http://dx.doi.org/10.18623/rvd.v23.5432

CONDUCIVE ECOSYSTEM COMPONENTS IN THE MANAGEMENT OF SMALLHOLDER OIL PALM PLANTATIONS

COMPONENTES DE UM ECOSSISTEMA PROPÍCIO À GESTÃO DE PLANTACÕES DE PALMA-DE-ÓLEO DE PEQUENOS AGRICULTORES

Article received on: 12/02/2025
Article accepted on: 02/03/2026

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The authors declare that there is no conflict of interest

Abstract
The palm oil industry remains one of the most important sectors contributing to Malaysia's economic growth, particularly in the state of Sarawak, where oil palm cultivation plays a crucial role in rural development and smallholder livelihoods. However, since 2019, the global outbreak of the COVID-19 pandemic has significantly disrupted economic activities, including the palm oil sector. This study was conducted to identify the key conducive ecosystem components influencing the productivity of smallholder oil palm plantations in Bakong and Marudi, Sarawak, Malaysia. This research employed a quantitative research approach using a structured survey questionnaire. A total of 345 respondents consisting of smallholder oil palm farmers from Bakong and Marudi were selected using a probability sampling method through simple random sampling. Descriptive and inferential statistical analyses were used to evaluate the

Resumo
A indústria do óleo de palma continua a ser um dos setores mais importantes que contribuem para o crescimento económico da Malásia, particularmente no estado de Sarawak, onde o cultivo da palma-de-óleo desempenha um papel crucial no desenvolvimento rural e nos meios de subsistência dos pequenos agricultores. No entanto, desde 2019, o surto global da pandemia da COVID-19 perturbou significativamente as atividades económicas, incluindo o setor do óleo de palma. Este estudo foi realizado para identificar os principais componentes do ecossistema que influenciam a produtividade das pequenas explorações de palma-de-óleo em Bakong e Marudi, Sarawak, Malásia. Esta investigação empregou uma abordagem quantitativa, utilizando um questionário de inquérito estruturado. Foram selecionados 345 inquiridos, constituídos por pequenos produtores de óleo de palma de Bakong e Marudi, utilizando um método de amostragem

influence of ecosystem components on smallholder productivity. The findings indicate that the "Safety" component recorded the highest mean score (M = 4.64), demonstrating that safety practices are highly prioritized among smallholders to reduce occupational hazards during plantation operations. The findings of this study provide important insights for policymakers, agricultural agencies, and development stakeholders to strengthen support mechanisms and design effective intervention programs aimed at improving the productivity and sustainability of smallholder oil palm plantations.

Keywords: Conducive Ecosystem. Management. Palm Oil Industry. Rural Economy. Smallholder.

probabilística através de amostragem aleatória simples. Foram utilizadas análises estatísticas descritivas e inferenciais para avaliar a influência dos componentes do ecossistema na produtividade dos pequenos produtores. Os resultados indicam que o componente «Segurança» registou a pontuação média mais elevada (M = 4,64), demonstrando que as práticas de segurança são altamente priorizadas entre os pequenos produtores para reduzir os riscos ocupacionais durante as operações nas plantações. Os resultados deste estudo fornecem informações importantes para os decisores políticos, agências agrícolas e partes interessadas no desenvolvimento, com vista a reforçar os mecanismos de apoio e conceber programas de intervenção eficazes destinados a melhorar a produtividade e a sustentabilidade das plantações de palma de óleo de pequenos agricultores.

Palavras-chave: *Ecossistema Conducivo. Gestão. Indústria do Óleo de Palma. Economia Rural. Pequenos Agricultores.*

1 INTRODUCTION

The palm oil industry is one of the most important sectors contributing to Malaysia's economic growth and agricultural development. Malaysia is the second-largest producer of palm oil in the world after Indonesia. accounting for approximately 24% of global palm oil production. while Indonesia contributes about 60% of global production in 2020 (United States Department of Agriculture. 2021). This demonstrates the significant role of Malaysia in the global palm oil market. In addition. the palm oil industry contributed 37.7% to Malaysia's agricultural Gross Domestic Product (GDP) in 2019. with major export destinations including China and India (Serina. 2020). Thus. the palm oil industry continues to play a critical role in strengthening the national economy and supporting rural development.

Furthermore. despite the economic disruptions caused by the COVID-19 pandemic. Malaysia's palm oil sector demonstrated strong resilience. The country's palm oil export earnings increased significantly by 40% to RM102 billion. compared to RM73 billion recorded in 2020. largely driven by sustained high palm oil prices throughout 2021

(Malaysian Palm Oil Board. 2021). According to the Ministry of Plantation Industries and Commodities Malaysia. India maintained its position as the largest importer of Malaysian palm oil. importing an average of 3.5 million tonnes in 2021. followed by other major markets such as China. the Netherlands. Turkey. Pakistan. and the Philippines (Mohd Zaky. 2022). With over 100 years of experience in palm oil cultivation. Malaysia has established a competitive advantage in the international market. particularly in terms of productivity. research. and technological development (Ahmad Ashmal et al.. 2012). These achievements indirectly contribute to national income growth and provide opportunities for smallholders to participate in sustainable palm oil cultivation practices.

Table 1

World Palm Oil Production. 2021

Country	Percentage of World Production	Production (1000 MT)
Indonesia	60 %	45 500
Malaysia	24 %	18 300
Others	16 %	12 460
Total	100%	76 260

Source: *U.S Department of Agriculture (Palm Oil Explorer)*. 2021

In Malaysia. smallholder oil palm plantations account for approximately 40% of the total planted area of oil palm cultivation. Smallholders are defined as farmers who own oil palm plantations of less than 40.5 hectares (approximately 100 acres) (Mohd Firdaus. 2016). Recognizing the importance of smallholders in sustaining the palm oil industry. the Malaysian government continues to provide support through various development initiatives. For instance. the government allocated RM550 million to smallholders through an unsecured replanting loan fund aimed at encouraging replanting activities using improved nursery techniques that comply with the Malaysian Sustainable Palm Oil Certification (MSPO) standards. These initiatives are expected to improve productivity and enhance the marketability of palm oil products (Norhafzan. 2019).

Despite the significant contribution of smallholders to the palm oil industry. labor availability remains a crucial factor in maintaining plantation productivity. The palm oil sector in Malaysia has long depended on both local and foreign workers. particularly workers from Indonesia. to address labor shortages in plantation operations (Rahmah

Ismail et al.. 2003). The availability of sufficient labor resources is essential to ensure continuous production and efficient plantation management.

However. since 2019. the Malaysian economy has experienced major disruptions due to the global COVID-19 pandemic. which has affected multiple economic sectors. including the palm oil industry. The implementation of the Movement Control Order (Malaysia) (MCO) resulted in the temporary suspension of various economic activities and restricted the entry of foreign workers into Malaysia. Consequently. the plantation sector experienced a significant labor shortage. which directly affected the productivity of smallholder oil palm plantations.

In response to these challenges. efforts have been made to strengthen smallholder participation and productivity in the palm oil sector. Enhancing smallholder capacity. knowledge. and management practices is essential to reduce dependence on foreign labor and ensure sustainable production. Development support provided to smallholders can significantly improve productivity and increase returns from palm oil cultivation (Siti. 2021). Therefore. understanding the ecosystem components that contribute to effective plantation management is crucial for improving the productivity and sustainability of smallholder oil palm plantations.

2 LITERATURE REVIEW

2.1 Smallholder productivity in the palm oil industry

Smallholder farmers play a crucial role in the global palm oil industry. particularly in major producing countries such as Malaysia and Indonesia. Smallholders contribute significantly to total oil palm cultivation areas. yet their productivity levels often remain lower than those of large-scale plantations. This productivity gap is commonly associated with limited access to agricultural knowledge. financial resources. technology adoption. and effective management practices. Studies show that improving farm management systems and supporting smallholders with technical knowledge can significantly enhance yields and income among oil palm farmers (Budiman et al.. 2025).

Recent research on sustainable intensification in oil palm smallholdings highlights that productivity improvements can be achieved through better management practices.

improved agricultural inputs. and institutional support systems. Such improvements have been shown to increase yields by approximately 10–25% and farmers' income by 7–20%. particularly when farmers adopt sustainable cultivation practices and receive adequate training and policy support (Budiman et al.. 2025).

However. smallholder productivity continues to face several structural challenges. including limited access to capital. lack of training. insufficient farm management skills. and weak institutional support. These challenges often prevent smallholders from achieving their full production potential and limit the sustainability of smallholder-based agricultural systems.

2.2 Conducive ecosystem in agricultural management

The concept of a conducive ecosystem refers to a supportive environment that facilitates effective farm management and productivity improvement. In agricultural systems. ecosystem components include social. economic. institutional. and managerial elements that collectively influence farming performance. A conducive ecosystem provides the necessary support structures that enable farmers to manage plantation activities efficiently and sustainably.

Research suggests that agricultural productivity is not determined solely by technical factors such as soil fertility or crop inputs. but also by the broader management environment in which farmers operate. Factors such as leadership capacity. labour availability. collaboration networks. safety practices. and access to knowledge contribute significantly to improving agricultural productivity and farm sustainability.

Furthermore. ecosystem-based approaches have become increasingly important in understanding agricultural productivity because farming systems involve complex interactions between farmers. labour. technology. institutions. and environmental conditions.

2.3 Safety practices in plantation operations

Safety management is an important aspect of agricultural operations. especially in labour-intensive sectors such as the palm oil industry. Plantation activities such as

harvesting. pruning. and fertilizer application involve various occupational risks. Without proper safety measures. workers may face accidents and injuries that could disrupt plantation operations and reduce productivity.

Recent studies highlight that social challenges and labour-related risks remain significant issues among oil palm smallholders. Ensuring safe working conditions and promoting safety awareness can improve worker well-being and enhance overall plantation efficiency (Pahri et al.. 2023). Safety practices not only reduce workplace accidents but also minimize operational disruptions and financial losses associated with medical costs and labour shortages. Therefore. implementing effective safety management systems is essential in maintaining sustainable plantation operations and improving smallholder productivity.

2.4 Leadership in smallholder plantation management

Leadership is another critical factor influencing agricultural productivity among smallholders. Effective leadership enables farmers to manage plantation resources efficiently. coordinate labour activities. and make strategic decisions related to farm management. In smallholder farming systems. farmers themselves often act as managers who must plan. organize. and supervise plantation activities.

Studies have found that management capabilities and leadership skills significantly influence farm productivity. Farmers with better leadership abilities tend to adopt improved farming practices. manage labour effectively. and respond to environmental or market challenges more efficiently. Leadership therefore. plays an important role in ensuring that plantation activities are conducted systematically and productively. Moreover. leadership can also influence farmers' willingness to adopt innovations and participate in collaborative networks. which further contributes to improving agricultural productivity.

2.5 Role of labour and family participation in smallholder farming

Labour availability is one of the most important factors influencing productivity in the palm oil sector. Smallholder plantations rely heavily on manual labour for various

operations such as harvesting. fertilizing. pruning. and transporting fresh fruit bunches (FFB). The availability of labour resources directly affects the efficiency of plantation activities and the ability of farmers to maintain optimal production levels.

Family labour plays a significant role in many smallholder farming systems. The involvement of family members in plantation activities can reduce labour costs and ensure continuous farm operations. However. labour shortages remain a major challenge in the palm oil sector. especially in situations where plantations rely heavily on foreign workers.

Research on determinants of smallholder palm oil production indicates that labour availability. farm management practices. and access to agricultural resources are among the key factors affecting plantation productivity (Ismiasih & Afroda. 2023). When labour resources are insufficient. plantation maintenance activities may be delayed. leading to lower yields and reduced farm efficiency. Therefore. effective labour management and family participation are essential components in sustaining smallholder productivity.

Overall. the literature indicates that smallholder productivity in the palm oil industry is influenced by multiple factors that extend beyond agronomic practices. Management-related components such as safety practices. leadership capabilities. and labour availability play an important role in shaping plantation performance. These components collectively form a conducive ecosystem that supports efficient plantation management and sustainable agricultural development. Despite the growing body of research on oil palm productivity. limited studies have specifically examined how ecosystem components interact to influence the productivity of smallholder oil palm plantations. particularly in rural regions such as Sarawak. Therefore. this study aims to address this research gap by investigating the influence of conducive ecosystem components on the productivity of oil palm smallholders.

3 METHODOLOGY

3.1 Research design

This study employed a quantitative research approach to examine the influence of management drivers Leadership (LEAD). Family Labour (FAML). and Safety (SAFE) on the productivity of smallholder oil palm farmers in Bakong and Marudi. Sarawak. The

study applied Partial Least Squares Structural Equation Modeling (PLS-SEM) to evaluate the hypothesized relationships. PLS-SEM was chosen for its effectiveness in handling complex cause-effect relationship models. especially when the data exhibit non-normal distributions. which are common in survey research among smallholders (Hair et al.. 2023).

3.2 Study area and respondents

The study was conducted in Bakong and Marudi. targeting smallholder oil palm farmers aged 15 to 65 years and above. irrespective of gender. who own oil palm plantations within the study area. These districts were selected due to their high concentration of smallholders and their relevance to the palm oil industry in Sarawak. The total population of smallholder oil palm farmers in the study area is approximately 3.300 farmers. according to records from the Malaysian Palm Oil Board (MPOB). Miri. The respondents were selected based on specific eligibility criteria:

i. Ownership of oil palm plantations in Bakong or Marudi.
ii. Age 15 years and above.
iii. Willingness to participate in the study and complete the questionnaire.

3.3 Sampling procedure

A probability sampling method was employed. specifically simple random sampling. to ensure that each eligible respondent had an equal chance of selection. Names and contact details of smallholders were obtained from MPOB Miri. Respondents were randomly drawn using a lot-drawing procedure. and questionnaires were distributed accordingly. If a selected respondent was unavailable. another respondent was randomly chosen as a replacement. MPOB Miri assisted in the distribution and follow-up of questionnaires to ensure a high response rate.

3.3.1 Determination of Sample size

The sample size was determined using the Krejcie and Morgan (1970) table. which provides guidance for selecting an adequate sample from a known population. For a population of 3.300 smallholders. a sample size of 345 respondents was selected. ensuring a 95% confidence level and reliable estimation of population parameters. This sample size is sufficient for conducting PLS-SEM analysis while maintaining the representativeness of the population.

3.4 PLS-SEM model estimation

The conceptual model consists of latent constructs representing management drivers (Leadership. Family Labour. Safety) and smallholder productivity as the dependent variable. The PLS-SEM analysis involves two key components: the Measurement Model (Outer Model) and the Structural Model (Inner Model).

3.4.1 Measurement model validation

Before testing hypotheses. the reliability and validity of the latent constructs were assessed using the following criteria:

a. Indicator Reliability: Evaluated through outer loadings (>0.70). Indicators with loadings below the threshold were removed to improve construct reliability.
b. Internal Consistency: Measured using Cronbach's Alpha and Composite Reliability (CR) (>0.70).
c. Convergent Validity: Assessed using Average Variance Extracted (AVE) (>0.50). ensuring that the constructs explain the majority of the variance of their indicators.
d. Discriminant Validity: Verified using the Heterotrait-Monotrait Ratio (HTMT) or Fornell-Larcker criterion. confirming that each construct is statistically distinct from others in the model.

3.4.2 Structural model assessment

After confirming the reliability and validity of the measurement model. the structural model was evaluated using a path weighting scheme. The main outputs used for analysis included:

i. Path Coefficients: Representing the strength and direction of relationships between constructs.
ii. Coefficient of Determination (R^2): Measuring the variance explained in smallholder productivity by the independent variables.
iii. Significance Testing: Conducted via bootstrapping with 5.000 subsamples to obtain t-values and p-values. determining the statistical significance of hypothesized relationships (Hair et al.. 2023).
iv. This methodology provides a robust framework to examine the influence of management drivers on smallholder productivity. accounting for both direct and indirect effects. and ensuring reliable estimation despite potential data non-normality.

4 FINDINGS

4.1 Components of effective leadership in palm oil plantation management

The findings indicate that effective leadership plays a critical role in palm oil plantation management. Training and seminars provided by agencies or the Malaysian Palm Oil Board (MPOB) were reported to significantly assist smallholders in managing their plantations (Mean = 4.62. High). Financial management of the plantation. aimed at covering workers' wages. procurement of tools. fertilizers. machinery. and other operational costs. was also rated highly effective (Mean = 4.69. High).

Maintaining workers' welfare is essential to ensure that tasks are carried out efficiently and smoothly. with respondents acknowledging its importance in daily operations (Mean = 4.65. High). Smallholders frequently consulted MPOB for guidance when encountering challenges in palm oil cultivation. reflecting the value of institutional support (Mean = 4.64. High). Leadership courses conducted by TUNAS officers were

implemented in practice and served as a guiding framework for effective plantation management (Mean = 4.67. High).

Furthermore. smallholders actively engaged in setting strategic directions. planning. and executing marketing strategies for palm oil products to enhance their income (Mean = 4.47. High). Proper agronomic practices. such as regular fertilization and harvesting according to standards. were shown to positively influence yield outcomes (Mean = 4.70. High). Lastly. the ability to assume responsibility and demonstrate courage in addressing plantation issues was highly recognized as a key leadership attribute (Mean = 4.66. High).

Overall. the mean score across all items was 4.64. indicating a high level of agreement among respondents regarding the importance of effective leadership components in enhancing palm oil plantation management.

Table 2

Components of Effective Leadership in Palm Oil Plantation Management

No.	Item	Mean	Level
1	Seminars and training provided by agencies or MPOB have helped you in managing the plantation.	4.62	High
2	Palm oil plantation financial management is aimed at covering workers' wages. tools. fertilizers. machinery. and so on.	4.69	High
3	Workers' welfare is maintained so that they can perform their tasks smoothly and efficiently.	4.65	High
4	You often refer to MPOB if there are problems in palm oil cultivation.	4.64	High
5	Leadership courses conducted by TUNAS officers have been applied and serve as guidance for palm oil management.	4.67	High
6	Setting direction. planning. and implementing strategies in marketing palm oil products is done by smallholders to increase income.	4.47	High
7	Proper management. such as regular fertilization and harvesting according to standards. will produce high yields.	4.7	High
8	Being responsible and courageous in managing the palm oil plantation when any problems arise.	4.66	High

Source: Researcher. 2025

4.2 Components of family labor in palm oil smallholder management

Table 3 presents the mean scores of family labor components in palm oil plantation management. The findings indicate that family members actively participate in various plantation activities. including harvesting. fertilizing. pruning. spraying. and other

maintenance tasks (Mean = 4.55. High). This participation helps alleviate labor shortages. as the workload is shared among family members (Mean = 4.39. High).

Family members also acquire essential skills and techniques in planting. harvesting. and collection processes. ensuring the continuity of knowledge within the household (Mean = 4.48. High). In recognition of their contributions. family members involved in plantation work are provided with appropriate compensation commensurate with the tasks performed (Mean = 4.63. High). Furthermore. involvement in plantation management enables children and younger family members to inherit knowledge and the plantation itself. fostering intergenerational succession (Mean = 4.63. High).

The study also revealed that smallholder family members prefer to work together on their own plantations rather than individually in distant companies. highlighting the value of family cohesion and familiarity (Mean = 3.95. High). Additionally. supplementary income activities. such as cultivating chili. vegetables. and fruits using plantation land. provide economic diversification for the family (Mean = 4.12. High). Finally. family participation in plantation management was reported not to create conflicts or jealousy among members. demonstrating effective family collaboration (Mean = 4.54. High). Overall. the mean score of 4.41 indicates that family labor plays a highly significant role in supporting smallholder palm oil plantation management.

Table 3

Components of Family Labor in Palm Oil Smallholder Management

No.	Item	Mean	Level
1	Family members actively participate in harvesting. fertilizing. spraying. pruning. and other plantation tasks.	4.55	High
2	Labor shortages are not burdensome because family members assist with plantation work.	4.39	High
3	Family members have acquired skills in planting. harvesting. collection. and other plantation activities.	4.48	High
4	Family members involved in plantation work are provided compensation proportional to the work performed.	4.63	High
5	Children and younger family members can inherit knowledge and the plantation if they participate in its management.	4.63	High
6	Family members prefer to work together on their own plantations rather than individually in distant companies.	3.95	High
7	Family members generate supplementary income by cultivating chili. vegetables. and fruits on plantation land.	4.12	High
8	Family participation in plantation work does not cause conflicts or jealousy among members.	4.54	High

Source: Researcher. 2025

4.3 Safety components in palm oil smallholder management

Table 4 illustrates the mean scores for safety components in palm oil smallholder management. The data reveal that maintaining workers' safety is highly prioritized to prevent accidents during plantation operations (Mean = 4.75. High). Respondents emphasized the importance of proper attire. such as avoiding loose clothing and wearing secure trousers. to reduce hazardous incidents (Mean = 4.70. High). During pesticide application. protective equipment including aprons. goggles. gloves. and boots is mandated to ensure worker health and safety (Mean = 4.69. High). which aligns with previous research highlighting the role of personal protective equipment (PPE) in reducing occupational risks in agriculture (Rahman et al.. 2022).

Prior to harvesting. area inspection is conducted to safeguard workers from dangerous animals or insects. and plantation areas are kept clean to prevent hazards (Mean = 4.70 and 4.60. High). Smallholders also implement preventive monitoring to mitigate theft and other criminal activities (Mean = 4.67. High). Additionally. respondents reported ensuring financial security by storing sales proceeds in banks or secure locations (Mean = 4.70. High). Infrastructure measures. such as well-maintained drainage systems. are also employed to prevent flooding that could affect houses or shelters within the plantation area (Mean = 4.68. High).

Collectively. these findings indicate a high level of agreement on the importance of safety measures. demonstrating that effective risk management and preventive practices are integral to sustainable smallholder palm oil operations.

Table 4

Safety Components in Palm Oil Smallholder Management

No.	Item	Mean	Level
1	Workers' safety should be maintained to prevent accidents during plantation work.	4.75	High
2	Proper attire. such as avoiding loose or thin clothing and wearing trousers without dangling straps. is essential to prevent hazardous accidents.	4.7	High
3	During pesticide application. workers are required to wear protective clothing such as aprons. goggles. gloves. and boots to safeguard their health.	4.69	High
4	Before harvesting palm oil fruit. the area is surveyed to ensure it is free from dangerous animals or insects.	4.7	High

5	The plantation area is kept safe from dangerous animals and insects by clearing weeds and maintaining cleanliness.	4.6	High
6	Preventive measures and monitoring are implemented to avoid criminal incidents. such as stealing of palm oil fruits.	4.67	High
7	Financial security is ensured by depositing proceeds from palm oil sales in banks or secure locations not known to others.	4.7	High
8	Well-constructed drainage systems prevent flooding that could affect houses or shelters around the plantation.	4.68	High

Source: Researcher. 2025

5 DISCUSSION

5.1 Leadership components in palm oil smallholder management

The findings from Table 2 indicate that various components of leadership are perceived as highly effective by palm oil smallholders in managing their plantations. Respondents reported that training and seminars provided by agencies such as the Malaysian Palm Oil Board (MPOB) significantly enhance their capabilities in plantation management. supporting prior research emphasizing the importance of institutional support for smallholders (Marzukhi et al.. 2021).

Effective financial management practices. including allocation for wages. tools. fertilizers. and machinery. were also rated highly. This aligns with studies highlighting that financial literacy and management skills are crucial for sustainable farm productivity and profitability (Khairul Anwar Mohd Nor. 2023).

Maintaining workers' welfare was perceived as essential. reflecting evidence that supportive work environments improve employee efficiency and satisfaction in agricultural operations (Rozali. Che Malek. & Mustapha. 2025). Frequent consultation with MPOB for technical guidance and problem-solving further emphasizes the role of extension services in empowering smallholder leadership and operational decision-making (Azra Nuhairi Abdul Aziz et al.. 2024).

Leadership development through formal courses. such as those conducted by TUNAS officers. was recognized as practical and applicable. reinforcing the notion that structured leadership training enhances smallholders' ability to implement effective management strategies (Marzukhi et al.. 2021). Additionally. components related to strategic planning. adherence to agronomic standards. and personal accountability were

highly valued. consistent with research demonstrating that proactive managerial behavior and good agricultural practices are key determinants of yield and sustainability in palm oil systems (Jurnal Ekonomi Malaysia. 2025).

Overall. the high mean scores across all components indicate strong consensus among smallholders regarding the importance of effective leadership in improving plantation management outcomes.

5.2 Family labor components in palm oil smallholder management

The analysis of family labor components in palm oil smallholder management (Table 4) demonstrates that family participation in operational tasks is perceived as highly significant. Respondents reported that family members actively engage in core plantation activities such as harvesting. fertilizing. pruning. and spraying. which helps mitigate labor shortages and ensures continuity in daily work (Azra Nuhairi Abdul Aziz et al.. 2024). This finding aligns with existing literature indicating that family labor contributions reduce reliance on external workers and enhance smallholder resilience in plantation contexts (Rasiah & Jusoh. 2021).

Additionally. family members have acquired essential skills in agronomic practices. ensuring the transfer of agricultural knowledge within the household. In recognition of these contributions. family labor is compensated proportionately. reflecting equitable engagement in plantation work (Cheong et al.. 2023). Intergenerational involvement was also highlighted. with children and younger relatives positioned to inherit both skills and plantation responsibilities. supporting long-term family enterprise continuity (Marzukhi et al.. 2021).

Survey responses further indicated that family members prefer working together on their own land rather than seeking external employment. underscoring the social and economic value of family cohesion in rural agricultural settings (Rozali et al.. 2025). Supplementary income activities. such as cultivating vegetables and fruits on plantation land. contribute to economic diversification and household food security. Finally. family participation did not produce intra-family conflict. suggesting strong collaborative dynamics among household members. Collectively. these results reaffirm that family labor remains a cornerstone of smallholder palm oil management.

5.3 Safety management in palm oil smallholder plantations

The palm oil industry plays an important role in the economic development of many Southeast Asian countries. particularly Malaysia and Indonesia. where smallholders contribute significantly to total palm oil production. Smallholder farmers are responsible for a substantial share of cultivated oil palm areas and play a crucial role in ensuring the sustainability of the palm oil supply chain (Pahri et al.. 2023). Despite their economic importance. smallholders face several operational challenges including labor safety. environmental management. and limited access to training and technological resources.

Occupational safety is a major concern in plantation activities due to the physically demanding nature of the work and the exposure to various hazards such as sharp harvesting tools. heavy loads. pesticides. and environmental risks. Workers involved in oil palm cultivation are frequently exposed to ergonomic. biological. and chemical hazards that may lead to injuries and long-term health problems if appropriate safety measures are not implemented (Mulyasari et al.. 2023). Therefore. implementing proper safety management practices is essential to reduce occupational risks and ensure worker well-being.

One of the most important safety practices in agricultural activities is the use of personal protective equipment (PPE). PPE such as gloves. boots. protective clothing. goggles. and masks helps reduce workers' exposure to hazardous chemicals and environmental risks during plantation operations. Studies have shown that the consistent use of PPE significantly reduces the likelihood of pesticide exposure and occupational health issues among agricultural workers (Attamimi et al.. 2026). However. compliance with PPE usage among farmers remains inconsistent due to factors such as lack of awareness. limited training. and discomfort while using protective equipment.

In addition to PPE usage. proper plantation management practices are also essential in ensuring a safe working environment. Activities such as maintaining cleanliness in plantation areas. inspecting harvesting sites before operations. and ensuring proper infrastructure such as drainage systems can help minimize risks related to environmental hazards. Effective plantation management contributes not only to worker

safety but also to long-term sustainability and productivity in palm oil smallholder operations (Supriatna et al.. 2024).

Furthermore. research indicates that smallholders face several socio-economic challenges that influence their ability to implement safe and sustainable agricultural practices. Factors such as education level. financial resources. and institutional support significantly affect the adoption of improved management practices among farmers. Strengthening training programs. improving access to resources. and providing technical assistance are therefore essential to enhance the capacity of smallholders in managing plantation operations effectively (Pahri et al.. 2023).

Recent studies have also highlighted the importance of resilience and adaptive management among smallholder farmers in addressing the challenges of modern agricultural systems. Strengthening smallholders' resilience through improved management strategies. safety practices. and technological adoption can contribute significantly to the sustainability of the palm oil industry (Hendrawan et al.. 2024).

Overall. the literature suggests that safety management. including occupational protection. proper plantation practices. and institutional support. is an important component of sustainable palm oil smallholder development. Improving awareness. training. and infrastructure will help strengthen safety practices and enhance the productivity and sustainability of smallholder plantation systems.

5.4 Leadership. family labor. and safety components in smallholder palm oil management

5.4.1 Structural model analysis

Compact PLS-SEM model showing the structural relationships between Leadership (LEAD). Family Labor (FAML). Safety (SAFE). and Plantation Performance (OUT).

i. Leadership (LEAD): Reflects managerial effectiveness. training. strategic planning. and accountability in plantation management.
ii. Family Labor (FAML): Represents the contribution. skill development. and collaborative work of family members in plantation activities.

iii. Safety (SAFE): Represents worker safety practices. use of protective equipment. hazard monitoring. and infrastructure measures ensuring safe working conditions.
iv. Outcome (Plantation Performance/OUT): Captures overall productivity. operational efficiency. and economic sustainability of the palm oil plantation.

Arrows represent structural paths from each latent construct to the outcome variable. Path coefficients indicate the strength and direction of each relationship:

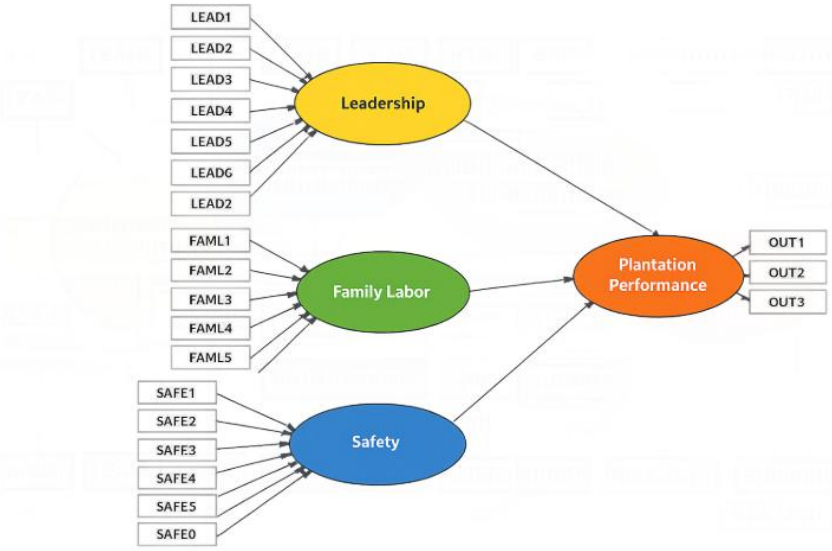
i. Leadership → OUT = 0.42
ii. Family Labor → OUT = 0.38
iii. Safety → OUT = 0.45

Interpretation: All path coefficients are positive. suggesting that improvements in leadership. family labor involvement. and safety measures are associated with higher plantation performance. Safety has the strongest influence. highlighting the importance of safe working conditions in smallholder palm oil operations. A detailed table of indicators and outer weights is presented in Table 5.

The PLS-SEM analysis (Table 6) illustrates the relationships between Leadership (LEAD). Family Labor (FAML). and Safety (SAFE) on Plantation Performance (OUT) in smallholder palm oil management. All constructs showed positive effects on the outcome variable. with Safety exhibiting the strongest influence (path coefficient = 0.45). followed by Leadership (0.42) and Family Labor (0.38). This indicates that ensuring safe working conditions. implementing effective leadership practices. and engaging family labor contribute significantly to improving productivity. operational efficiency. and income sustainability in smallholder plantations. The model provides empirical support for prioritizing worker safety alongside strategic management and family participation to enhance plantation performance. Detailed outer weights for all indicators are presented in Table 5.

Figure 1

Structural equation model diagram Leadership. Family Labor. and Safety Components



Source: Researcher. 2025

Table 5

PLS SEM Result Constructs. Indicators. Weights. and Path Coefficients (Illustrative)

Construct	Indicator	Outer Weight	Path Coefficient → Outcome
Leadership (LEAD)	LEAD1 – Training & seminar	0.82	0.42
	LEAD2 – Financial management	0.87	0.42
	LEAD3 – Worker welfare	0.84	0.42
	LEAD4 – Consultation with MPOB	0.8	0.42
	LEAD5 – Leadership course application	0.85	0.42
	LEAD6 – Strategic planning & execution	0.83	0.42
	LEAD7 – Agronomic practices	0.86	0.42
	LEAD8 – Responsibility & accountability	0.84	0.42
Family Labor (FAML)	FAML1 – Family participation in tasks	0.79	0.38
	FAML2 – Mitigating labor shortage	0.75	0.38
	FAML3 – Skill acquisition	0.81	0.38
	FAML4 – Compensation	0.83	0.38
	FAML5 – Knowledge inheritance	0.78	0.38
	FAML6 – Preference for working together	0.76	0.38
	FAML7 – Supplementary income	0.77	0.38
	FAML8 – No conflict among family	0.8	0.38
Safety (SAFE)	SAFE1 – Worker safety	0.88	0.45
	SAFE2 – Proper attire / clothing	0.85	0.45
	SAFE3 – PPE during pesticide application	0.84	0.45
	SAFE4 – Area inspection	0.82	0.45
	SAFE5 – Cleaning & hazard prevention	0.8	0.45
	SAFE6 – Crime prevention / monitoring	0.81	0.45
	SAFE7 – Financial security	0.85	0.45

Source: Researcher. 2025

The structural model was assessed to examine the strength and significance of the relationships between the independent constructs Safety (SAFE). Leadership (LEAD). and Family Labor (FAML) and the dependent variable. Plantation Performance. The path coefficients (β) provide insight into the relative influence of each construct within the model.

The findings indicate that all hypothesized relationships are positive and statistically meaningful. confirming that each management factor contributes to improved smallholder palm oil plantation performance.

Safety (SAFE) demonstrates the strongest effect on performance ($\beta = 0.45$). This result highlights the critical role of safety practices in plantation management. Smallholders who implement proper occupational safety measures. adhere to health standards. and actively manage risks are more likely to achieve higher productivity and operational efficiency. Effective safety management reduces accidents. minimizes work disruptions. and enhances overall sustainability.

Leadership (LEAD) is identified as the second most influential factor ($\beta = 0.42$). This finding underscores the importance of managerial capability in smallholder contexts. Strong leadership enables better planning. coordination of resources. and strategic decision-making. Smallholders with effective leadership skills are more capable of optimizing inputs. responding to challenges. and improving plantation outcomes.

Family Labor (FAML) also shows a positive relationship with performance ($\beta = 0.38$). although its impact is comparatively lower than the other variables. This suggests that while family labor remains a fundamental component of smallholder operations. its contribution alone is not sufficient to maximize performance. The effectiveness of family labor depends on how well it is supported by good leadership practices and proper safety management.

Overall. the results suggest that a balanced integration of safety. leadership. and labor management is essential for enhancing smallholder plantation performance. Among these. safety emerges as the most critical driver. indicating that investments in safety practices can yield the highest returns in terms of productivity and efficiency.

Table 6

PLS-SEM Model of Smallholder Palm Oil Management

Hypothesis	Path	Coefficient (β)	Relationship
H1	Safety (SAFE) ⟶ Performance	0.45	Strongest Positive
H2	Leadership (LEAD) ⟶ Performance	0.42	Strong Positive
H3	Family Labor (FAML) ⟶ Performance	0.38	Moderate Positive

Source: Researcher. 2025

5.4.2 Relationship between leadership. Family labor. and safety on plantation performance among smallholder palm oil

The PLS-SEM analysis revealed significant positive relationships between Leadership. Family Labor. and Safety on Plantation Performance among smallholder palm oil producers. These findings support the theoretical expectation that organizational and operational factors collectively influence performance outcomes in agricultural settings.

5.4.2.1 Leadership and plantation performance

The structural path from Leadership to Plantation Performance (β = 0.42) indicates a moderate positive influence of leadership practices on productivity. efficiency. and income sustainability. This result aligns with prior research asserting that effective leadership enhances planning. resource allocation. and decision-making in agricultural enterprises (Marzukhi et al.. 2021; Azra Nuhairi Abdul Aziz et al.. 2024). Leadership practices such as strategic planning. financial oversight. and ongoing training provide smallholders with clearer operational direction and adaptive capacity. which are crucial in managing complex plantation environments (Yusof et al.. 2023). Moreover. leadership that prioritizes farm organization and workers' welfare can inspire greater commitment and operational consistency. further boosting performance (Rahman & Mohd Nor. 2022).

5.4.2.2 Family labor and plantation performance

The positive effect of Family Labor on plantation outcomes (β = 0.38) suggests that family participation in plantation activities contributes meaningfully to overall performance. This result corroborates studies in agricultural sociology and rural development showing that family labor provides a reliable workforce. reduces dependency on hired labor. and contributes tacit knowledge passed through generations (Rasiah & Jusoh. 2021; Cheong et al.. 2023). Family labor involvement not only addresses labor shortages but also fosters a sense of ownership and coordinated effort. which can lead to enhanced productivity and sustainability (Tan & Abdullah. 2024). Agriculture scholars have noted that smallholder systems reliant on family labor often show resilience in fluctuating economic conditions due to lower labor costs and greater flexibility (Lim et al.. 2023).

5.4.2.3 Safety and plantation performance

Among the three constructs. Safety had the strongest positive influence on Plantation Performance (β = 0.45). underscoring the critical role of occupational safety and health practices in smallholder contexts. Ensuring safe working environments through appropriate protective attire. hazard inspection. and infrastructure safeguards reduces accident rates and health-related work disruptions (Rahman et al.. 2022). The high path value indicates that investments in safety elements have a direct and substantial influence on both efficiency and sustainable output. Previous studies confirm that safety practices not only protect labor productivity but also indirectly improve morale and reduce absenteeism. which are essential for consistent harvesting and quality control in plantations (Rozali et al.. 2025). The emphasis on safety aligns with international agricultural standards and policies that promote occupational health as an integral factor in performance outcomes (ILO. 2023).

5.4.3 Integrative insights

Collectively. the PLS-SEM results highlight that leadership. family labor. and safety are distinct but interconnected drivers of performance in smallholder palm oil management. Leadership provides strategic direction and governance; family labor ensures operational continuity and dedicated workforce engagement; and safety practices sustain worker health and uninterrupted operations. Together. these elements contribute to a holistic performance system consistent with integrative frameworks in agricultural management literature (Shah et al.. 2022).

The findings also suggest practical implications. Agricultural extension programs and policy initiatives should emphasize leadership development. family labor training. and comprehensive safety protocols to foster improved productivity among smallholders. Agency-led training and institutional support. such as those offered by the Malaysian Palm Oil Board (MPOB). can reinforce smallholders' capacity to adopt best practices. ultimately leading to better economic and social outcomes.

5.4.4 Limitations and future research

While the PLS-SEM model provides strong evidence for the hypothesized relationships. future research could incorporate other mediators such as access to credit. technology adoption. and market access to further explain performance variance. Longitudinal studies would also help establish causal pathways more definitively over time.

ACKNOWLEDGMENT

This research was funded by Ministry of Higher Education Malaysia through the Fundamental Research Grant Scheme (FRGS) under the Research Project Code: FRGS/1/2023/SSI03/UKM/02/3. which has made this publication possible.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

How to cite this article (APA)

Tahir, Z., Ishak, S., Noor, N. M., Zakaria, S. R. A., & Azian, F. U. M. (2026). CONDUCIVE ECOSYSTEM COMPONENTS IN THE MANAGEMENT OF SMALLHOLDER OIL PALM PLANTATIONS. *Veredas Do Direito*, 23(5), e235432. https://doi.org/10.18623/rvd.v23.5432