



TPB–DOI Model of Sustainable Palm Oil Adoption in Indonesia

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Abstract

The palm oil industry plays a pivotal role in Indonesia's economy and contributes to achieving the United Nations Sustainable Development Goals (SDGs). However, concerns regarding economic, environmental, and social sustainability highlight the urgent need to promote sustainable agricultural practices. This study examines potential challenges in implementing the Indonesian Sustainable Palm Oil (ISPO) certification system in 2025 and develops a comprehensive adoption model by integrating Ajzen's Theory of Planned Behavior (TPB) and Rogers' Diffusion of Innovation (DOI). The model incorporates eight factors: attitude, subjective norms, perceived behavioral control, relative advantage, compatibility, complexity, trialability, and observability. Structured questionnaires were administered to 300 independent smallholder palm oil farmers in West Kalimantan, Indonesia, and the data were analyzed using structural equation modeling (SEM). The findings confirm that attitude, subjective norms, perceived behavioral control, relative advantage, compatibility, and trialability positively and significantly influence the adoption of sustainable farming practices, while complexity exerts a significant negative effect. Observability showed no significant impact. These results provide valuable insights for policymakers and practitioners to design targeted strategies, programs, and policies that strengthen social norms, enhance perceived behavioral control, and emphasize the relative advantage and compatibility of sustainable practices. By fostering voluntary adoption among independent smallholders, the successful implementation of ISPO can be ensured, benefiting both farmers and the environment.

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INTRODUCTION

The palm oil industry in Indonesia plays a vital role in the country's economy and in achieving the United Nations Sustainable Development Goals (SDGs), providing employment for more than 16 million people and contributing approximately 3.5% to the national Gross Domestic Product (Ridwannulloh & Sunaryati, 2018; Rosyadi et al., 2021). As the world's largest palm oil producer, Indonesia possesses significant capacity to promote sustainable agricultural practices in relation to the cultivation of this commodity.

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Through its implementation, the country can make a major contribution to achieving several United Nations Sustainable Development Goals (SDGs), including SDG 2: Zero Hunger, SDG 12: Responsible Consumption and Production, and SDG 13: Climate Action (Kuo et al., 2014; Limaho et al., 2022).

Although there are many benefits associated with the palm oil industry in Indonesia, several significant economic, environmental, and social issues have arisen as a result. Some of these include deforestation, habitat degradation, exploitation of local communities, forest fire issues, ambiguous land ownership, excessive pesticide use, human rights violations, worker welfare issues, controversies surrounding the use of palm oil-based biodiesel, and a lack of adequate monitoring and law enforcement (Brandi et al., 2015; Choiruzzad et al., 2021; Farobie & Hartulistiyoso, 2022; Mukherjee et al., 2022). Various efforts have been made to promote sustainable palm oil production, including the implementation of the Indonesian Sustainable Palm Oil (ISPO) certification system, which will be applied to independent palm oil farmers in Indonesia by 2025 (Ruysschaert & Salles, 2014; Umayah et al., 2022).

The implementation of the Indonesian Sustainable Palm Oil (ISPO) certification system must take into account the wishes of independent smallholders to avoid unintended consequences (Brandi et al., 2015; Khatiwada et al., 2021; Pramudya et al., 2022; Widyatmoko, 2023) including resistance and non-compliance by farmers; therefore, it is crucial for stakeholders to understand the motivations and barriers independent farmers face in adopting sustainable agricultural practices. Failure to promote sustainable agricultural practices in the palm oil industry can have long-term economic impacts, such as restrictions on international markets and negative perceptions among global consumers (Brandi et al., 2015).

This study analyzes the motivations influencing the adoption of sustainable agricultural practices by independent oil palm farmers, with a specific focus on the Indonesian Sustainable Palm Oil (ISPO) certification system. Although previous studies have addressed the economic, environmental, and social issues associated with independent oil palm farming practices, limited attention has been given to understanding farmers' perspectives (Choiruzzad et al., 2021). This study offers a more comprehensive perspective on the individual-level and contextual factors driving the adoption of sustainable oil palm practices by integrating Ajzen's Theory of Planned Behavior and Rogers' Theory of Innovation Diffusion. Understanding what motivates farmers to voluntarily adopt sustainable agricultural practices is crucial for policymakers. The successful implementation of the ISPO certification system by 2025 without enforcing it requires a comprehensive understanding of the factors driving farmers' decision-making. The adoption of certification schemes that promote sustainable agriculture involves substantial effort and costs for farmers, particularly considering the field inspection requirements once the scheme is established (Khatiwada et al., 2021). Understanding farmers' motivations can mitigate economic, environmental, and social impacts and ensure the successful and sustainable implementation of the ISPO certification system (Pramudya et al., 2022).

Ajzen's Theory of Planned Behavior and Rogers' Theory of the Diffusion of Innovations can provide insights into the adoption of sustainable practices in the palm oil industry (Adiprasetyo et al., 2019). These two theories complement each other and provide a comprehensive understanding of the factors influencing independent farmers' motivation to adopt or reject a new

innovation (Bagheri et al., 2021; Tinh et al., 2021). According to Ajzen's Theory of Planned Behavior, attitude, subjective norms, and perceived behavioral control are key factors influencing adoption (Ajzen, 1991). Rogers' Theory of Diffusion of Innovations emphasizes several primary determinants that shape the adoption and diffusion process. In its application, there are several key factors in this theory, namely relative advantage, compatibility, complexity, trial, and observability (Rogers, 2010). Integrating Ajzen's Theory of Planned Behavior and Rogers' Diffusion of Innovations theory can provide a comprehensive understanding of adoption and diffusion, by holistically considering individual-level factors and contextual influences (Al Breiki et al., 2023; Warner et al., 2022). Combining insights from both theories can provide appropriate strategic development recommendations to promote the adoption of sustainable oil palm farming practices among stakeholders and policymakers in addressing potential barriers to the implementation of the ISPO certification system among independent smallholders by 2025.

The agricultural practices of independent oil palm farmers are an important phenomenon to study in Indonesia, particularly in the context of the oil palm industry, which plays a strategic role in the country's economy (Ridwannulloh & Sunaryati, 2018; Rosyadi et al., 2021). Independent oil palm farmers are a group of farmers who own oil palm plantations independently. Research on the agricultural practices of independent oil palm farmers in Indonesia holds significant relevance in the context of sustainable agricultural development (Pareira, 2023). Sustainable agricultural practices involve various aspects, including plantation management, fertilizer and pesticide use, crop maintenance, harvesting, and oil palm processing (Ernah et al., 2020; Watts et al., 2021).

The adoption of sustainable agricultural practices in Indonesia refers to the implementation of farming methods that take into account environmental, economic, and social aspects in order to achieve sustainable agricultural goals (Castillo, 2021; Dharmawan et al., 2021; Turnbull et al., 2020). Sustainable agricultural practices focus on the efficient use of natural resources, environmental conservation, waste reduction, and the improvement of farmers' social and economic well-being (Umayah et al., 2022). In this context, sustainable agricultural practices include the use of organic or natural fertilizers, integrated pest and disease management, efficient water use, soil and water conservation, agricultural waste management, agricultural business diversification, as well as the protection and management of biodiversity (Abas et al., 2022).

The adoption of sustainable agricultural practices in Indonesia, particularly by smallholder farmers, faces various challenges (Adiprasetyo et al., 2019; Gebhard & Martin, 2015; Suprehatin, 2021), such as limited access to knowledge and information regarding sustainable agricultural practices (Bagheri et al., 2021; Oladehinde, 2025). Smallholder farmers often lack adequate access to the training, education, and information sources needed to understand the benefits and implementation of such practices (Wahyudi & Wulandari, 2019).

Strategic steps that can be taken to address the challenges of adopting sustainable agricultural practices in Indonesia, particularly among smallholder farmers, include improving access to knowledge and information on sustainable agricultural practices (Foguesatto et al., 2020). This can be achieved through the provision of intensive training, education, and extension campaigns, as well as the development of easily accessible agricultural information systems (Sewell et al., 2017). Additionally, financial and technical

support must be provided to smallholder farmers to facilitate the implementation of sustainable practices.

Indonesian Sustainable Palm Oil (ISPO) is a crucial certification system in Indonesia's palm oil industry (Umayah et al., 2022), aimed at promoting sustainable palm oil farming practices while considering economic, social, and environmental aspects (Hutabarat & Binawidya, 2017). ISPO is closely linked to two global initiatives: the Roundtable on Sustainable Palm Oil (RSPO) and the United Nations Sustainable Development Goals (SDGs).

The Roundtable on Sustainable Palm Oil (RSPO) is an organization focused on international certification of sustainable palm oil (Ruyschaert & Salles, 2014). The RSPO has contributed to promoting environmentally and socially responsible palm oil farming practices. Collaboration between ISPO and the RSPO can enhance the positive impact of ISPO implementation in Indonesia by integrating the RSPO's well-established and proven principles and criteria. This collaboration can strengthen ISPO's efforts to promote sustainable palm oil farming practices (Pereira, 2023). The United Nations Sustainable Development Goals (SDGs) are a set of development goals established by the UN, encompassing sustainable development objectives in economic, social, and environmental sectors (Ferranti, 2018). ISPO can make contributions aligned with several SDG goals (Shrestha, 2021).

This study aims to examine the implementation of ISPO among independent farmers in Indonesia by 2025 (Dewa et al., 2023; Pramudya et al., 2022), focusing on indicators related to the Theory of Planned Behavior and the Theory of Diffusion of Innovations. One of the main focuses of this study is to mitigate potential issues that may arise in the implementation of ISPO and to analyze the factors influencing the acceptance and adoption of ISPO by independent farmers.

This study will pay special attention to factors related to the Theory of Planned Behavior and the Diffusion of Innovations theory, which play a crucial role in the implementation of ISPO. This study also aims to enhance understanding of these factors and provide deeper insights into the successful and farmer-acceptable implementation of ISPO. The results of this study are expected to provide recommendations for improving the effectiveness of ISPO implementation in achieving sustainable development goals, using Ajzen's Theory of Planned Behavior and the Diffusion of Innovations theory as the analytical framework.

METHODS

This study employs a quantitative approach because it is considered strategic and capable of yielding objective and generalizable results (Engkizar et al., 2024, 2025; Stockemer, 2018). This approach allows for the collection and statistical analysis of numerical data to understand the factors influencing the adoption of sustainable agricultural practices by oil palm farmers, based on the Theory of Planned Behavior (TPB) and the Diffusion of Innovations (DOI) theory. Quantitative methods also allow for comparative analysis and correlations between relevant variables (Adol et al., 2025; Engkizar et al., 2023; Rashid et al., 2021; Sari et al., 2025).

Data were collected using a closed-ended questionnaire in the local language to enhance understanding and the quality of responses (Pinho et al., 2021). This instrument uses a 1–7 semantic differential scale to measure research variables (Vecchio et al., 2022). Before being widely distributed, the questionnaire underwent pilot testing on a small sample to ensure its validity and reliability (Collins et al., 2021). This pilot study also helped identify

potential issues and adapt the instrument to respondents' understanding (Ong & Puteh, 2017).

The study was conducted over a 10-week period through the following systematic phases: instrument piloting (2 weeks), data collection (2 weeks), data processing (2 weeks), analysis of results (2 weeks), and preparation of the final report (2 weeks). Through this design, the study is expected to provide in-depth insights and policy recommendations to enhance the adoption of sustainable agricultural practices among independent oil palm farmers.

The population in this study consists of oil palm farmers in West Kalimantan, Indonesia. This population was selected based on the need to understand oil palm cultivation practices in the region. This study focuses on three districts, namely Kubu Raya, Landak, and Sambas, as these three districts account for more than 50% of oil palm production in West Kalimantan (Arifin, 2020; Collins et al., 2021). The selection of populations from these three districts will provide a representative picture of the broader state of independent oil palm farming practices in West Kalimantan.

The sampling technique used in this study was cluster random sampling, which involves dividing the population into several groups (clusters) and then selecting a random sample of proportional size from each cluster (Acharya et al., 2013). In this study, a cluster refers to a geographic area grouping independent oil palm farmers. Clusters were randomly selected from the study area, which includes Kubu Raya Regency, Landak Regency, and Sambas Regency. After the clusters were selected, 100 respondents representing independent oil palm farmers in each cluster were chosen to be part of the sample. This cluster random sampling method was employed to ensure an accurate representation of independent oil palm farmers in the study area (Alimohamadi & Sepandi, 2019).

This study also utilized the Rule of Thumb sampling rule with a heuristic approach to ensure sufficient statistical power. This guideline suggests that for a structural equation model (SEM) with a measurement model consisting of 32 observed variables, a minimum sample size of 8 times the number of observed variables is required to ensure adequate statistical power ($n = 256$) (Siddiqui, 2013). The data obtained are expected to provide a broader picture and represent the relevant characteristics within the research context. This allows the research findings to be generalized to a broader population (Sedgwick, 2012).

RESULT AND DISCUSSION

Characteristics of Independent Oil Palm Farmers

This study distributed 300 questionnaires to independent oil palm farmers, yielding 291 complete responses. After careful screening (Akyüz & Theuvsen, 2020; Castillo, 2021; Cheung, 2014; Choiruzzad et al., 2021), 18 responses were deemed invalid, leaving 273 valid responses available for further analysis. Based on the analysis of the research data, the findings reveal the characteristics (figure 1) of independent oil palm farmers in West Kalimantan.

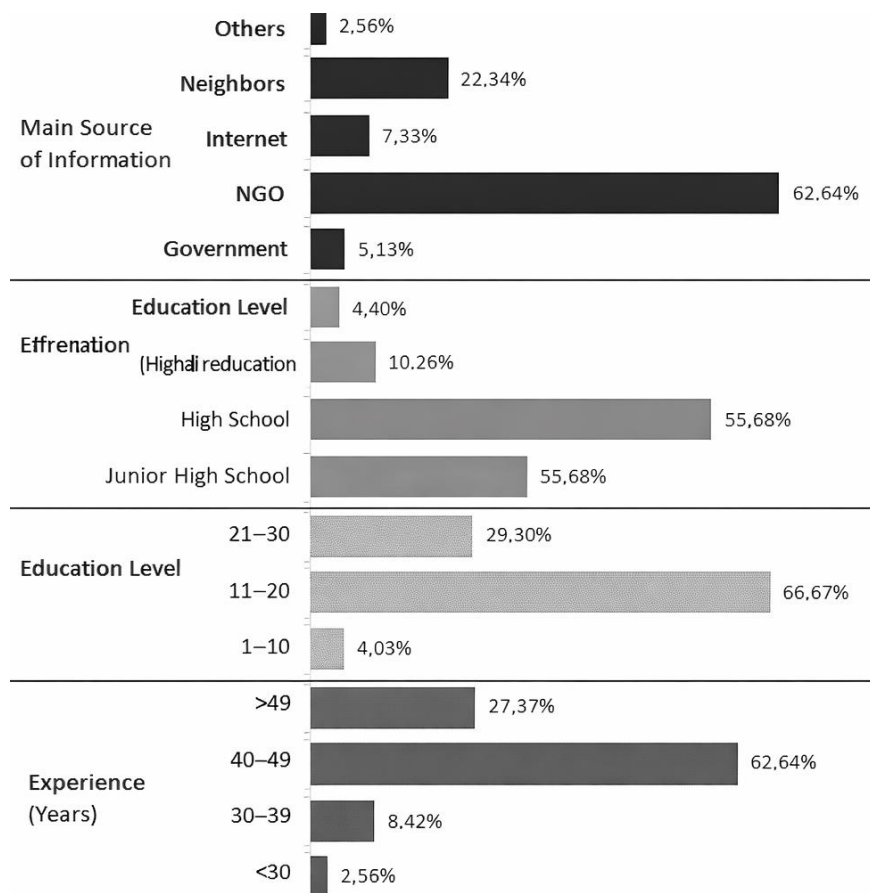


Fig 1. Sample Characteristics

The majority of the study’s respondents were in the 40–49 age group, indicating that most of the independent farmers involved in this study belong to the adult age group. This age range has important implications regarding the adoption of sustainable agricultural practices, as more mature experience and knowledge can be factors influencing the acceptance and implementation of such practices (Zeweld et al., 2017). However, on the other hand, age can also be a barrier to the adoption of new innovations.

Furthermore, the analysis revealed that the average primary work experience of independent oil palm farmers is approximately 10 years, ranging from 1 to 30 years. This significant work experience has the potential to influence the attitudes and readiness of independent oil palm farmers to adopt sustainable agricultural practices. The longer the work experience, the greater the likelihood that independent oil palm farmers have a better understanding of the benefits and challenges associated with these practices (Ernah et al., 2020). However, on the other hand, experience can also be a barrier to the adoption of new innovations.

Furthermore, the educational level of the study respondents indicates that the majority of independent oil palm farmers have completed junior high school or have an even lower level of education. This generally low educational level may influence independent oil palm farmers’ risk perceptions and their ability to adopt innovations and advancements in sustainable agricultural practices. Therefore, effective education and extension efforts are needed to improve independent oil palm farmers’ understanding and awareness of the benefits and importance of sustainable agricultural practices (Santika et al., 2021).

In addition, the study’s findings indicate that the primary source of information for independent oil palm farmers is non-governmental organizations (NGOs). This fact provides insight into the common practices and information sources that influence independent oil palm farmers’ adoption

of sustainable agricultural practices. The role of NGOs in providing information, training, and mentoring to independent farmers is crucial in enhancing farmers' knowledge and understanding of sustainable agricultural practices (Ernah et al., 2020). However, on the other hand, a lack of diversity in primary information sources can also act as a barrier to the adoption of innovations.

Overall, these findings provide a clearer picture of the characteristics and factors influencing the adoption of sustainable agricultural practices by independent oil palm farmers. Knowledge of these backgrounds and determinants can offer deeper insights and valuable information for promoting the acceptance and implementation of sustainable agricultural practices among independent oil palm farmers.

Characteristics of Factors Based on TPB and DOI

In this study, several factors were measured based on the Theory of Planned Behavior (TPB) and the Diffusion of Innovations (DOI) theory, as shown in table 2. These factors are represented by latent variables and measured through observed variables.

Table 1. Factors Based on TPB and DOI

Latent Variable		Observed Variable	Percentage (%)
Attitude (ATT)		High Outcome (ATT ₁)	97,07
		Low cost Requirement (ATT ₂)	78,39
		Having Experience (ATT ₃)	83,52
Subjective Norm (SNM)	Norm	Receiving Community Support (SNM ₁)	79,49
		Industrial Pressure (SNM ₂)	71,79
		Environmental Value Appreciation (SNM ₃)	96,70
Perceived Behavioral Control (PBC)	Behavioral	Adequate Resources (PBC ₁)	90,84
		Available Training (PBC ₂)	82,05
Relative Advantage (RAD)	Advantage	Providing Personal Benefits (RAD ₁)	95,24
		Reducing Environmental Impact (RAD ₂)	71,79
		Enhancing Social Status (RAD ₃)	73,99
Compatibility (COA)		Aligned with Culture (COA ₁)	75,46
		Having Successful Experience (COA ₂)	72,89
Complexity (COE)		Sufficient Knowledge (COE ₁)	10,26
		Causing Positive Impact (COE ₂)	11,36
		Adequate Government Support (COE ₃)	6,59
Trialability (TRA)		Positive Treatment Impact (TRA ₁)	96,34
		Limited Resources (TRA ₂)	70,70
		Personal Perception (TRA ₃)	93,04
Observability (OBV)		Able to Inspire (OBV ₁)	74,73
		Impact of Trusted Information (OBV ₂)	89,01
		Having Learning Opportunities (OBV ₃)	93,77
Sustainable Agriculture Adoption (ASA)		Water Use Efficiency (ASA ₁)	67,77
		Energy Conservation (ASA ₂)	53,11
		Biodiversity Influence (ASA ₃)	57,14
		Practice Investment (ASA ₄)	69,23
		Crop Diversity (ASA ₅)	47,62
		Soil Health (ASA ₆)	50,55
		Climate Change Mitigation (ASA ₇)	60,07

Latent Variable	Observed Variable	Percentage (%)
	Organic Matter Content (ASA ₈)	53,11
	Greenhouse Gas Emissions (ASA ₉)	61,90
	Synthetic Fertilizers and Pesticides (ASA ₁₀)	66,30

The percentage of agreement was used as an indicator to assess the extent to which respondents agreed with statements related to each variable. First, within the attitude factor (ATI), observed variables such as high achievement (ATT1) had a high percentage of agreement, at 97.07%. Other variables, such as low cost (ATT2) and experience (ATT3), also show fairly high agreement rates, at 78.39% and 83.52%, respectively. This indicates that respondents hold positive attitudes toward these factors in the context of adopting sustainable agricultural practices. Second, within the subjective norm (SNM) factor, observed variables such as family support (SNM1) and environmental values (SNM3) also showed high agreement rates, at 79.49% and 96.70%, respectively. However, the industrial pressure variable (SNM2) showed a relatively lower percentage of agreement, namely 71.79%. This indicates that family support and environmental values have a stronger influence on respondents' subjective norms.

Furthermore, the perceived behavioral control (PBC) factor also includes observed variables with relatively high percentages of agreement. The resource (PBC1) and training (PBC2) variables showed agreement percentages of 90.84% and 82.05%, respectively. This indicates that respondents believe that resources and training can influence perceived behavioral control in the context of adopting sustainable agricultural practices. Additionally, factors such as relative advantage (RAD), compatibility (COA), trial (TRA), and observability (OBV) also have observed variables with varying agreement rates. For example, within the relative advantage factor, the benefits variable (RAD1) showed a percentage of agreement of 95.24%, while the environmental impact variable (RAD2) showed a percentage of agreement of 71.79%. This indicates that respondents consider benefits to have a more significant influence within the relative advantage factor. However, several variables such as complexity (COE), positive impact (COE2), and sufficient support (COE3) have relatively low agreement rates, namely below 15%.

Overall, the percentage of agreement for these observed variables provides an initial insight into the characteristics of the factors associated with the adoption of sustainable agricultural practices in this study. Further analysis can be conducted to examine the relationship between these factors and the adoption of sustainable agricultural practices, as well as their practical implications for the development of policies and strategies to promote the adoption of sustainable practices in the agricultural sector.

Causal Model Based on the Theory of Planned Behavior (TPB) and Diffusion of Innovation (DOI)

Analysis of Results and Model Fit

In this study, a causal model based on TPB (Theory of Planned Behavior) and DOI (Diffusion of Innovation) was developed using the Structural Equation Modeling (SEM) approach with Exploratory Factor Analysis (EFA) and confirmed with Confirmatory Factor Analysis (CFA). The results of the CFA analysis were used as a basis for identifying the underlying factors of the constructs measured in this study, as shown in figure 2.

This study employed reliability and convergent validity analysis methods to evaluate the reliability and validity of the instruments used in data collection.

Additionally, multicollinearity analysis was conducted using Pearson's correlation to examine the presence of linear relationships among the independent variables in the model. An evaluation of model fit indices and actual values was also performed to assess the quality of the structural model and determine the extent to which the model fits the empirical data. Furthermore, the results of hypothesis testing and statistical significance were used to test the relationships between variables in the model. Finally, the beta coefficients of the structural equation model in SEM were estimated to measure the degree of influence of latent variables on observed variables and to explain the causal relationships between variables in the model. All of these analytical methods were employed to obtain valid and reliable results in this study.

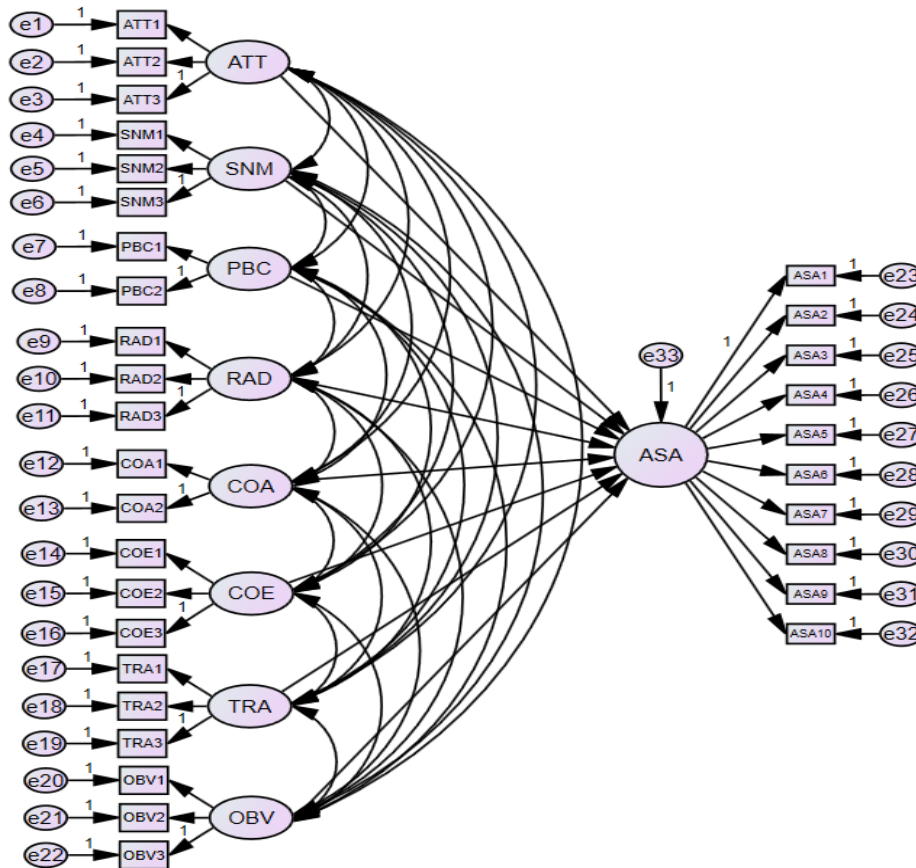


Fig 2. Causal Model Based on TPB and DOI

First, reliability and convergent validity analyses were conducted to ensure that the measurement instruments used in this study could produce consistent and reliable results. Table 2 shows that all factors measured in this study meet the necessary requirements for reliability. This indicates that the measurement instruments used have demonstrated good consistency in measuring the constructs under study (Shrestha, 2021).

Specifically, all fit indices met the recommended criteria for model fit in structural equation modeling (SEM). The CFI and TLI values were greater than 0.900, indicating a good fit between the model and the observed data. The RMSEA value is less than 0.070, indicating adequate fit between the model and the data. Additionally, the CMIN/df value is less than 2, indicating an acceptable fit (Zahedi & Sommer, 2022).

These findings suggest that the proposed model fits the data well, providing support for the theoretical framework and the relationships among the variables under study. Adequate fit indices contribute to the model's validity and reliability, enhancing confidence in the conclusions and implications of this study.

Table 2. Results of the Reliability and Convergent Validity Analysis

	ATT	SNM	PBC	RAD	COA	COE	TRA	OBV	ASA
<i>Composite Reliability (CR)</i>	0.729	0.729	0.795	0.729	0.794	0.719	0.729	0.730	0.800
<i>Cronbach Alpha (CA)</i>	0.809	0.823	0.768	0.795	0.715	0.777	0.820	0.864	0.938
<i>Average Variance Extracted (AVE)</i>	0.562	0.570	0.698	0.553	0.674	0.578	0.569	0.599	0.508
<i>Mean Square Variance (MSV)</i>	0.228	0.389	0.183	0.241	0.180	0.228	0.354	0.277	0.314

Second, table 3 presents the Pearson correlation coefficients between these variables. The results of this study indicate that the correlations between variables are less than 0.800 at a significance level below 0.01, indicating no issues with multicollinearity. These findings support the reliability, validity, and distinctiveness of the measurement constructs used in this study, thereby enhancing confidence in the data analysis and subsequent interpretation (Sedgwick, 2012).

Table 3. Pearson Correlation Coefficients between Variables

Variables	ATT	SNM	PBC	RAD	COA	COE	TRA	OBV	ASA
ATT	1.000								
SNM	0.455**	1.000							
PBC	0.566**	0.645**	1.000**						
RAD	0.477**	0.556**	0.673**	1.000					
COA	0.344**	0.666**	0.732**	0.521**	1.000				
COE	0.445**	0.445**	0.512**	0.482**	0.352**	1.000			
TRA	0.442**	0.763**	0.622**	0.733**	0.532**	0.753**	1.000		
OBV	0.654**	0.633**	0.576**	0.455**	0.633**	0.546**	0.642**	1.000	
ASA	0.762**	0.712**	0.743**	0.576**	0.723**	0.552**	0.637**	0.522**	1.000

Note: **: $p < .01$

Third, the results of the model fit index evaluation in this study, as shown in Table 4, indicate that the measurement instruments used in this study are consistent and reliable.

Furthermore, the analysis results also show that the proposed model has adequate fit indices. All fit index values meet the recommended criteria. A Comparative Fit Index (CFI) or Tucker-Lewis Index (TLI) value greater than 0.900 indicates good fit between the model and the observed data. A Root Mean Square Error of Approximation (RMSEA) value of less than 0.070 indicates an acceptable fit between the model and the data. Furthermore, a Chi-Square to Degrees of Freedom (CMIN/df) value of less than 2 indicates an acceptable fit (Cheung, 2014).

These findings indicate that the model proposed in this study fits the data. This provides support for the theoretical framework used and the relationships among the variables under study. The presence of adequate fit indices also contributes to the validity and reliability of the model used, enhancing confidence in the conclusions and implications of the research findings.

Table 4. Evaluation of Model Fit Indices and Actual Values

Model fit index	Evaluation standard	Actual value
CMIN/df	≤ 2 (acceptable)	1.42
RMSEA	≤ 0.08 (acceptable)	0.038

GFI	≥ 0.9 (acceptable)	0.930
TLI	≥ 0.9 (acceptable)	0.911
CFI	≥ 0.9 (acceptable)	0.924

Fourth, the results of the hypothesis testing and statistical significance listed in Table 5 provide information on the strength and significance of the relationship between the variables under study. The estimates (β) indicate the magnitude of the effect of this relationship, while the standard error (S.E.) provides an indication of the level of uncertainty associated with these estimates. The critical ratio (C.R.) and P-value provide further evidence of the significance of the observed relationship (C.R. < 1.96 at $P < 0.05$) or (C.R. < 2.576 at $P < 0.01$) (Cheung, 2014). This enhances the robustness and validity of the study's conclusions and provides a better understanding of the implications of this research in the context of the adoption of sustainable agricultural practices.

Table 5. Hypothesis Testing Results and Statistical Significance

Hypothesis	Relationship	Estimate(β)	S.E.	C.R.	P-Value
H1	ATT- \rightarrow ASA	0.256	0.055	1.468	0.034
H2	SNM- \rightarrow ASA	0.105	0.040	1.262	0.049
H3	PBC- \rightarrow ASA	0.108	0.021	2.507	< 0.01
H4	RAD- \rightarrow ASA	0.117	0.037	2.047	< 0.01
H5	COA- \rightarrow ASA	0.316	0.033	1.960	< 0.01
H6	COE- \rightarrow ASA	-0.195	0.039	-1.494	0.032
H7	TRA- \rightarrow ASA	0.474	0.034	1.393	0.016
H8	OBV- \rightarrow ASA	0.106	0.026	2.402	< 0.01

Fifth, the beta coefficient estimates shown in Figure 3 provide information on the extent to which a change in one variable will affect changes in other variables, when those variables are controlled for other variables in the model. Beta coefficients have two important components: magnitude and sign. Magnitude indicates the strength of the relationship between variables, while sign indicates whether the relationship is positive or negative (Cheung, 2014).

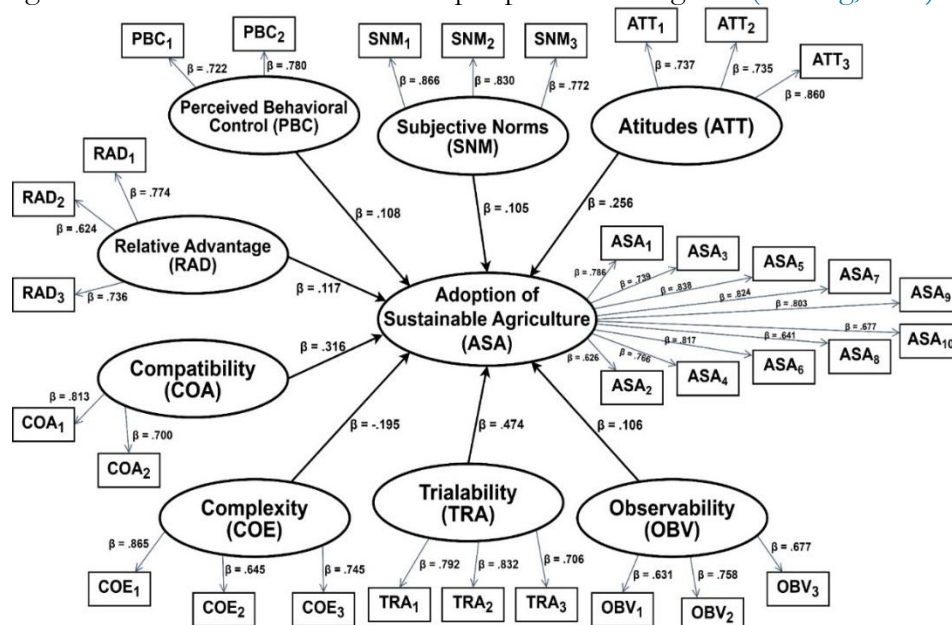


Fig 3. Estimated Beta Coefficients of the Structural Equation Model (SEM)

Discussion of Analysis Results Based on Hypothesis Fit

First, the analysis results indicate a statistically significant positive relationship between farmers' attitudes toward the adoption of sustainable agricultural practices and actual adoption rates. The research findings underscore the importance of promoting the benefits associated with sustainable practices such as higher crop yields, improved soil health, and reduced environmental impact as a means to encourage increased adoption rates; thus, it is crucial to effectively educate farmers about the various advantages linked to sustainable agricultural practices (Bagheri et al., 2021; Zaremohzzabieh et al., 2022). This can be achieved through the implementation of well-designed awareness campaigns, workshops, and training programs, aimed at disseminating accurate and comprehensive information and enhancing farmers' knowledge and awareness (Akyüz & Theuvsen, 2020). In addition, it is highly recommended to provide farmers with evidence-based information and empirical data that underscore the cost-effectiveness of adopting sustainable practices.

Second, the analysis results indicate a statistically significant positive relationship between farmers' subjective norms regarding the adoption of sustainable agricultural practices and their actual adoption rates. The findings underscore the importance of social influences including support from family members, peers, and community leaders in shaping farmers' decisions to adopt sustainable agricultural practices. This underscores the importance of considering the broader social and cultural context so that farmers can implement agricultural practices aligned with their needs, involving stakeholders in promoting sustainable agricultural practices (Seegers et al., 2023). Furthermore, to promote the adoption of sustainable practices, it is crucial to involve family members, peers, community leaders, agricultural organizations, and government agencies that can contribute to creating a supportive environment (Dharmawan et al., 2021). Collaboration and joint efforts are essential for establishing social norms that support and encourage the adoption of sustainable agricultural practices, as well as for providing the necessary support and resources to farmers (Adiprasetyo et al., 2019).

Third, the analysis results indicate a significant positive relationship between farmers' perceived behavioral control and the adoption of sustainable agricultural practices. The findings underscore the importance of farmers' beliefs regarding their access to the necessary resources and training in influencing their decisions to adopt sustainable practices. This highlights the critical role of addressing factors such as land availability, financial resources, labor availability, and access to training and extension services in enhancing farmers' perceived behavioral control over the adoption of sustainable practices. Policymakers and stakeholders must prioritize efforts to improve farmers' access to resources essential for sustainable agriculture, including land allocation, financial incentives, labor support, and comprehensive training and extension services (Savari & Gharechae, 2020).

Fourth, the analysis results indicate a significant positive relationship between farmers' perceptions of the relative advantages of adopting sustainable agricultural practices and their likelihood of adoption. This highlights the importance of farmers' beliefs regarding the financial, environmental, and social benefits associated with sustainable practices in influencing their decision to adopt them. Specifically, this study reveals that farmers who perceive sustainable agricultural practices as leading to improved crop yields and lower input costs, environmental protection, and enhanced community reputation are more likely to adopt sustainable agricultural practices (Mannan et al., 2017), making it crucial to emphasize and communicate the economic, environmental, and social

benefits associated with their implementation to promote the adoption of sustainable agricultural practices (Foguesatto et al., 2020). Furthermore, highlighting how adopting sustainable agricultural practices can lead to increased profits, lower input costs, a better reputation, and positive impacts on the environment and society can serve as motivational factors for farmers (Azarian et al., 2023; Elahi et al., 2022).

Fifth, the analysis results indicate a significant positive relationship between farmers' perceptions of the suitability of sustainable agricultural practices and their likelihood of adopting them. This highlights the importance of considering farmers' beliefs, traditions, and social norms when promoting sustainable practices. This study indicates that farmers are more likely to adopt sustainable agricultural practices if they perceive them as aligning with their desire to practice good soil management, conserve natural resources, and safeguard community health and well-being (Morgan-Davies et al., 2021). Therefore, it is crucial to acknowledge and respect farmers' local knowledge, beliefs, and traditions, and to involve them in the development and implementation of sustainable practices to increase the likelihood of successful adoption (Gama et al., 2016). Collaboration between researchers, policymakers, and farmers in identifying solutions that align with the local social and cultural context can strengthen suitability and encourage the adoption of sustainable practices (Limaho et al., 2022).

Sixth, the analysis results indicate a significant negative relationship between farmers' perceptions of the complexity of adopting sustainable agricultural practices and their likelihood of adoption. This highlights the challenges posed by perceptions of complexity, which can hinder farmers from adopting sustainable agricultural practices. Farmers who perceive sustainable practices as requiring extensive knowledge and skills tend to be reluctant to adopt them (McCann et al., 2015; Tractenberg, 2016). Additionally, concerns regarding potential negative impacts on crop yields or profits, as well as insufficient support from agricultural organizations or government agencies, can further reinforce resistance to adoption (Rodriguez-valez et al., 2005), making it crucial to simplify the adoption process by providing farmers with clear and practical guidelines, hands-on demonstrations, and step-by-step implementation plans to address these barriers. Furthermore, simplifying the complexities associated with sustainable agricultural practices can help alleviate farmers' concerns and increase their willingness to adopt them (Vecchio et al., 2022). Furthermore, strong support from agricultural organizations and government agencies can help address perceived barriers and ensure that farmers have the necessary resources and guidance to effectively adopt sustainable agricultural practices (Reimer et al., 2023).

Furthermore, the analysis results indicate a significant positive relationship between farmers' perceptions of pilot projects regarding the adoption of sustainable agricultural practices and their likelihood of adoption. This highlights the importance of providing farmers with the opportunity to test and observe the outcomes of sustainable practices on a limited scale before fully adopting them. Farmers who have the opportunity to assess the feasibility, effectiveness, and potential benefits of sustainable agricultural practices within the context of their specific farming operations are more likely to adopt them, therefore it is recommended to create platforms and initiatives that allow farmers to experiment with sustainable practices on a limited scale to promote trial factors (Dewa et al., 2023). Research findings emphasize the importance of providing farmers with opportunities to gain firsthand experience and evaluate the feasibility and potential benefits of sustainable practices before implementing

them on a larger scale (Hassan et al., 2023; Zondo & Ndoro, 2023). Additionally, facilitating knowledge sharing among farmers who have already adopted sustainable agricultural practices can inspire other farmers and provide practical insights (Sewell et al., 2017).

Finally, the analysis results indicate a significant positive relationship between farmers' perceptions of observability and their likelihood of adopting sustainable agricultural practices. This underscores the importance of farmers being able to easily observe the positive outcomes of sustainable agricultural practices, both on their own farms and on other farms. Observable benefits, such as improved soil health, reduced chemical use, increased biodiversity, and recognition from the community, have a significant influence on farmers' decisions to adopt sustainable agricultural practices (McCann et al., 2015), therefore it is recommended to highlight and showcase the positive outcomes of sustainable agricultural practices through examples using platforms easily accessible to farmers to encourage adoption (Strong et al., 2022). This can be achieved by demonstrating how sustainable agricultural practices have led to improvements in farmers' well-being (Seegers et al., 2023). Furthermore, farmers are more likely to be motivated to adopt sustainable agricultural practices when they see tangible benefits from other agricultural practices through observable outcomes (Warner et al., 2022).

CONCLUSION

The characteristics of independent oil palm farmers the majority of whom are aged 40–49, with an average of 10 years of work experience and a generally low level of education have significant implications for the adoption of sustainable agricultural practices. Factors such as age, work experience, and educational level play a crucial role in the acceptance and implementation of innovations, with the potential to act as either drivers or barriers. Given the importance of sustainable agricultural practices, the results of this study recommend further efforts to raise awareness and understanding among independent oil palm farmers regarding the benefits and implementation of sustainable practices.

Based on the data analysis conducted, this study reveals specific characteristics in the factors influencing the adoption of sustainable agricultural practices, with reference to the Theory of Planned Behavior (TPB) and the Theory of Diffusion of Innovations (DOI). The majority of variables showed a high percentage of agreement, indicating a positive attitude among respondents toward several factors, such as high yields, family support, and training. However, the presence of variables with low percentages highlights the importance of understanding the barriers that may be encountered in the implementation of sustainable practices. Therefore, it is important for policymakers and other stakeholders to understand and address these barriers to support the transition toward more sustainable agriculture, while simultaneously maximizing the positive factors identified in this study.

Statistical analysis, which includes structural equation modeling, has confirmed the significant and positive influence of attitudes, subjective norms, perceived behavioral control, relative advantage, compatibility, trialability, and observability on the adoption of sustainable agricultural practices by independent oil palm farmers in West Kalimantan. On the other hand, complexity exerts a significant negative influence. The causal model constructed can illustrate the cause-and-effect relationships among the variables influencing the adoption of sustainable agricultural practices, thereby providing better insights and understanding of the mechanisms underlying the

adoption of sustainable agricultural practices, particularly among independent oil palm farmers in West Kalimantan.

The findings of this study provide recommendations for policymakers and practitioners to support the adoption of sustainable oil palm farming by independent smallholders and address potential barriers to the expansion of the Indonesian Sustainable Palm Oil (ISPO) certification system by 2025. Implementing these recommendations is expected to prevent negative consequences from the implementation of ISPO. Future research could focus on analyzing regional and contextual differences, evaluating long-term impacts, assessing the effectiveness of existing policies and programs, comparative studies with other agricultural sectors, and the role of stakeholders in promoting the adoption of sustainable practices to deepen understanding of the factors influencing farmers' adoption of sustainable agricultural practices, thereby providing deeper insights into the adoption of sustainable agricultural practices.

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