JOURNAL OF TROPICAL AGRO-ENVIRONMENTAL
VOL. 1 NOMOR 1 TAHUN 2025
DOI: ----------
Hal: 11 – 17

AN ANALYSIS OF THE IMPACT OF CULTIVATION TECHNOLOGY ON THE PRODUCTIVITY OF SMALLHOLDER OIL PALM PLANTATION

Riky Junianto[1,2]

[1] *Magister Ilmu Pertanian Sekolah Pascasarjana Universitas Lancang Kuning Pekanbaru – Indonesia*
[2] *PT. Gandaerah Hendana, Pelalawan, Riau - Indonesia*

** rikyjunianto19@gmail.com*

ABSTRACT

The productivity of smallholder oil palm plantations in Indonesia remains lower than that of large-scale estates, primarily due to the limited adoption of cultivation technologies. This study aims to analyze the relationship between technological application and productivity improvements in smallholder plantations through a systematic review of ten national and international scientific articles. The technologies reviewed include the 5T fertilization method, pollination using Elaeidobius kamerunicus via the hatch & carry system, and ecologically based landscape conservation. The findings indicate that these technologies generally have a positive impact on fresh fruit bunch (FFB) weight, harvesting efficiency, and farmers' technical awareness. However, significant challenges persist in the social and institutional domains, such as lack of training, limited field assistance, and restricted access to information and capital. The study recommends that technology development strategies be integrated with participatory and adaptive approaches to support the sustainable development of smallholder oil palm plantations.

Keyword: Smallholder Oil Palm, Cultivation Technology, Productivity, Hatch and Carry, Pollinator Conservation

Manuscript received: July 16, 2025; revised: July 27, 2025; accepted: July 28, 2025; date of publication: August 21, 2025

I. INTRODUCTION

Oil palm is a leading national commodity that plays a significant role in supporting Indonesia's economy, particularly in rural areas. A large portion of the country's palm oil production does not only come from large-scale state or private plantations but also from smallholder farms managed by plasma farmers and independent smallholders. However, the productivity of smallholder oil palm plantations tends to be lower than that of company-managed estates due to several factors, including poor seed quality, limited technical knowledge, and low adoption of cultivation technologies (Utomo *et al.*, 2014; Hidayati *et al.*, 2016).In recent years, various technological innovations have been introduced to enhance the

productivity and efficiency of smallholder oil palm cultivation. These include precision fertilization techniques based on the 5T principle (right type, dosage, timing, method, and location), standard operating procedures (SOP) for harvesting, integrated weed and pest management, and pollination technologies using Elaeidobius kamerunicus insects through the hatch & carry method (Efendi & Rezki, 2020; Ikhsan *et al.*, 2020). Additionally, landscape-based ecological strategies, such as conserving small forest fragments near plantations, have been promoted to support pollinator biodiversity and stabilize ecosystem services (Power *et al.*, 2022; Zemp *et al.*, 2019).

Although these technologies have shown promising results in several empirical studies, adoption rates among smallholders remain relatively low. This reflects a persistent gap between academic research and actual field implementation, often influenced by socioeconomic constraints and limited institutional support (Ikhsan *et al.*, 2020; Hidayati *et al.*, 2016). For instance, participatory training and demonstration plots have been found effective, yet limited access to inputs and weak farmer organizations continue to hinder adoption. To address this issue, this study aims to analyze the relationship between the application of cultivation technologies and productivity outcomes in smallholder oil palm plantations by conducting a systematic review of ten selected national and international scientific articles. The review is expected to offer empirical insights into the effectiveness of these technologies and contribute to the formulation of policy recommendations and adaptive intervention models for sustainable smallholder-based oil palm development.

II. METHODOLOGY

This study employed a systematic literature review approach based on ten previously reviewed scientific articles. Five of the articles were published in accredited national journals, while the remaining five were high-impact international publications, including journals such as Biotropica and the Journal of Applied Ecology. All selected articles were published between 2014 and 2023 and had a clear focus on the application of technology in oil palm cultivation, particularly within the context of smallholder plantations. The selection criteria were based on thematic relevance to technological practices in oil palm cultivation that influence productivity. These articles presented empirical findings obtained through field experiments, community-based training programs, and ecological observations. The main focus was on technological inputs such as fertilization methods, insect-based pollination techniques, water and soil management, and biodiversity conservation strategies that support sustainable

production systems. Additionally, the selected studies were required to include measurable productivity indicators, such as fresh fruit bunch (FFB) yield, bunch weight, plant growth, or input-use efficiency.

The methodologies employed in the reviewed articles varied, including experimental approaches such as randomized block designs (RBD), factorial field experiments, participatory training models, and quantitative statistical methods such as chi-square tests, Spearman's rho, ANOVA, and Generalized Linear Mixed Models (GLMM). Several studies also utilized supporting technologies such as hatch & carry pollination boxes, automated cameras for monitoring pollinators, and soil moisture sensors, particularly in the context of peatland management. Data analysis was carried out using software such as SPSS, Super Decisions, and R. All information from the selected articles was then interpreted and analyzed qualitatively using a thematic approach. Each article was examined in depth by highlighting its research objectives, experimental design, key findings, theoretical and practical contributions, as well as its strengths and limitations. This approach provided a comprehensive understanding of how technological applications in cultivation have contributed to increasing smallholder oil palm productivity. Through this synthesis, the author aimed to construct a mapping of the relationship between the applied technologies and the outcomes achieved by farmers. The review also offered insights into the challenges faced in adopting these technologies, such as limited access to information, reliance on traditional practices, and weak institutional support in the long term.

Table 1. National Journals

No	Authors & Year	Article Title	Main Focus
1	Ariyanti *et al.* (2017)	Dissemination of Sustainable Oil Palm Cultivation Techniques	Farmer training, compost, and organic fertilizer
2	Hidayati *et al.* (2016)	Revitalization of Oil Palm Plantations in North Sumatra	ANP on fertilization and replanting
3	Utomo *et al.* (2014)	Relationship Between Cultivation Technology and Plasma Productivity	Relationship between SOP application & productivity
4	Efendi & Rezki (2020)	Hatch & Carry Technology for Pollination	Use of E. kamerunicus insects for fresh fruit bunches
5	Ikhsan *et al.* (2020)	Empowering Farmers Through 5T Technology	Precision fertilization and use of superior seedlings

Table 2. Reviewed International Journals

No	Authors & Year	Article Title	Main Focus
1	Power *et al.* (2022)	Small Forest Patches & Bee Visits	Conservation of pollinator habitats in oil palm landscapes
2	Warren-Thomas *et al.* (2022)	Peatland Restoration and Oil Palm Productivity	Effects of peatland rewetting on yields and ecosystem health
3	Zemp *et al.* (2019)	Biodiversity Enrichment in Oil Palm Landscapes	Planting tree islands to enhance biodiversity
4	Kasmiatun *et al.* (2023)	Forest Conversion and Canopy Beetles	Impact of land conversion on beetle species and biomass
5	Power *et al.* (2021)	Bee Visits on Oil Palm Landscapes	Forest proximity influences b

III. RESULT AND DISCUSSION

The analysis of ten journals indicates that the application of cultivation technology has a significant impact on improving the productivity of smallholder oil palm plantations. Commonly used technologies include the 5T fertilization method, hatch & carry pollination using Elaeidobius kamerunicus, participatory training systems, and ecological approaches such as the use of small forest fragments as natural pollinator habitats. In the smallholder context, these technologies not only enhance the volume and quality of fresh fruit bunches (FFB) but also improve farmers' skills in plantation management. For example, the study by Efendi and Rezki (2020) reported an increase in bunch weight from 12–16 kg to 17–20 kg within four months of hatch & carry application. Similar results were observed among farmers who underwent 5T fertilization training and utilized organic fertilizers although short-term productivity gains were limited, improvements in plant growth were evident.

International journals such as Power *et al.* (2022) and Warren-Thomas *et al.* (2022) emphasize the ecological dimensions of technology implementation. Small forest patches were shown to increase pollinator visits by up to 70%, supporting pollination and crop productivity near oil palm plantations. This highlights that technology is not always in the form of tools but can also involve strategic landscape management. Meanwhile, the study by Hidayati *et al.* (2016) using the Analytical Network Process (ANP) method identified fertilization, plant population, and growth uniformity as the main determinants of productivity. Cultivation technologies directly influence two of these factors, indicating that

smallholder revitalization planning must be based on technologies that are simple, effective, and aligned with farmers' capabilities.

From a social perspective, almost all national journals highlight the importance of training and extension. New technologies can only be effective when accompanied by capacity building, farmer group strengthening, and institutional support. Training models based on demonstration plots involving students and extension agents have proven effective in expanding technology adoption at the field level. However, several obstacles remain. Some studies report a low rate of SOP adoption among farmers (only 24%). This is due to limited understanding of long-term benefits, financial constraints, and the persistence of traditional practices. Therefore, technology interventions must be accompanied by empowerment strategies and sustained risk communication.Overall, the relationship between technology adoption and smallholder oil palm productivity is strong and positive, especially when technologies are adapted to local conditions and applied collaboratively.

Table 3. Summary of Ten Reviewed Articles on Technology and Smallholder Oil Palm Productivity

No	Main Technology	Impact on Productivity	Supporting Studies
1	5T Fertilization	Improved plant growth and input-use efficiency	Ikhsan *et al.* (2020), Hidayati *et al.* (2016)
2	Hatch & Carry Pollination	FFB weight increased from 12–16 kg to 17–20 kg	Efendi & Rezki (2020)
3	Compost & Organic Fertilizer	Increased knowledge, no significant yield improvement	Ariyanti *et al.* (2017)
4	Forest/Landscape Patches	Pollinator visits increased by 70%	Power *et al.* (2022), Zemp *et al.* (2019)
5	Peatland Restoration	Stable productivity, biodiversity preserved	Warren-Thomas *et al.* (2022)

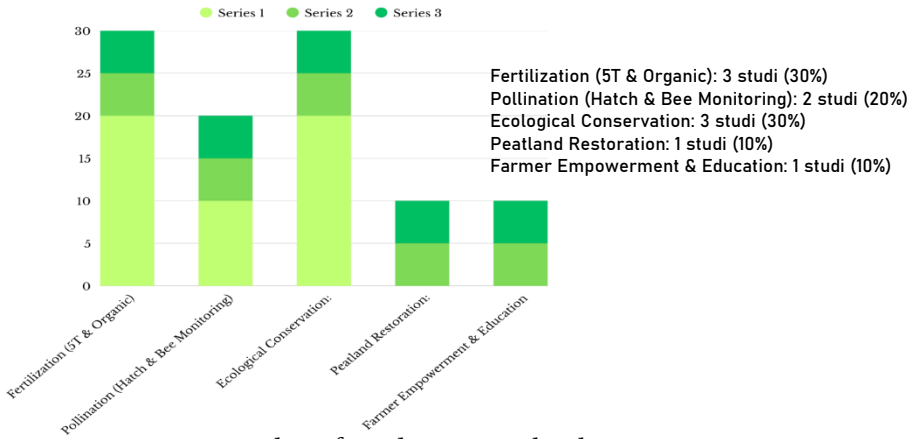

Figure 1. Number of Studies per Technology Focus

Figure 1 above shows the distribution of study focuses in a systematic literature review. Fertilization technologies (both 5T and organic) and ecological conservation dominated the number of publications analyzed, each comprising three studies. Pollination technologies such as hatch & carry and pollinator monitoring appeared in two studies, while peatland restoration and farmer empowerment were each found in only one study. This visualization confirms that agronomic and ecological approaches are the two primary focuses in research on smallholder oil palm productivity.

IV. CONCLUSION

This systematic review of ten national and international scientific articles demonstrates that the application of cultivation technologies—such as the 5T fertilization method, Elaeidobius kamerunicus–based pollination (hatch & carry), organic fertilization, and ecological landscape management—has a demonstrable positive impact on the productivity and sustainability of smallholder oil palm plantations. Beyond increasing fresh fruit bunch (FFB) yield and quality, these technologies contribute to improving farmers' agronomic knowledge and management skills. However, the review also identifies persistent structural challenges that limit the broad-based adoption of these technologies. These include limited access to inputs and training, weak farmer institutions, lack of inclusive extension systems, and policy environments that often prioritize estate-scale interventions over smallholder needs. The comparative insights from both national and international contexts suggest that the success of technological innovations depends not only on their technical soundness but also on how they are socially embedded and institutionally supported. Therefore, this review underscores the need for a policy shift from a technology-centered to a system-centered approach where technology adoption is not viewed in isolation, but as part of a broader reform agenda involving:

a. Strengthening farmer institutions and cooperatives as platforms for knowledge exchange, input procurement, and collective bargaining;
b. Expanding participatory extension models that are locally tailored and gender-inclusive;
c. Integrating ecological sustainability into national smallholder revitalization programs;
d. Improving land tenure security to incentivize long-term investments in sustainable practices;

e. Providing access to blended financing for smallholders to afford technological upgrades.

In sum, increasing smallholder oil palm productivity requires more than technological transfer; it demands coordinated reform across technical, social, institutional, and policy dimensions. Policymakers, researchers, and development actors must work collaboratively to build enabling ecosystems that foster the equitable and sustainable transformation of the smallholder oil palm sector.

REFERENCES

Ariyanti, E., Syamsu, J. A., & Hamdani, H. (2017). Sosialisasi teknik budidaya kelapa sawit berkelanjutan di Nagari Silago Kecamatan Silago Kabupaten Dharmasraya.

Efendi, R., & Rezki, Y. (2020). Aplikasi teknologi Hatch & Carry sebagai upaya peningkatan hasil produksi kelapa sawit rakyat.

Hidayati, S., Rauf, A., & Lubis, R. (2016). Analisis prioritas faktor penentu produktivitas kebun sawit rakyat berbasis teknologi.

Ikhsan, M., Ramli, Y., & Siregar, I. (2020). Pemberdayaan petani sawit melalui penerapan teknologi pemupukan 5T dan pemilihan bibit unggul.

Kasmiatun, M., Nuraini, A., & Sari, N. (2023). The effect of forest conversion on canopy beetle diversity in oil palm plantations.

Power, E. F., *et al.* (2021). Landscape drivers of bee visitation rates in oil palm plantations.

Power, E. F., *et al.* (2022). The role of small forest patches in enhancing pollination services in oil palm landscapes.

Utomo, R., Siregar, H., & Hartoyo, S. (2014). Hubungan penerapan teknologi budidaya terhadap produktivitas kebun plasma PIR-Trans kelapa sawit di Riau.

Warren-Thomas, E., *et al.* (2022). Ecological impacts of rewetting tropical peatlands for oil palm production.

Zemp, D. C., *et al.* (2019). Biodiversity enrichment in oil palm landscapes: Mitigating trade-offs between ecosystem functioning and productivity.