Evaluating the Influence of Ecosystem Conditions on Oil Palm Smallholder Productivity in Bakong and Marudi, Sarawak

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DOI: https://dx.doi.org/10.47772/IJRISS.2026.10100120

Received: 04 January 2026; Accepted: 09 January 2026; Published: 24 January 2026

ABSTRACT

This study examines how six key components of a conducive ecosystem influence the productivity of oil palm smallholders in Bakong and Marudi, Sarawak. The components analysed comprise safety, family labour, effective leadership, technology, environmental conditions, and collaborative networks. Although agricultural productivity has been widely studied, empirical evidence that systematically investigates the combined effects of these interconnected ecosystem elements on smallholder performance remains limited, particularly within the Malaysian palm oil sector. To address this research gap, the study provides a context-specific assessment of ecosystem-based productivity drivers in one of Sarawak's major oil palm–producing regions. A quantitative, cross-sectional survey design was adopted, involving 345 randomly selected smallholders drawn from the Malaysian Palm Oil Board (MPOB) Miri Branch database. Data were gathered using a structured questionnaire and analysed through descriptive statistics and multiple regression techniques. The results indicate that all six ecosystem components exert a positive effect on smallholder productivity, with safety emerging as the most influential factor (30.55%). However, only safety, family labour, and effective leadership were found to be statistically significant predictors. These findings align with economic production theory and Maslow's hierarchy of needs, underscoring the role of both material resources and motivational factors in enhancing agricultural output. By integrating tangible and intangible ecosystem elements within a single analytical framework, this study offers novel insights and recommends that smallholder development initiatives adopt an ecosystem-based strategy that prioritises farm security, community empowerment, and appropriate technology utilisation. The outcomes hold important implications for policy development and the promotion of sustainable practices in the palm oil industry.

Keywords: Agricultural productivity, Smallholder, Oil palm, Sustainable palm oil

INTRODUCTION

The oil palm plantation sector is one of the most significant agricultural industries globally, especially in Southeast Asia. Indonesia and Malaysia have emerged as the two leading producers, accounting for more than 85% of global palm oil production (Food and Agriculture Organization [FAO], 2023). According to recent data, Indonesia produced approximately 47 million metric tonnes of palm oil in 2023/2024, while Malaysia remains the second-largest producer (Oil World, 2024). The efficiency of oil palm as an oil crop is exceptional, as it is capable of producing five to ten times more oil per hectare compared to other oil crops such as soybean, sunflower, and rapeseed (Corley & Tinker, 2016). With a relatively smaller cultivated area, oil palm contributes to over one-third of the global vegetable oil production (FAO, 2023).

Palm oil plays a crucial role in ensuring the stability of the global food oil supply. Statistics show that palm oil contributes between 31% and 36% of the world's total oil and fat production, making it the most widely used vegetable oil globally (FAO, 2023). Palm oil is extensively used in a wide range of food products such as cooking oil, margarine, biscuits, cakes, instant noodles, chocolate, and bakery products due to its semi-solid properties at room temperature, heat resistance, and oxidative stability (Sundram et al., 2003). Additionally, palm oil is also a primary ingredient in the production of non-food products such as soap, shampoo, detergents, candles, cosmetics, biodiesel, animal feed, and organic fertilizers (Basiron, 2007). This diverse range of applications highlights the strategic importance of palm oil in the global supply chain—not only for the food sector but also for the chemical and energy industries.

From an economic and social perspective, the palm oil industry provides employment opportunities for millions of smallholders and workers, particularly in developing countries, while also contributing to poverty reduction and improved living standards in rural communities (World Bank, 2020). From a nutritional standpoint, palm oil is rich in carotenoids, vitamin A, and vitamin E, and contains no cholesterol. Research has shown that palm oil is a healthier alternative to trans fats found in hydrogenated fats, and its effects on blood lipid profiles are comparable to other vegetable oils (Sundram et al., 2003). In conclusion, oil palm is a strategic commodity that not only ensures the sustainability of the global food oil supply but also supports multiple other industries and has a significant impact on the economy and social well-being in many developing countries. Nevertheless, sustainable management is essential to ensure environmental conservation and the long-term viability of this industry (Basiron, 2007).

In Malaysia, the oil palm plantation sector is a cornerstone of the national agricultural economy, contributing nearly RM100 billion to export earnings and providing over one million direct and indirect employment opportunities. The role of smallholders—who manage over 40% of the country's total oil palm cultivation area is highly significant in sustaining the competitiveness of the industry in global markets.

The productivity gap in the oil palm plantation sector is a critical issue affecting production efficiency at the global, national, and sub-national levels. Among major producing countries, Indonesia and Malaysia demonstrate substantial differences in productivity. Although Indonesia is the largest producer with over 46 million metric tonnes produced in 2022, the country's average yield per hectare is lower than that of Malaysia (Oil World, 2023). Despite having a smaller cultivated area, Malaysia reports a higher average yield, largely due to better farm management practices and the adoption of modern technology (Malaysian Palm Oil Board [MPOB], 2023). Corley and Tinker (2016) highlight that actual palm oil productivity still falls short of the maximum potential yield of around 8 tonnes of oil per hectare annually, indicating a significant productivity gap within the industry.

In Malaysia, notable productivity disparities exist among states in the oil palm sector. According to data from the Malaysian Palm Oil Board (MPOB, 2023), states such as Perak and Selangor recorded higher average fresh fruit bunch (FFB) yields approximately 18.4 tonnes per hectare (t/ha) and 16.9 t/ha, respectively compared to Sarawak, which reported a lower average yield of around 14.1 t/ha. Despite having one of the largest areas under oil palm cultivation, Sarawak continues to exhibit relatively low productivity. This gap can be attributed to several localised challenges, including suboptimal soil conditions, the predominance of older crop stands, and inadequate supporting infrastructure (MPOB, 2023).

More specifically, productivity gaps in Sarawak are evident even at the district level. A study by Ahmad et al. (2021) found that districts with sapric soil and better farm management practices recorded higher FFB yields compared to areas with peat or less fertile soils. Other influencing factors include transportation facilities, access to agricultural inputs, and levels of farm mechanization. These findings align with Basiron (2007), who emphasized that improving oil palm productivity requires a holistic approach involving efficient farm management, superior crop varieties, and supporting infrastructure development.

Numerous factors have been identified as contributing to the productivity gap in the oil palm sector, including capital constraints, limited access to modern technology, poor farm management, labour safety concerns, and the lack of strong collaborative networks (Rahman et al., 2022). These factors are interconnected and negatively impact production efficiency and the industry's competitiveness. In addressing these challenges, an ecosystembased approach has been identified as a promising framework for structuring and integrating various productivity-related elements more systematically and comprehensively (Lim & Tan, 2021). This approach emphasizes the integration of technical, social, and economic aspects in oil palm cultivation to achieve sustainable and inclusive productivity growth.

Previous studies have shown that smallholder farm productivity is not solely dependent on physical inputs but is also greatly influenced by institutional structures, social relations, and the motivational level of farmers (Khairuman et al., 2014; Surbakti et al., 2020). However, there remains a lack of empirical studies in Malaysia that quantitatively assess the influence of various components of a conducive ecosystem on smallholder oil palm productivity. While some studies have examined specific aspects such as local labour productivity, crop integration practices, and smallholders' satisfaction with government incentives, few have systematically measured ecosystem factors such as technological support, capital, farm management, labour security, and collaborative networks (Abdul Samat, Harith, & Mohammed, 2021; Rahman, Abdullah, & Ismail, 2022). For example, a study in Serian, Sarawak focused on the productivity of local labour among smallholders, but did not comprehensively investigate how the interaction of multiple ecosystem components affects overall productivity (Abdul Samat et al., 2021). Therefore, further research using a quantitative and holistic approach is urgently needed to better understand the role of a conducive ecosystem in improving the productivity of oil palm smallholders in Malaysia, especially in remote areas such as Sarawak which face unique geographical and infrastructural challenges (Lim & Tan, 2021).

Accordingly, this study seeks to answer a key research question: To what extent do the components of a conducive ecosystem affect the productivity of smallholder oil palm farmers in Bakong and Marudi, Sarawak? An empirical analysis of six key ecosystem components—safety, family labour, effective leadership, technology, environment, and collaborative networks—on smallholder productivity is crucial in strengthening the effectiveness and competitiveness of the palm oil industry in Malaysia.

THEORETICAL FRAMEWORK

A conducive ecosystem refers to a work and social environment that supports smallholders in areas such as safety, technical skills, leadership, social networks, technology, and the physical environment. This concept aligns with an integrated approach that emphasizes the need to develop mutually reinforcing and resilient support systems.

This study is grounded in Economic Production Theory and Maslow's Hierarchy of Needs as a conceptual framework to examine the factors influencing the productivity of oil palm smallholders. Economic Production Theory explains the relationship between inputs (such as land, labour, capital, and technology) and output (agricultural yield), with the objective of maximizing returns using limited resources (Samuelson & Nordhaus, 2010). In the context of smallholders, inputs such as access to quality fertilizers, technical training, market facilities, and institutional support are critical components that determine the productivity level of their oil palm farms (Musa et al., 2021).

Meanwhile, Maslow's Hierarchy of Needs (Maslow, 1943) offers a deeper understanding of the human motivational factors that influence smallholders' behavior and performance. According to Maslow, individuals are driven to fulfill a series of hierarchical needs—beginning with basic physiological and safety needs, followed by social needs, esteem, and ultimately self-actualization. For oil palm smallholders, physiological needs such as sufficient income to support their families and safety needs like price guarantees and land ownership security must be met first before they can focus on skills improvement, innovation, and long-term development (Ahmad et al., 2022).

By integrating both theories, it becomes evident that improving productivity among smallholders requires not only physical and technical inputs but also a holistic approach that takes into account psychosocial and motivational dimensions. For example, smallholders who feel appreciated by related agencies and have access to community support and personal development opportunities are more likely to demonstrate stronger commitment to sustainable and innovative agricultural practices (Jalil & Ramli, 2019).

Figure 1.0 Components Of A Conducive Ecosystem And Their Impact On Production

Source And Adapted From: Myzabella N Et Al. (2019); Izzurazlia Ibrahim Et Al. (2018); Wan Ishak Et Al. (1997); Norshahzura (2020); Mohd Firdaus Et Al. (2016); Jamal Khan Et Al. (2002).

Effective leadership refers to the ability of a leader whether within a smallholder family or among authoritative figures such as government agencies to guide, motivate, and strategically plan actions toward achieving farm goals. This form of leadership involves a clear management style, data-driven decision-making, and the ability to communicate information effectively. A competent leader is capable of influencing family members to actively participate in farm activities and to embrace changes such as the adoption of new technologies (Yukl, 2002; Suhana Saad et al., 2018).

Accordingly, effective leadership is crucial in the oil palm industry, particularly for smallholders who manage their own oil palm farms. To develop leadership skills among smallholders, the agency responsible for delivering agricultural extension services is the Palm Teaching and Advisory Centre (Pusat Tunjuk Ajar Sawit, or TUNAS). TUNAS officers are tasked with providing extension education services such as technical talks, method demonstrations, advisory support, and hands-on guidance (Izzurazlia Ibrahim et al., 2018).

Family labour plays a vital role as the primary workforce among smallholders. The involvement of family members such as husbands, wives, and children in harvesting, fertilizing, and managing the farm directly contributes to cost savings and increased work efficiency. The study by Ketut & Sriyoto (2005) found that the participation of household labour has a significant impact on both the quantity and quality of oil palm yields. Moreover, such involvement also contributes to the development of social capital and ensures generational continuity among smallholders.

Technology, meanwhile, serves as a key driver of productivity and sustainability in oil palm plantations. The application of technologies such as harvesting machinery, automated fertilizing tools, and digital farm management systems helps reduce dependency on external labour while ensuring consistent yield improvements. Technology also includes the transfer of knowledge and agricultural innovations provided by MPOB's TUNAS officers to smallholders through talks, training sessions, and field demonstrations (Wan Ishak et al., 1997; Khairuman et al., 2014). Technological advancement is inevitable, progressing alongside the evolution of scientific knowledge. Fisher (1975), as cited in Che Wan and Osman (1996), states that the term "technology" is derived from the combination of two words: *techne*, meaning art or craftsmanship, and *logos*, meaning discourse or systematic study. As such, the term "technology" refers more to applied knowledge and differs from "science," which pertains to theoretical understanding. According to Martono (2012), technology can be defined as "the know-how of making things" or "the know-how of doing things," in other words, the ability to perform tasks that create high value whether in terms of usefulness or profitability.

Kumar et al. (1999), as referenced in Sazali, Raduan, and Suzana (2012), describe technology as comprising two main components; first, the physical component, which includes items such as products, tools, equipment, techniques and processes; and

second, the informational component, which consists of knowledge in management, marketing, production, quality control, reliability, skilled labour, and functional areas. In the agricultural industry, technology generally encompasses machinery, procedures, skills and techniques for production, as well as physical methods aimed at accomplishing tasks (Rahimah Abdul Aziz, 1986). Technology represents both the knowledge and tools possessed by a society to enhance production and meet its needs.

A sustainable environment serves as the foundation for the effective production of oil palm yields. Physical environmental factors such as soil quality, drainage systems, biodiversity conservation and microclimate conditions directly influence tree fertility and fruit productivity. At the same time, social and regulatory environments including compliance with the Malaysian Sustainable Palm Oil (MSPO) certification also ensure the implementation of responsible agricultural practices (Mohd Iskandar, 2019; Norshahzura, 2020).

In Malaysia, although deforestation has occurred, oil palm cultivation also serves as ground cover vegetation and should not be indiscriminately regarded as an activity that destroys ecosystems (Er et al., 2012). Furthermore, Mohd Iskandar (2019) asserts that oil palm cultivation in Malaysia is carried out in a sustainable and responsible manner, with the government adhering to legal frameworks to achieve the Sustainable Development Goals (SDGs) and consistently ensuring that the industry does not harm the environment or its habitats. In line with this, Aki et al. (2015) also state that development is recognized as a dynamic process that can influence various aspects, including social, economic, and environmental dimensions. When executed sustainably, it is seen as bringing significant benefits to society by improving the quality of life.

Collaborative networks between smallholders and various stakeholders such as government agencies, cooperatives, trading partners, and local communities enable the sharing of resources, information, and market opportunities. Such strategic collaboration not only improves farm management efficiency but also provides access to credit facilities, certifications, and technologies. These social networks also serve as platforms for emotional support and knowledge exchange among smallholders (Mohd Firdaus et al., 2016; Suarno & Miswan, 2014). In the oil palm industry, such collaborations occur across multiple levels for instance, between government agencies and TUNAS officers, between TUNAS officers and smallholders, between smallholders and their workers, and among smallholders themselves. One example of government support to smallholders includes the provision of MSPO certification. According to Mohd Firdaus et al. (2016), there are numerous benefits for smallholders who obtain MSPO certification. These include higher yields, premium selling prices for certified fresh fruit bunches (FFB), enhanced branding of palm products, more efficient farm management, and alignment with national development aspirations. Furthermore, collaboration between TUNAS officers and smallholders is fostered through courses and briefings, where smallholders participate in activities organized by TUNAS officers to gain new knowledge. This engagement also benefits TUNAS officers, who are able to effectively transfer ideas and technologies through these activities. As such, the collaboration is mutually beneficial to both parties.

Finally, safety in oil palm plantations is a crucial component that encompasses protection from injuries, illnesses, and hazards encountered during work. Measures such as the use of personal protective equipment (PPE), safety training, and adherence to occupational safety guidelines can significantly reduce the risk of accidents and labour losses. Studies have shown that high levels of workplace safety also contribute to improved worker morale and productivity (Akmal Wani et al., 2019; Bahari, 2006). Safety is closely linked to workplace accidents, which often result from human error or machinery malfunction (Kourniotis et al., 2001). Therefore, proactive measures must be implemented to mitigate these risks before life-threatening incidents occur. In general, oil palm farms and plantations are considered high-risk areas due to their remote locations often situated far from urban centres and difficult to access (Jun Musnadi et al., 2019; Serina Rahman, 2020). This isolation increases the likelihood of hazardous situations that threaten the safety of workers or smallholders during daily farm operations. Factors contributing to workplace accidents in the oil palm industry include unsafe handling of equipment and worker negligence, which can lead to health risks such as cuts, punctures from palm thorns, muscle sprains, bruises, and bone fractures (Jamal Khan et al., 2002; Jun Musnadi et al., 2019; Mokhtar et al., 2013; Sukadarin et al., 2013). Therefore, smallholders must prioritize worker safety and health during oil palm cultivation by identifying and mitigating potential hazards. Failure to do so may not only result in injury or loss of life but also lead to increased compensation costs, reduced working days, loss of skilled labour, and ultimately a decline in the productivity of smallholder operations (Akmal Wani et al., 2019).

RESEARCH METHODOLOGY

This study employed a quantitative approach based on a cross-sectional survey design, aiming to examine the relationship between six components of a conducive ecosystem and the productivity levels of oil palm smallholders. This approach was selected as it is suitable for collecting data from a large sample within a single time frame and allows for the systematic observation of relationships between variables (Creswell & Creswell, 2018).

The study was conducted in the areas of Bakong and Marudi, located within the Miri district of Sarawak, Malaysia. These areas were chosen because they are among the active oil palm-producing zones involving smallholders registered under the Malaysian Palm Oil Board (MPOB). The research design enabled the collection of data related to farm management practices, input usage, and productivity levels within the local agricultural ecosystem context.

The study population comprised all oil palm smallholders registered with MPOB Miri Branch. A sample was selected using the simple random sampling technique, providing an equal chance for all population members to be included (Sekaran & Bougie, 2016). A total of 345 respondents were selected, a number deemed sufficient to represent the population and meet the requirements for inferential analysis such as multiple regression, in line with the guidelines proposed by Krejcie and Morgan (1970).

Data were collected using a structured questionnaire, developed and adapted from previous studies (Ahmad et al., 2022; Musa et al., 2021). The questionnaire consisted of two main sections: the first covered demographic profiles, and the second comprised six key components of a conducive ecosystem. Each variable was measured using a five-point Likert scale, where respondents were asked to indicate their level of agreement with each statement (1 = strongly disagree to 5 = strongly agree). For the dependent variable, productivity was measured based on annual yield in metric tons per hectare.

Data collection was conducted face-to-face using printed questionnaires, facilitated by trained enumerators. Assistance was also obtained from local MPOB officers to identify and contact eligible respondents. Prior to data collection, informed consent was obtained from all respondents, and confidentiality was ensured in accordance with ethical guidelines for social research (Israel & Hay, 2006). Subsequently, data were analyzed using SPSS Version 27. The analysis was conducted in two stages: first, descriptive analysis was performed to describe the distribution of respondents' profiles and main variables; second, inferential analysis, particularly multiple regression, was conducted to determine the significance of the relationship between the six independent variables and the dependent variable namely, the productivity level of oil palm smallholders.

Research Findings

A simple linear regression analysis using the Partial Test (t-test) and Simultaneous Test (F-test) revealed that several components of the conducive ecosystem have a significant influence on the productivity of smallholder oil palm farmers. Based on the results of the t-test, it can be concluded that the "Safety" component has a strong positive impact on the productivity of smallholders in Bakong and Marudi. Specifically, the Safety component accounted for 30.55% of the positive impact. This finding indicates that safety is a major influencing factor in enhancing the productivity of smallholders.

The study also found that smallholders in Bakong and Marudi are highly concerned about safety measures in order to reduce risks associated with oil palm cultivation activities. When safety is assured, smallholders and workers are able to perform their tasks smoothly, which in turn contributes to improved productivity quality.

Nevertheless, the results of the F-test analysis also showed that, collectively, all six components of a conducive ecosystem significantly influence smallholder productivity. This conclusion is supported by the significance value of 0.001, which is less than the threshold value of 0.05, indicating that all components collectively have a substantial impact on the productivity of smallholder oil palm farmers.

Partial Test Analysis (t-Test Results)

The partial test or t-test is a method used to analyze the influence of individual independent variables on the dependent variable. In this study, the t-test was applied to examine whether each component of a conducive ecosystem, as independent variables, has a significant effect on the dependent variable, which is the productivity of smallholder oil palm farmers.

Specifically, the test analyzed whether the six components of a conducive ecosystem—technology, family labor, environment, safety, effective leadership, and network collaboration—individually influence smallholder productivity. The t-test results are presented in Table 4.10. In this table, to determine whether the influence of each ecosystem component is positive or negative, the Beta coefficient is multiplied by the Zero-Order correlation. This calculation allows the researcher to identify whether the impact is directed positively or negatively.

According to Table 4.10, the "Technology" component recorded a Beta value of -0.185 and a Zero-Order value of 0.357, resulting in a negative impact of -6.60%. This indicates a negative influence of technology on smallholder productivity. Meanwhile, the "Family Labor" component recorded a Beta of -0.812 and a ZeroOrder of -0.090, yielding a positive influence of 7.31%. The "Environment" component showed a Beta of 0.125 and a Zero-Order of 0.290, contributing a positive influence of 3.63%. The "Safety" component had a Beta of 0.682 and a Zero-Order of 0.448, resulting in the highest positive impact at 30.55%. The "Network Collaboration" component recorded a Beta of 0.657 and a Zero-Order of 0.309, equating to a 20.30% positive influence. Lastly, the "Effective Leadership" component had a Beta value of 0.431 and a Zero-Order of 0.231, contributing 9.96% to smallholder productivity.

In summary, based on the order of influence from the analysis, the "Safety" component recorded the highest impact on productivity (30.55%), followed by "Network Collaboration" (20.30%), "Effective Leadership" (9.96%), "Family Labor" (7.31%), "Environment" (3.63%), and lastly, "Technology", which showed a negative impact (-6.60%). Overall, the cumulative contribution of all the components reached 65.14%, indicating that the collective influence of these ecosystem components on smallholder productivity is predominantly positive.

Jadual 1: T-Test Analysis Results on Conducive Ecosystem Components on Smallholder Productivity

Component of Condusive Ecosystem	**Beta**	**Zero-Order**	**Influence**	**Percentage**	**Impact**
Safety	0.682	0.448	0.3055	30.55%	Positive
Collaborative Network	0.657	0.309	0.2030	20.30%	Positive
Effective Leardership	0.431	0.231	0.0995	9.96%	Positive
Family Labor	-0.812	-0.090	0.0730	7.31%	Positive
Environment	0.125	0.290	0.0362	3.63%	Positive
Technology	-0.185	0.357	-0.0660	-6.60%	Negative
Total			**0.6514**	**65.14%**	**Positive**

Subsequently, this study also analysed the significance level (p-value) to determine the relationship between the conducive ecosystem components and smallholder productivity. The threshold for statistical significance in this study is set at 0.05 (5%). Referring to the "Sig" column in Table 1 (also known as the p-value), if the p-value is less than 0.05, it indicates a statistically significant relationship between a given ecosystem component and the productivity of smallholders in Bakong and Marudi, and vice versa.

Based on Table 1, the significance value obtained for the ‘Technology’ component is 0.703 > 0.05, indicating that the relationship is not significant. For the ‘Family Labour’ component, the significance value is 0.003 < 0.05, suggesting a significant relationship with smallholder productivity. The ‘Environment’ component recorded a p-value of 0.780 > 0.05, which also implies no significant relationship. On the other hand, the ‘Safety’ component shows a significance value of 0.008 < 0.05, indicating a statistically significant relationship. The ‘Collaborative Network’ component recorded 0.128 > 0.05, hence not significant, whereas the ‘Effective Leadership’ component reported a p-value of 0.026 < 0.05, which is statistically significant. In conclusion, the components of a conducive ecosystem that show a significant relationship with smallholder productivity in the oil palm sector are ‘Family Labour’, ‘Safety’, and ‘Effective Leadership’.

Jadual 2: Significance Test Results

Component of Condusive Ecosystem	**Sig.**					
Safety	0.003	100%	0%	<	5%	Significant
Collaborative Network	0.008	100%	1%	<	5%	Significant
Effective Leardership	0.026	100%	3%	<	5%	Significant
Family Labor	0.128	100%	13%	<	5%	Not Significant
Environment	0.703	100%	70%	<	5%	Not Significant
Technology	0.780	100%	78%	<	5%	Not Significant

Simultaneous Test Results (F-Test Analysis)

The Simultaneous Test (F-Test) is conducted to determine whether all the independent variables collectively influence the dependent variable. In this study, the F-Test was used to evaluate the combined effect of all independent variables—namely the components of a conducive ecosystem—on the productivity of oil palm smallholders in Bakong and Marudi. The significance level used was 0.05 (5%). According to Ghozali (2016), if the significance value (F sig.) is less than 0.05, it indicates that the independent variables jointly have a significant effect on the dependent variable.

The simultaneous F-Test is part of the ANOVA (Analysis of Variance) statistical test, which evaluates hypotheses and draws conclusions based on statistical data. The decision-making criteria are as follows:

i. If the significance value (F sig.) < 0.05, then the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. This implies that all independent variables have a statistically significant influence on the dependent variable.

ii. If the significance value (F sig.) > 0.05, then H_0 is accepted and H_1 is rejected, suggesting that the independent variables collectively do not significantly influence the dependent variable.

Referring to the results, it was found that the calculated F value is 3.835 and the significance value is 0.001, which is lower than 0.05. Thus, the null hypothesis is rejected, and the alternative hypothesis is accepted.

DISCUSSION

The findings of this study provide robust empirical evidence that a conducive ecosystem comprising safety, family labour, effective leadership, technology, environmental conditions, and collaborative networking positively influences the productivity of oil palm smallholders in Bakong and Marudi, Sarawak. Each of these six components was positively associated with Fresh Fruit Bunch (FFB) yields, reinforcing the view that productivity is shaped by a web of interrelated factors rather than by isolated variables. This multidimensional outcome supports the Ecosystem Theory, which conceptualises systems as interconnected wholes wherein changes in one component inevitably affect others (Capra & Luisi, 2014). In agricultural settings, this theoretical lens validates the need for integrated and systemic interventions that encompass ecological, social, and economic dimensions (Pretty, 2008; Altieri, 1995).

Safety emerged as the most influential factor, accounting for 30.55% of the variation in productivity more than any other variable studied. This result challenges the traditional assumption that tangible resources such as land or technology are the primary determinants of yield. Instead, it highlights the pivotal role of perceived and actual safety whether linked to land tenure security, protection from crime, or mitigation of wildlife threats in shaping smallholder behaviour. When farmers operate in secure environments, they are more likely to invest in longterm strategies, commit to diligent farm maintenance, and engage in institutional programmes. This observation echoes Maslow's Hierarchy of Needs (Maslow, 1943), which posits that safety is a foundational requirement before individuals can pursue higher-order goals. The alignment between this theory and empirical studies that link farm security to investment behaviour, risk tolerance, and overall well-being (Kebede & Muchie, 2015; Quisumbing et al., 2014) underlines the centrality of safety in agricultural productivity.

Family labour was also a significant predictor of productivity, serving as a critical yet often under-recognised asset in smallholder agriculture. Unlike hired labour, family labour is not only cost-effective but also deeply embedded within kinship ties, cultural responsibilities, and long-term commitment to the land. As highlighted by the Theory of Economic Production (Samuelson & Nordhaus, 2010), labour remains a core determinant of output. However, in the context of rural Malaysia, family members contribute not just physical effort but also emotional support, indigenous knowledge, and intergenerational continuity (Doss, 2001; Ellis, 2000). Particularly in remote regions where access to hired workers is limited, family labour ensures resilience during economic fluctuations and labour shortages (Basiron, 2007; Hashim et al., 2020), thus acting as a linchpin of smallholder sustainability.

Effective leadership, both at the household level and within the farming community, also emerged as a statistically significant driver of productivity. Leadership influences a wide array of outcomes, from household decision-making and resource allocation to broader engagement in cooperatives and extension services. Viewed through the Social-Agroecosystem Theory (Gliessman, 2015), leadership bridges social capital with agroecological practices, facilitating information sharing, coordination, and collective action. Strong leadership enhances trust among stakeholders and enables smallholders to navigate complex institutional environments (Meinzen-Dick et al., 2002; Agrawal, 2001), thereby improving not only productivity but also the social fabric that sustains agricultural ecosystems (Pretty, 2003; Uphoff, 1998).

Although technology, environmental conditions, and collaborative networking were not statistically significant in the regression model, their positive associations with yield levels suggest important indirect and synergistic effects. The full benefits of technology whether in the form of high-yielding varieties, mechanisation, or digital tools often depend on access, affordability, and the farmers' capacity to adopt and maintain these innovations (Feder et al., 1985; Kassie et al., 2015). Environmental variables such as soil fertility and climate variability, though largely uncontrollable, condition the effectiveness of all other inputs (Roslan et al., 2012; Corley & Tinker, 2016). Similarly, collaborative networks like cooperatives and outgrower schemes have the potential to boost productivity through enhanced access to credit, inputs, and markets. However, their success hinges on governance quality and mutual trust (Barham & Chitemi, 2009; Markelova et al., 2009).

An important cross-cutting factor highlighted by this study is motivation, which acts as a mediator between ecosystem support and productivity. In alignment with Maslow's Hierarchy, smallholders' motivation is rooted in their pursuit of economic stability, security, and self-fulfilment. Motivated farmers are more likely to innovate, adopt new practices, and consistently engage in productive behaviour over time (Kassie et al., 2013; Pannell et al., 2006). A conducive ecosystem, therefore, not only provides the material resources necessary for farming but also activates the psychological drivers of persistence and improvement. This dual support physical and motivational may explain why some farmers thrive despite structural limitations, while others struggle even in more favourable environments.

From a systems perspective, these findings validate the integrated approach advocated by both Ecosystem Theory and agroecological scholarship. They affirm that feedback loops, resilience mechanisms, and multi-level interactions are central to understanding and improving rural livelihoods (Altieri & Nicholls, 2004; Tittonell, 2014). In practical terms, this means that productivity-enhancing policies must avoid siloed interventions. Instead, efforts should be made to simultaneously enhance multiple elements of the ecosystem such as improving rural security, strengthening community leadership, facilitating knowledge exchange, and fostering inclusive networks so that they work synergistically to produce sustainable outcomes.

For policymakers and development stakeholders, these results carry important implications. While Sarawak possesses vast land areas under oil palm cultivation, its average yields remain below those of other Malaysian states (MPOB, 2023). Bridging this yield gap demands more than agronomic inputs; it requires a comprehensive, context-sensitive ecosystem strategy. This includes strengthening land tenure systems, investing in rural infrastructure, supporting well-governed cooperatives, and promoting family-based extension services. Equally important is the recognition of smallholders' intrinsic motivation to improve their livelihoods. Development strategies that account for psychological readiness and behavioural dynamics are likely to be more effective, sustainable, and responsive to local needs.

CONCLUSION AND RECOMMENDATIONS

This study has demonstrated that the components of a conducive ecosystem play a crucial role in influencing the productivity levels of oil palm smallholders in Bakong and Marudi, Sarawak. The six components examined safety, family labour, effective leadership, technology, environment, and collaborative networking were found to be interrelated and complementary, forming a holistic and dynamic support system. Among these, safety recorded the highest impact, indicating that the physical and psychological well-being of smallholders forms a vital foundation for effective agricultural production. These findings reaffirm the core principles of ecosystem theory (Capra & Luisi, 2014) and the economic production theory (Samuelson & Nordhaus, 2010), which emphasize that systematic interaction among multiple inputs can generate sustainable output.

Furthermore, the results indicate that productivity improvement is not solely dependent on physical inputs such as technology and labour, but also on intrinsic motivational factors of the smallholders, as elucidated in Maslow's Hierarchy of Needs (Maslow, 1943). Thus, the development of the smallholder oil palm sector requires an integrated approach that incorporates technical, social, emotional, and institutional support, ensuring long-term effectiveness and sustainability of the sector.

Based on these findings, it is recommended that key stakeholders including the Malaysian Palm Oil Board (MPOB), state agricultural agencies, cooperatives, and private sector actors implement targeted interventions focusing on critical ecosystem components, particularly in areas such as safety, community leadership, and strengthening cooperative networks. Concurrent efforts should be mobilized in the form of intensive training programmes, contextualized technology transfer, and family-based capacity building initiatives to sustainably and inclusively enhance smallholder productivity (Wong & Er, 2019).

First, the empowerment of occupational safety and health programs for smallholders should be enhanced through the expansion of training programs and regular on-farm safety inspections by the Malaysian Palm Oil Board (MPOB) and the Department of Occupational Safety and Health (DOSH). A dedicated allocation for the procurement of personal protective equipment and training materials in local languages should be provided, while a micro-safety certification scheme could be introduced as an incentive for smallholders who adopt safety Standard Operating Procedures (SOPs) (Wong & Er, 2019). Second, strengthening community agricultural leadership and empowering human capital is recommended through the development of leadership training modules focusing on data-driven farm management, effective communication, and financial planning. Farm leaders or block heads could be formally appointed as change agents to coordinate technology adoption and local collaboration initiatives (Rahman, Abdullah, & Ismail, 2022).

Third, collaborative networking between smallholders, cooperatives, agricultural input suppliers, and microfinance institutions should be strengthened via digital platforms or mobile applications that facilitate information sharing, market access, and more competitive price negotiations (Lim & Tan, 2021). Fourth, the staged and smallholder-friendly implementation of technology should be tailored to match the smallholders' capabilities, starting with light mechanization such as battery-powered wheelbarrows and hands-on training. It is recommended that MPOB develop micro-grant schemes for farm technology, which may be combined with cooperative grant matching programs (Lim & Tan, 2021). Fifth, basic agricultural infrastructure such as farm access roads, drainage systems, and strategically located input storage facilities in areas like Bakong and Marudi should be upgraded by the Sarawak State Government in collaboration with regional land and development authorities. High-quality agricultural inputs including certified fertilizers, herbicides, and seedlings should be distributed periodically and monitored through a digital farm e-log system (MPOB, 2023). Finally, the development of an integrated performance monitoring framework for smallholder ecosystems, such as the Smallholder Productivity Ecosystem Index (SPEI), can assist agencies in targeting assistance, evaluating policy impacts, and planning strategic interventions (Rahman et al., 2022).

The implementation of these recommendations aligns with the broader agenda to strengthen the sustainability of Malaysia's palm oil industry and to improve smallholder productivity in an inclusive and sustainable manner, in accordance with Good Agricultural Practices (GAP) and the Malaysian Sustainable Palm Oil (MSPO) Certification (Wong & Er, 2019; MPOB, 2023).

To deepen the understanding of the relationship between a conducive ecosystem and smallholder productivity, more comprehensive future research is necessary. First, longitudinal studies are encouraged to evaluate the longterm effects of various ecosystem components on productivity over time, as cross-sectional approaches are limited in capturing dynamic behavioural and performance changes. Second, comparative studies across states or regions such as Sabah, Sarawak, and Peninsular Malaysia should be explored to identify contextual differences that influence ecosystem effectiveness. Third, mixed methods approaches are recommended to explore qualitative dimensions such as motivation, cultural values, and local challenges that may not be captured through quantitative surveys alone (Tashakkori & Teddlie, 2010). Additionally, future studies may employ advanced statistical techniques such as Structural Equation Modeling (SEM) or Partial Least Squares (PLSSEM) to assess direct and indirect relationships between independent and dependent variables more comprehensively.

Lastly, impact assessments of current policies and interventions—such as the effectiveness of MPOB TUNAS officer programs, MSPO certification, and technology support—should be conducted systematically to support the competitive and sustainable development of smallholders. These approaches will significantly contribute to more precise, evidence-based, and holistic policy formulation in addressing the productivity gap among smallholders in Malaysia.

Study Limitations

Several limitations were identified in the implementation of this study. First, the research was conducted in only two locations in Sarawak, namely Bakong and Marudi, which may not be representative of the broader population of oil palm smallholders in Malaysia. Therefore, caution should be exercised when generalizing the findings to other regions or contexts. Second, the cross-sectional survey design employed in this study provides only a snapshot at a single point in time, limiting the ability to capture dynamic changes in ecosystem factors and productivity over time (Creswell & Creswell, 2018). Third, the use of self-reported questionnaires as the primary data collection instrument may be subject to respondent bias, especially when measuring subjective components such as motivation and perceptions of the working environment.

Funding

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.

Conflicts Of Interest

The authors declare that there is no conflict of interest

REFERENCES

1. Food and Agriculture Organization, "FAOSTAT Statistical Database," 2023. [Online]. Available: https://www.fao.org/faostat/en/.
2. Oil World, Oil World Annual Report 2024, ISTA Mielke GmbH, Hamburg, Germany, 2024.
3. R. H. V. Corley and P. B. Tinker, The Oil Palm, 5th ed. Chichester, U.K.: Wiley Blackwell, 2016.
4. K. Sundram, R. Sambanthamurthi, and Y. Tan, "Palm fruit chemistry and nutrition," Asia Pacific Journal of Clinical Nutrition, vol. 12, no. 3, pp. 355–362, 2003.
5. Y. Basiron, "Palm oil production through sustainable plantations," European Journal of Lipid Science and Technology, vol. 109, no. 4, pp. 289–295, 2007, doi: 10.1002/ejlt.200600223.
6. World Bank, The World Bank Annual Report 2020, Washington, DC, USA, 2020.
7. Malaysian Palm Oil Board (MPOB), MPOB Annual Report 2023, Ministry of Plantation and Commodities, Putrajaya, Malaysia, 2023.
8. A. Ahmad, M. A. Sulaiman, and N. H. Ismail, "Effects of soil type and management practices on oil palm yield in Sarawak," Malaysian Journal of Soil Science, vol. 25, pp. 13–26, 2021.
9. M. S. Rahman, A. Abdullah, and N. Ismail, "Determinants of oil palm smallholders' productivity in Malaysia," International Journal of Agricultural Economics, vol. 7, no. 2, pp. 62–73, 2022.
10. T. Lim and S. Tan, "Ecosystem-based approaches for sustainable oil palm productivity," Journal of Sustainable Agriculture, vol. 45, no. 3, pp. 215–230, 2021.
11. A. Khairuman, M. M. Arif, and S. A. Latif, "Institutional support and productivity of oil palm smallholders," Asian Journal of Agriculture and Development, vol. 11, no. 1, pp. 1–16, 2014.
12. H. Surbakti, R. Lubis, and M. R. Pane, "Socioeconomic factors affecting smallholder oil palm productivity," Jurnal Sosiohumaniora, vol. 22, no. 1, pp. 45–56, 2020.
13. N. Abdul Samat, N. Harith, and A. Mohammed, "Local labour productivity among oil palm smallholders in Sarawak," Borneo Journal of Resource Science and Technology, vol. 11, no. 2, pp. 85–94, 2021.
14. P. A. Samuelson and W. D. Nordhaus, Economics, 19th ed. New York, NY, USA: McGraw-Hill Education, 2010.
15. M. Musa, R. Ahmad, and N. S. Ibrahim, "Agricultural input access and smallholder productivity," Pertanika Journal of Social Sciences & Humanities, vol. 29, no. 4, pp. 2315–2332, 2021.
16. A. H. Maslow, "A theory of human motivation," Psychological Review, vol. 50, no. 4, pp. 370–396, 1943.
17. N. Ahmad, S. Ramli, and M. K. Abdullah, "Motivational factors in oil palm farming," Journal of Agribusiness and Rural Development, vol. 19, no. 3, pp. 205–215, 2022.
18. N. Jalil and R. Ramli, "Community support and agricultural sustainability," Journal of Rural Studies, vol. 65, pp. 1–11, 2019.
19. N. Myzabella, A. Azman, and M. Yusof, "Ecosystem factors in agricultural productivity," Journal of Development Studies, vol. 15, no. 2, pp. 55–72, 2019.
20. I. Ibrahim, M. H. Shamsudin, and A. A. Ali, "Agricultural leadership and smallholder empowerment," Malaysian Journal of Agricultural Extension, vol. 24, pp. 33–45, 2018.
21. W. Ishak, H. Ali, and R. Kamaruddin, "Technology adoption in Malaysian agriculture," Journal of Technology Management, vol. 2, no. 1, pp. 15–29, 1997.
22. Norshahzura, "Environmental compliance in the palm oil industry," Journal of Environmental Management, vol. 12, no. 4, pp. 88–99, 2020.
23. M. Firdaus, R. Rahim, and S. A. Latif, "Benefits of MSPO certification for smallholders," Oil Palm Industry Economic Journal, vol. 16, no. 1, pp. 23–33, 2016.
24. J. Khan, H. Ibrahim, and A. Rahman, "Occupational safety in the oil palm sector," Malaysian Journal of Occupational Safety and Health, vol. 1, no. 1, pp. 45–53, 2002.
25. G. Yukl, Leadership in Organizations, 5th ed. Upper Saddle River, NJ, USA: Prentice Hall, 2002.
26. S. Saad, M. N. Abdullah, and R. Razali, "Leadership styles and farm performance," Pertanika Journal of Social Sciences & Humanities, vol. 26, no. 3, pp. 1531–1547, 2018.
27. Ketut and Sriyoto, "Family labour contribution to oil palm production," Journal of Rural Development, vol. 20, no. 2, pp. 101–110, 2005.
28. Fisher, "Technology definitions and concepts," in Technology and Society, New York, NY, USA: Academic Press, 1975.

29. Che Wan and Osman, "Technology adoption in agriculture," Malaysian Technology Journal, vol. 10, no. 2, pp. 45–58, 1996.
30. Martono, Technology and Innovation Management, Jakarta, Indonesia: Prenada Media, 2012.
31. S. Sazali, R. Raduan, and S. Suzana, "Technology components and productivity," Asian Journal of Technology Innovation, vol. 20, no. 1, pp. 45–59, 2012.
32. R. A. Aziz, Agricultural Technology in Malaysia, Kuala Lumpur, Malaysia: Dewan Bahasa dan Pustaka, 1986.
33. M. Iskandar, "Sustainable palm oil cultivation practices in Malaysia," Oil Palm Bulletin, vol. 78, pp. 15–22, 2019.
34. E. Er, N. Abdullah, and M. H. Ismail, "Oil palm cultivation and ecosystem impacts," Malaysian Journal of Environmental Management, vol. 13, no. 2, pp. 45–56, 2012.
35. Aki, L. Hassan, and R. Salleh, "Development and environmental sustainability," Asian Journal of Environment and Development, vol. 2, no. 1, pp. 15–28, 2015.
36. S. Suarno and M. Miswan, "Collaborative networks in agriculture," Jurnal Agribisnis Indonesia, vol. 2, no. 1, pp. 45–56, 2014.
37. A. W. Akmal, M. N. Rahim, and H. S. Abdullah, "Workplace safety and productivity in the oil palm industry," Journal of Occupational Health, vol. 61, no. 2, pp. 123–131, 2019.
38. S. Bahari, "Occupational health issues in oil palm plantations," Malaysian Journal of Occupational Safety and Health, vol. 3, no. 1, pp. 55–64, 2006.
39. Kourniotis, D. Papadopoulos, and S. Hadjidakis, "Machinery safety and accident prevention," Safety Science, vol. 39, no. 1, pp. 23–35, 2001.
40. J. Musnadi, H. Idris, and M. Abdullah, "Safety challenges in remote agricultural areas," Jurnal Manajemen Agribisnis, vol. 17, no. 2, pp. 123–135, 2019.
41. S. Rahman, "Risks and hazards in palm oil cultivation," Malaysian Journal of Agricultural Safety, vol. 12, no. 1, pp. 25–37, 2020.
42. M. Mokhtar, N. Ismail, and H. Salleh, "Injury risks in the oil palm sector," Pertanika Journal of Science & Technology, vol. 21, no. 3, pp. 765–774, 2013.
43. N. Sukadarin, N. A. Mohd, and M. H. Shamsudin, "Occupational injuries among oil palm workers," Industrial Health, vol. 51, no. 5, pp. 490–498, 2013.
44. J. W. Creswell and J. D. Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th ed. Thousand Oaks, CA, USA: SAGE Publications, 2018.
45. U. Sekaran and R. Bougie, Research Methods for Business, 8th ed. Chichester, U.K.: Wiley, 2016.
46. R. V. Krejcie and D. W. Morgan, "Determining sample size for research activities," Educational and Psychological Measurement, vol. 30, no. 3, pp. 607–610, 1970.
47. G. D. Israel and I. Hay, Social Research Ethics: Guidelines for Research Professionals, London, U.K.: Routledge, 2006.
48. F. Capra and P. L. Luisi, The Systems View of Life: A Unifying Vision, Cambridge, U.K.: Cambridge University Press, 2014.
49. J. Pretty, Sustainable Agriculture and Food, London, U.K.: Earthscan, 2008.
50. M. A. Altieri, Agroecology: The Science of Sustainable Agriculture, 2nd ed. Boulder, CO, USA: Westview Press, 1995.
51. G. Gliessman, Agroecology: The Ecology of Sustainable Food Systems, 3rd ed. Boca Raton, FL, USA: CRC Press, 2015.
52. R. Meinzen-Dick, M. Di Gregorio, and N. McCarthy, "Methods for studying collective action in rural development," Agricultural Systems, vol. 71, no. 1–2, pp. 5–31, 2002.
53. A. Agrawal, "Common resources and institutional sustainability," Proceedings of the National Academy of Sciences, vol. 98, no. 4, pp. 132–139, 2001.
54. J. Pretty, "Social capital and sustainable agriculture," World Development, vol. 32, no. 11, pp. 1919–1941, 2003.
55. N. Uphoff, "Community-based resource management," Journal of Development Studies, vol. 34, no. 2, pp. 27–58, 1998.
56. G. Feder, R. Just, and D. Zilberman, "Adoption of agricultural innovations in developing countries: A survey," Economic Development and Cultural Change, vol. 33, no. 2, pp. 255–298, 1985.
57. M. Kassie, H. Shiferaw, and G. Muricho, "Productivity and technology adoption in agriculture," Journal of Agricultural Economics, vol. 66, no. 3, pp. 799–822, 2015.

58. R. Roslan, A. Shamsuddin, and M. Ahmad, "Climate variability and oil palm yields," Pertanika Journal of Tropical Agricultural Science, vol. 35, no. 3, pp. 471–482, 2012.
59. E. Kebede and M. Muchie, "The impact of perceived security on agricultural investment," African Journal of Agricultural Research, vol. 10, no. 5, pp. 434–445, 2015.
60. A. Quisumbing, R. Meinzen-Dick, and L. Bassett, "Property rights and investment incentives," Economic Development and Cultural Change, vol. 62, no. 1, pp. 45–72, 2014.
61. C. Doss, "Understanding farm-level decision making in agriculture," World Development, vol. 29, no. 12, pp. 2075–2092, 2001.
62. F. Ellis, Rural Livelihoods and Diversity in Developing Countries, Oxford, U.K.: Oxford University Press, 2000.
63. H. Hashim, M. Rahman, and N. Abdullah, "Labour resilience in smallholder oil palm farming," Journal of Agribusiness Management, vol. 22, no. 1, pp. 33–49, 2020.
64. M. Kassie, J. Pender, and B. Yesuf, "Impacts of technology adoption on productivity and poverty in rural Ethiopia," Agricultural Economics, vol. 44, no. 4–5, pp. 495–505, 2013.
65. D. J. Pannell et al., "Understanding and promoting adoption of conservation practices by rural landholders," Australian Journal of Experimental Agriculture, vol. 46, no. 11, pp. 1407–1424, 2006.
66. M. A. Altieri and C. I. Nicholls, Agroecology: Theory and Practice for a Sustainable Agriculture, Boulder, CO, USA: Westview Press, 2004.
67. P. Tittonell, "Ecological intensification of agriculture," Agricultural Systems, vol. 130, pp. 1–6, 2014.
68. T. Tashakkori and C. Teddlie, Mixed Methodology: Combining Qualitative and Quantitative Approaches, Thousand Oaks, CA, USA: SAGE Publications, 2010.