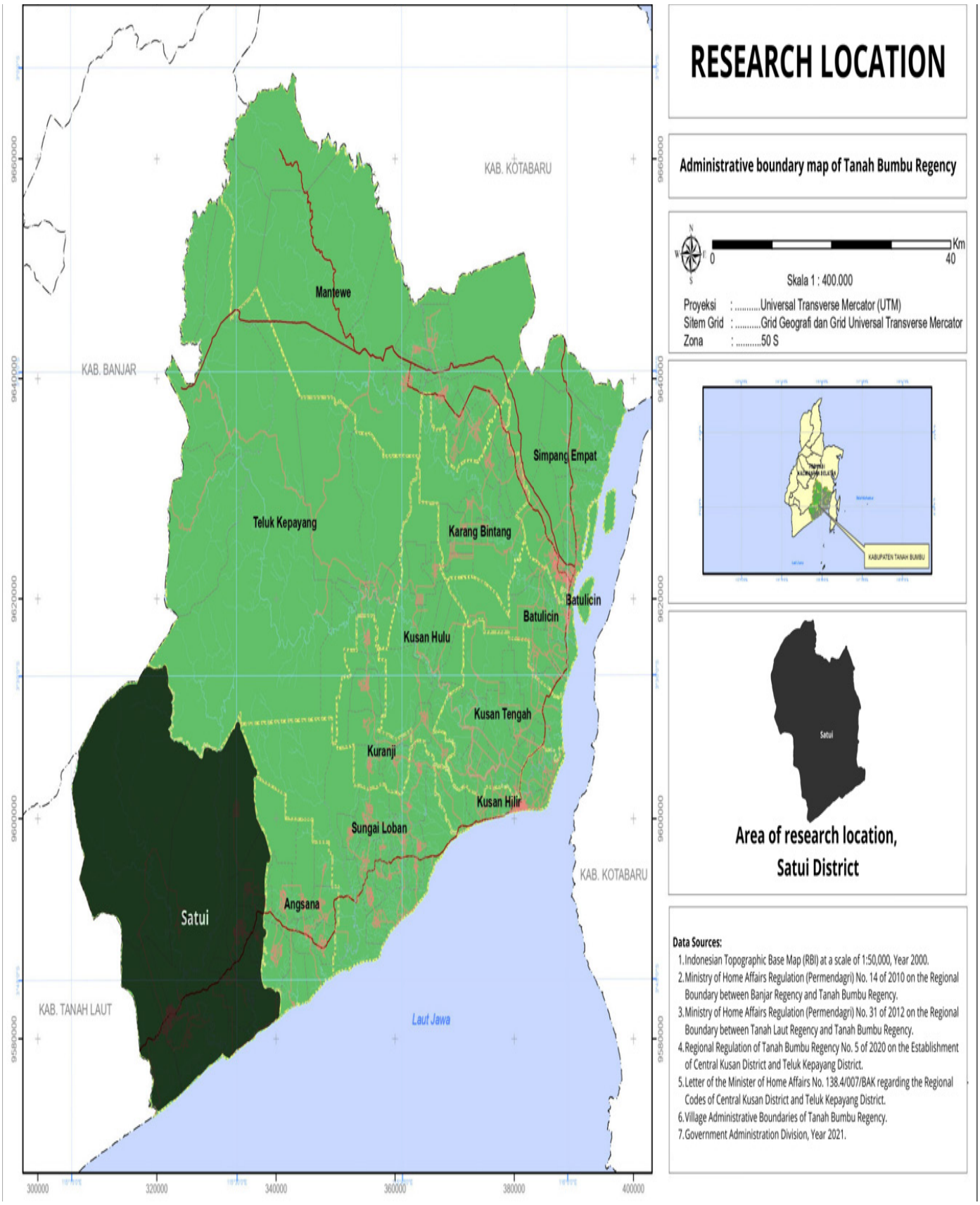

Figure 1: Research location map.

Table 1: Operational definitions and measurement of variables.

Variables	Definition and measurement
Dependent Variable	
Adoption status	Adoption of OPF utilization as an alternative feed by the respondent at the time of the survey (1 = adopter; 0 = non-adopter).
Independent Variables	
Farmer characteristics:	
Age	Age of the respondent at the time of the survey (years).
Education	Years of formal schooling completed by the respondent (years).
Farming experience	Number of years the respondent has been engaged in beef cattle farming (years).
Livestock ownership	Number of beef cattle owned by the respondent, expressed in animal units (AU).
Household dependents	Number of household members financially dependent on the respondent (persons).
Enterprise characteristics:	
Cattle-farming land area	Area used for cattle farming activities by the respondent (m^2 or ha).
Oil palm plantation area	Area of oil palm plantation owned, managed, or accessible to the respondent (m^2 or ha).
Land ownership	Tenure status of the land used for cattle farming (categorical; e.g. rented, privately owned, inherited, or family land).
Livestock management system	Cattle production system practiced by the respondent, classified as extensive, semi-extensive, or intensive based on feeding and housing practices (Livestock management system was classified into three categories based on feeding and housing practices: extensive, semi-extensive, and intensive. For regression analysis, this variable was treated as an ordinal variable reflecting increasing management intensity and coded as 1 = extensive, 2 = semi-extensive, and 3 = intensive).
Oil palm partnership scheme	Whether the respondent was involved in a partnership scheme related to oil palm production (1 = yes; 0 = no).
Main occupation	Main employment status of the respondent, indicating whether cattle farming was the primary occupation (1 = primary occupation; 0 = secondary occupation).
Feed processing cost	Cost incurred for processing feed materials, including OPF where applicable (IDR/kg).
Manure processed into fertilizer	Whether manure was processed into organic fertilizer by the respondent (1 = yes; 0 = no).
Manure applied to oil palm plots	Whether manure was applied to oil palm land by the respondent (1 = yes; 0 = no).
Participation in extension	Whether the respondent had participated in extension, training, or counselling activities related to OPF utilization or cattle feeding (1 = yes; 0 = no).
Farmer group membership	Whether the respondent was a member of a livestock farmer group (1 = yes; 0 = no).
Assistance received	Whether the respondent had received financial or non-financial support related to cattle farming or feed utilization (1 = yes; 0 = no).

Note: Categorical predictors were entered into the binary logistic regression model using dummy-variable coding, with one category serving as the reference group.

Livestock management systems were classified into three categories based on feeding and housing practices. Extensive systems relied mainly on grazing with minimal confinement and limited feed supplementation. Semi-extensive systems combined grazing with partial confinement and supplementary feeding. Intensive systems kept cattle under confinement, with feed provided entirely by the farmer.

Data analysis

Data were analysed using STATA version 16. Binary logistic regression was used to identify the factors influencing farmers' adoption of OPF utilization as an alternative feed because the dependent variable was dichotomous, coded as 1 for adopters and 0 for non-adopters (Hosmer *et al*., 2013; Nahayo *et al*., 2017). The binary logistic regression model can be expressed as follows:

$$\frac{P_i}{1-P_i} = \frac{Prob(Y_i = 1)}{Prob(Y_i = 0)} = e^{\beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+\cdots+\beta_k X_{ki}}$$

Where, P_i is the probability that Y_i takes the value 1

(adoption); 1-P_i is the probability that Y is 0 (no adoption); e is an exponential constant. By taking the natural logarithm of both sides of the equation, we obtain:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \varepsilon_i$$

Where, L_i stands for logit model, which is linear in X_i as well as in β; subscript i denotes the ith observation in the sample; P is the probability of the outcome; β_0 is the intercept term; $\beta_1 + \beta_2 + \ldots + \beta_k$ are the coefficients associated with each independent variable $X_1, X_2, \ldots, X_k$.

Ethical considerations

This study involved a survey of beef cattle farmers and did not include experimental procedures, invasive handling, or interventions on animals. Data were collected through voluntary interviews after informed consent was obtained from all participants. The study was conducted under an official assignment letter issued by Universitas Gadjah Mada: 6378/UN1/PT.1.1/MAG/PT.01.04/2025.

RESULTS

Farmer characteristics

The characteristics of the respondents are presented in Table 2. The respondents had a mean age of 52.07 ± 10.99 years, mean formal education of 8.33 ± 2.58 years, mean cattle farming experience of 15.31 ± 14.14 years, mean livestock ownership of 5.37 ± 5.44 animal units, and mean household dependents of 2.43 ± 1.55 persons. These values indicate that the surveyed farmers were generally experienced smallholder beef cattle producers.

Table 2: Farmer characteristics (n = 119).

Farmer characteristics	Value (Mean ± SD)
Age (years)	52,07±10,99
Education (years of schooling)	8,33 ± 2,58
Farming experience (years)	15,31±14,14
Livestock ownership (AU)	5,37±5,44
Household dependents (persons)	2,43±1,55

Source: Processed primary survey data (2025).

Enterprise characteristics

The enterprise characteristics of the respondents are shown in Table 3. Most respondents used privately owned land for cattle farming (90.75%), while smaller proportionsused rented land (7.56%) and inherited land (1.68%). In terms of livestock management system, semi-extensive management was the most common practice (58.82%), followed by intensive (21.84%) and extensive systems (19.32%). More than half of the respondents were involved in oil palm partnership schemes (52.10%), whereas 47.89% were not. Only 10.92% of respondents reported cattle farming as their primary occupation, while 89.07% considered it a secondary occupation. The average feed processing cost was IDR 10,316/kg. In addition, 49.57% of respondents processed manure into fertilizer, 51.26% applied manure to oil palm plots, 30.25% participated in extension activities related to OPF utilization, 29.41% were farmer group members, and 20.16% had received financial or non-financial assistance. Overall, 51.26% of respondents had adopted OPF utilization as an alternative feed.

Determinants of opf adoption

The results of the binary logistic regression analysis are presented in Table 4. The model showed acceptable fit and predictive performance. The Hosmer-Lemeshow test was non-significant ($p = 0.783$), indicating no evidence of poor model fit. The Omnibus Test of Model Coefficients was significant ($p < 0.001$), indicating that the explanatory variables jointly improved the model. The Nagelkerke R^2 value was 0.514, and the overall classification accuracy was 83.2%. Among the explanatory variables, livestock management system, participation in extension activities, and farmer group membership significantly influenced the adoption of OPF utilization. Livestock management system had a positive and significant coefficient (B = 5.219; p = 0.004; Exp(B) = 184.780), indicating that adoption was more likely among farmers operating under management systems with greater intensity. Participation in extension activities also had a positive and significant effect (B = 6.871; p = 0.010; Exp(B) = 964.039), indicating that farmers who participated in extension were more likely to adopt OPF utilization. In contrast, farmer group membership had a negative and significant coefficient (B = -5.525; p = 0.050; Exp(B) = 0.004), indicating a negative association with adoption in the study area. The remaining variables, including age, education, farming experience, livestock ownership, household dependents, cattle-farming land area, oil palm plantation area, land ownership, oil palm partnership scheme, main occupation, feed processing cost, manure processed into fertilizer, manure applied to oil palm plots, and assistance received, were not statistically significant in the model ($p > 0.10$).

DISCUSSION

The results show that adoption of OPF utilization among beef cattle farmers in Satui District was shaped primarily by livestock management system, participation in extension activities, and farmer group membership. This indicates that OPF adoption is influenced less by basic farmer demographics and more by farm management conditions and access to practical institutional support. In the context of oil palm-cattle integration, this pattern suggests that the availability of OPF alone is not sufficient

Table 3: Enterprise characteristics.

No	Variable	Respondents (n)	Percentage (%)
1	Cattle-farming land area		
	$15m^2 – 150m^2$	51	42,85
	$200m^2 – 10.000m^2$	51	42,85
	$> 300.000m^2$	17	14,28
2	Oil palm plantation area		
	$0m^2 – 500m^2$	37	31,09
	$2.500m^2 – 10.000m^2$	9	7,56
	$12.500m^2 – 30.000m^2$	51	42,85
	$50.000m^2 – 80.000m^2$	18	15,12
	$100.000m^2 – 300.000m^2$	4	3,36
3	Land ownership		
	Rented land	9	7,56
	Privately owned land	108	90,75
	Inherited land	2	1,68
	Family land	-	-
4	Livestock management system		
	Extensive	23	19,32
	Semi-extensive	70	58,82
	Intensive	26	21,84
5	Oil palm partnership scheme		
	Partnered	62	52,1
	Not partnered	57	47,89
6	Main occupation		
	Primary occupation	13	10,92
	Secondary occupation	106	89,07
7	Feed processing cost	119	IDR 10.316/Kg
8	Manure processed into fertilizer		
	Yes	59	49,57
	No	60	50,42
9	Manure applied to oil palm plots		
	Yes	61	51,26
	No	58	48,73
10	Extension on OPF utilization		
	Yes	36	30,25
	No	83	69,75
11	Farmer group membership		
	Yes	35	29,41
	No	84	70,59
12	Received financial/non-financial assistance		
	Yes	24	20,16
	No	95	79,84

Source: primary data analysis (2025).

Table 4: Binary logistic regression results on adoption of OPF utilization technology.

Variable	B	S.E.	Wald	Df	Sig.	Exp(B)
Farmer characteristics						
Age (X1)	0.20	.051	.149	1	.699	1.020
Education (X2)	-.413	.291	2.021	1	.155	.662
Farming experience (X3)	.047	.042	1.229	1	.268	1.048
Livestock ownership (X4)	-.227	.184	1.526	1	.217	.797
Household dependents (X5)	.234	.328	.509	1	.476	1.264
Business characteristics						
Cattle-farming land area (X6)	.001	.000	2.036	1	.154	1.001

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Variable	B	S.E.	Wald	Df	Sig.	Exp(B)
Oil palm plantation area (X7)	.000	.000	2.389	1	.122	1.000
Land ownership (X8)	17.532	7073.59	.000	1	.998	40770001.25
Livestock management system (X9)	5.219	1.816	8.255	1	.004***	184.780
Oil palm partnership scheme (X10)	.944	1.045	.816	1	.366	2.570
Main occupation (X11)	1.609	1.199	1.802	1	.179	4.998
Feed processing cost (X12)	.001	1.547	.000	1	1.000	1.001
Manure processed into fertilizer (X13)	.986	1.083	.829	1	.362	2.681
Manure applied to oil palm plots (X14)	-2.477	1.713	2.091	1	.148	.084
Participation in extension (X15)	6.871	2.676	6.594	1	.01**	964.039
Farmer group membership (X16)	-5.525	2.881	3.678	1	.05**	.004
Assistance received (X17)	40.552	9709.63	.000	1	.997	4.087×10^17
Constant	-29.635	17456.543	.000	1	.999	.000

Source: Primary data analysis (2025). Notes: * p ≤ 0.10; ** p ≤ 0.05; *** p ≤ 0.01.

to ensure adoption. Farmers also need management conditions that allow feed adjustment and support systems that facilitat learning and implementation Livestock management system had a positive and significant effect on OPF adoption. Because this variable was treated as an ordinal measure of increasing management intensity, the result indicates that farmers operating under more intensive management arrangements were more likely to adopt OPF utilization. This finding is reasonable because farmers with more structured feeding systems are more likely to make deliberate decisions about feed sourcing, ration adjustment, and the incorporation of alternative feed materials. In contrast, farmers relying on less controlled systems may depend more heavily on direct grazing and may face fewer incentives to process or utilize OPF systematically. This result is consistent with previous studies showing that management conditions shape farmers' readiness to adopt livestock-related innovations and influence their capacity to incorporate new practices into routine production activities (Lainawa and Lenzun, 2022; Hidayat *et al*., 2023; Mallinger *et al*., 2025). In integrated oil palm-cattle systems, more structured management can also improve the practical feasibility of using plantation by-products as feed resources and strengthen the efficiency of resource use within the farm (Pimpa *et al*., 2021; Álvarez *et al*., 2024).

In contrast, farmer group membership had a negative and significant association with OPF adoption. This result indicates that formal membership in a farmer group did not automatically support innovation uptake in the study area. A possible explanation is that group membership alone does not guarantee active participation, effective communication, or access to relevant technical information. Where groups function weakly, irregularly, or mainly for administrative purposes, their role as learning forums and dissemination platforms may be limited. Under such conditions, membership may not translate into greater exposure to OPF-related knowledge and may even reflect dependence on institutions that are not functioning effectively. Similar findings have been reported in previous research showing that farmer organizations do not always improve technology adoption unless they operate as active and meaningful channels of knowledge exchange and collective learning (Ahmed and Anang, 2019; Yuhendra *et al*., 2022). This suggests that policy efforts should not focus only on increasing membership numbers, but also on improving the quality, relevance, and internal functioning of farmer groups.

These findings indicate that the adoption of OPF utilization in Satui District depends more on practical production conditions and effective knowledge transfer than on farmer profile variables alone. This has an important implication for the development of SISKA in South Kalimantan. If OPF is to be promoted more widely as an alternative feed resource, interventions should prioritise field-level capacity building, repeated technical extension, and stronger alignment between feed innovation and farmers' day-to-day management practices. At the same time, farmer groups need to be revitalised so they can function not only as formal organisations but also as effective platforms for discussion, learning, and dissemination. In this way, the use of OPF can contribute more meaningfully to feed security, plantation biomass utilization, and the sustainability of integrated cattle-oil palm systems.

CONCLUSIONS

The adoption of OPF utilization as an alternative feed among beef cattle farmers in Satui District was significantly associated with livestock management system, participation in extension activities, and farmer group membership. Farmers operating under more intensive management conditions and those participating in extension activities were more likely to adopt OPF utilization, whereas farmer group membership showed a negative association

with adoption. These findings indicate that practical farm management and effective extension support are more important for OPF adoption than formal group affiliation alone. Strengthening field-based extension and improving the functional role of farmer groups are therefore essential to support wider adoption under SISKA

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NOVELTY STATEMENT

The novelty of this study lies in its specific focus on the behavioural and farm-level determinants of oil palm frond utilization as an alternative feed within the oil palm–cattle integration system in South Kalimantan. While previous studies have mainly discussed the technical potential or general feasibility of palm–cattle integration, this study identifies the adoption drivers of a specific feed innovation using empirical evidence from smallholder beef cattle farmers.

AUTHOR'S CONTRIBUTION

FIH and ARSP designed the study. FIH collected the data. FIH, MYS and ATA conducted data tabulation and statistical analysis. FIH, MYS and ATA prepared the first draft of the manuscript. ARSP reviewed and finalized the manuscript. All authors reviewed, revised, and approved the final manuscript.

Study limitations

This study was conducted in one district with purposively selected respondents, so the findings should not be generalized directly to all oil palm–cattle farming contexts in Indonesia. In addition, adoption was measured as a binary outcome and did not capture variation in the intensity, frequency, or technical quality of OPF utilization. A limitation of the regression model is that several explanatory variables had highly imbalanced category distributions, which may have produced unstable estimates for some non-significant predictors. Future studies should examine broader geographic settings and include more detailed indicators of adoption behaviour and feed-use practices.

Availability of data and material

The dataset used in this study is fully reported within the manuscript.

Consent to participate

All participants provided informed consent to take part in the study.

Generative AI and AI assisted technology Statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper. The research was conducted independently without any commercial or financial relationships that could be construed as a potential conflict of interest.

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