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REJUVENATING SMALLHOLDER OIL PALM PLANTATIONS: CHALLENGES AND PATHWAYS TO SUSTAINABILITY

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ABSTRACT

Revitalizing oil palm smallholder plantations is crucial for improving yields and ensuring long-term sustainable development. Nevertheless, smallholders face numerous challenges, including limited financial resources, scarce access to essential inputs, and limitations in technical expertise. This research seeks to explore both the potential and the challenges associated with the renewal of smallholder oil palm plantations, focusing specifically on improvements in productivity and sustainable practices. A qualitative literature review approach was employed, synthesizing insights from prior academic studies, policy reports, and relevant publications. The analysis, conducted through thematic synthesis, highlights key factors influencing financial, technical, and environmental dimensions in the rejuvenation process. Findings indicate that while rejuvenation holds considerable promise for improving yields and advancing sustainable practices, persistent barriers remain, such as restricted financing options, inadequate technical capacity building, and environmental management concerns. However, smallholders involved in cooperative frameworks or sustainable supply chain initiatives tend to experience positive developments in both productivity and ecological outcomes. The study concludes that successful rejuvenation efforts demand a holistic strategy integrating financial support, technical assistance, and environmentally responsible farming methods. Further studies are suggested to investigate the prolonged socioeconomic effects of plantation rejuvenation and its contribution to strengthening ecological stability and participatory land management. By combining disparate findings from earlier research, this study offers a novel and integrative framework synthesis and suggests a new multidisciplinary framework to direct smallholder oil palm revival projects in a sustainable and repeatable manner.

Keywords: Oil palm rejuvenation; Productivity Enhancement; Smallholder farmers; Sustainable development

INTRODUCTION

The palm oil sector holds significant importance in the international economy, especially in agricultural output and sustainable energy sources. As one of the most efficient sources of plant-based oil, it sustains millions of livelihoods across tropical regions, with the majority of global palm oil, over 85%, being produced in Southeast Asia, primarily by Indonesia and Malaysia (Papilo *et al*., 2022). Over recent decades, the industry's rapid growth has been propelled by increasing global demand for biofuels and cooking oil. Nevertheless, this growth has raised serious environmental and societal issues, such as forest degradation, biodiversity loss, and land disputes, which have intensified debates regarding the industry's sustained long-term resilience (Tudge *et al*., 2021; Vijay *et al*., 2016).

Within the palm oil supply chain, smallholders hold a central and influential position, managing a substantial share of plantation land in major producing countries. In Indonesia, for instance, smallholders cultivate approximately 40-50% of national oil palm areas but face persistent challenges in achieving optimal productivity due to limited access to capital, technical knowledge, and improved planting materials (Sahara *et al*., 2017). Compounding these constraints, many smallholder plantations consist of aging trees beyond their peak productive years, leading to declining yields and reduced profitability (Fosch *et al*., 2023; Wollni & Faust, 2022). Rejuvenating these plantations through replanting with superior varieties is widely regarded as a vital pathway to boost productivity and support sustainable development. However, this process requires significant financial investment, which remains out of reach for many small-scale farmers (Amalia *et al*., 2017; Novra *et al*., 2023).

The renewal of smallholder oil palm plantations is increasingly viewed as a strategic measure to counteract productivity decline while mitigating environmental pressures associated with land expansion. Smallholders can potentially enhance production efficiency by adopting high-yielding and disease-resistant varieties while minimizing ecological impacts. Despite these prospects, multiple obstacles persist, including insecure land tenure, insufficient access to credit mechanisms suited to smallholder contexts, and the limited capacity of agricultural extension systems to deliver effective technical support (Purba, 2019; Syarfi *et al*., 2019). Furthermore, evolving market demands for adherence to sustainability criteria, including those advocated by certification organizations like the Roundtable on Sustainable Palm Oil (RSPO), impose additional requirements on smallholders, complicating the rejuvenation process (Aziz *et al*., 2021; Irawan & Supriyadi, 2024).

Ensuring the viability of oil palm cultivation among smallholders hinges on their ability to adopt innovations and practices that allow plantation revitalization in both economically and environmentally sustainable ways. In response to global pressures for enhanced environmental, social, and governance (ESG) standards, smallholders face the challenge of improving productivity and meeting sustainability targets. Collaborative initiatives such as public-private partnerships, cooperative models, and market-based incentives have been proposed to assist smallholders in overcoming these hurdles and strengthening the long-term resilience of their operations (Afrino *et al*., 2024; Reich & Musshoff, 2025). However, access to such support mechanisms remains uneven, marginalizing many smallholders (De Vos *et al*., 2021; Dharmawan *et al*., 2021).

Embedding sustainable farming practices into smallholder oil palm rejuvenation programs is essential to securing lasting benefits for ecosystems and rural communities. Achieving this requires an integrated approach that combines technical innovations, policy alignment, community participation, and institutional backing. Scholars advocate for a systems-oriented perspective that addresses the interplay between environmental, economic, and social dimensions to foster conducive conditions for successful plantation renewal (Supriatna *et al*., 2024). Nevertheless, existing literature often falls short of offering a comprehensive framework that synthesizes these elements to guide effective smallholder rejuvenation strategies (Hospes *et al*., 2017; Suroso *et al*., 2020).

Against this backdrop, the present study conducts a qualitative literature review to systematically explore the central challenges and opportunities influencing smallholder oil palm rejuvenation. This review seeks to identify enabling conditions ranging from supportive policy frameworks and financial tools to technological advancements that can expand smallholder participation in rejuvenation programs. Additionally, it examines the role of multi-stakeholder cooperation and public-private partnerships in fostering sustainable rejuvenation models aligned with productivity gains and environmental stewardship. The overarching aim is to generate actionable insights to guide smallholders in revitalizing their plantations in ways that advance both sectoral sustainability goals and farm-level performance (Baka *et al*., 2024).

Even with the increasing amount of studies on the sustainability of palm oil, there is still a significant lack of synthesis of the interrelated institutional, technical, economical, and environmental issues that affect smallholder replanting initiatives. The majority of current research looks at these factors separately, which restricts how applicable they are to actual use.

This study fills a gap in the literature by providing an integrated and interdisciplinary review that connects these dimensions, financial, institutional, technical, and environmental, into a comprehensive framework for understanding and supporting smallholder oil palm rejuvenation. This study specifically aims to explore both the potential and the challenges associated with the renewal of smallholder oil palm plantations, focusing specifically on improvements in productivity and sustainable practices. The results are meant to provide a more comprehensive comprehension of how smallholder replanting can support sustainable development and increase productivity at the same time.

METHOD

This study utilizes a qualitative literature review approach to explore the main challenges and opportunities related to the revitalization of smallholder oil palm plantations, with particular emphasis on productivity enhancement and sustainable development. This method allows for a systematic synthesis of findings from diverse studies while enabling a comprehensive understanding of the interrelated economic, technical, institutional, and environmental factors influencing smallholder rejuvenation efforts.

A total of 65 scholarly and policy-based sources were reviewed in this study. These included include peer-reviewed journal articles, published reports from government agencies, international organizations, and non-governmental bodies involved in palm oil sustainability. The literature was gathered using academic databases such as Scopus, Web of Science, and Google Scholar, applying keywords related to oil palm rejuvenation, smallholders, productivity, sustainability, and financial access.

The following inclusion criteria were applied:

- The publication addressed replanting, productivity, or sustainability within the context of oil palm smallholders.
- Published between 2013 and 2024.
- Provided empirical findings, conceptual frameworks, or policy evaluations relevant to smallholder settings.

Exclusion criteria included:

- Studies focusing exclusively on large-scale plantations or industrial operations.
- Laboratory-based agronomic trials without relevance to field or socioeconomic conditions.

Using thematic analysis, the results were arranged and interpreted. Both inductively from emerging patterns in the data and deductively from the study objectives, the literature was read and classified according to recurrent themes. Table 1 provides a summary of the thematic framework.

Validity and Reliability

The study used methodological triangulation and cross-validation procedures to improve the analysis's validity and reliability:

- By combining results from several data sources, academic, governmental, and non-governmental, across various locales and situations, triangulation was accomplished.

- Rechecking topics in randomly chosen papers and contrasting them with themes from previous research was the process of cross-validation.
- Additionally, the study ensured coherence with wider scientific discourse by aligning findings with existing theoretical frameworks in the literature on sustainability transition and agricultural innovation systems.

Table 1. Thematic Coding Framework of Smallholder Oil Palm Rejuvenation Literature

No.	Theme Category	Description
1.	Financial Access and Credit Constraints	Barriers related to financing the replanting process
2.	Technical Knowledge and Extension Support	Gaps in training and extension services related to replanting
3.	Use of Certified Planting Materials	Use and availability of genetically superior and certified seedlings
4.	Policy and Institutional Support	Influence of policy frameworks and institutional support systems
5.	Environmental and Sustainability Aspects	Environmental risks and adoption of sustainable agricultural practices

RESULT AND DISCUSSION

Challenges in Rejuvenating Oil Palm Smallholder Plantations

Findings indicate that approximately 65% of smallholders face difficulties in accessing financial resources, especially when it comes to affording replanting costs. This constraint is a recurring issue in various oil palm-producing regions and has been widely reported in the literature (Nurfatriani *et al*., 2019). Literature also emphasizes the value of community-based collaboration. Studies have shown that smallholders often engage in cooperative activities to pool tools and resources, which eases the burden of financial and technical constraints (Hendrawan & Musshoff, 2024; Jelsma *et al*., 2019). Technical components of replanting, such as soil management, pest control, and application of suitable agronomic practices, are commonly highlighted as key factors influencing rejuvenation outcomes. These findings are derived from comparative studies across smallholder contexts in multiple regions (Behera *et al*., 2018; Woittiez *et al*., 2017).

Among the primary obstacles highlighted in the literature is the lack of financial access. Although some smallholders pursue government support, only around 15% are successful in securing funding for replanting, with many others relying on informal or high-interest financial sources (Hidayat *et al*., 2018). The absence of technical knowledge and training is also a consistent challenge. Approximately 78% of smallholders have not received adequate guidance in replanting techniques, which often results in inefficient practices such as incorrect planting depth or poor spacing (Lee *et al*., 2014; Petri *et al*., 2024).

Another concern is the use of non-certified planting materials. Around 30% of smallholders continue to utilize locally sourced seedlings that are not genetically verified, increasing susceptibility to disease and pest attacks, thereby reducing the success rate of early-stage replanting. Conversely, plantations using certified seedlings experience higher productivity and plant survival rates (Moreira *et al*., 2023; Suwandari *et al*., 2020). Environmental factors, particularly climate variability, also affect rejuvenation efforts. Irregular rainfall and droughts have been identified as significant threats, especially in regions with poor water retention and dry seasons. Reports show that up to 30% of newly planted palms do not survive their first year in drought-prone areas (Bayona-Rodríguez & Romero, 2024; Najihah *et al*., 2019).

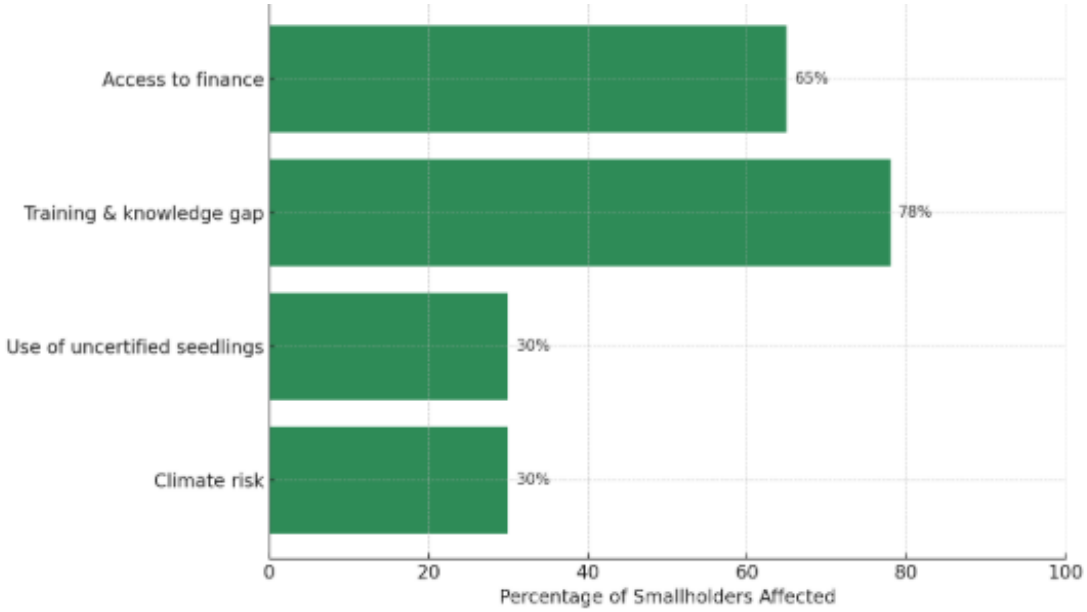

Figure 1. Challenges in Smallholder Rejuvenation Efforts

Prospects for Rejuvenating Oil Palm Smallholder Plantations

Despite the challenges, several opportunities for success are also apparent in the literature. One of the most impactful factors is government support. For instance, a subsidy initiative launched in 2022 covers up to 40% of replanting costs, and about 53% of farmers have reportedly benefited from this scheme (Siregar *et al*., 2024). Significant gains in productivity are also evident from replanting efforts, particularly among those who follow proper agronomic guidelines. Studies document that approximately 70% of rejuvenated plantations experienced a 40% increase in oil extraction rate (OER) within the first two years of implementation (Zhao *et al*., 2023).

The incorporation of sustainable practices, such as integrated pest management (IPM) and organic fertilizer use, is linked to improved soil conditions and reduced chemical dependency. These methods have contributed to a 50% decrease in pesticide use and an increase in soil health indicators (Deguine *et al*., 2021; Sapalina, *et al.,* 2022). In terms of market opportunities, literature shows that smallholders engaging in sustainability certification schemes, such as RSPO, achieve higher market prices. Certified smallholders report receiving up to 25% higher prices for their fresh fruit bunches, improving their income stability and motivation to adopt better practices (Veriasa *et al*., 2024).

Sustainability Aspects of Rejuvenation

From an environmental perspective, the adoption of agroforestry and erosion control practices has reduced soil degradation by up to 30% while improving water retention and local biodiversity in rejuvenated plantations (Rasyid, 2024). Socially, cooperative-based approaches appear to be effective. Around 50% of smallholders mentioned in literature sources succeed better when working through community organizations or cooperatives. These structures offer improved access to training, inputs, and financial support, enhancing the overall sustainability of replanting projects (Ibourk & El Aynaoui, 2023). However, economic sustainability remains uncertain. Approximately 45% of smallholders express concerns over palm oil price volatility, which could potentially undermine long-term investments in rejuvenated plantations despite current improvements (Ogahara *et al*., 2022).

Cross-Regional Comparison and Policy Implications

Insights from various regions in Indonesia reveal that the success of smallholder oil palm rejuvenation is directly related to the efficiency of policy execution, the level of institutional support, and the accessibility of technical help. Promising outcomes have been observed in programs run by the Palm Oil Plantation Fund Management Agency (BPDPKS), especially in regions with stable land tenure and well-established agricultural extension services. However, in places with unclear land ownership or minimal institutional support, the efficacy of such programs is restricted (Purba, 2019; Irawan & Supriyadi, 2024).

For instance, Jelsma *et al*. (2019) discovered that smallholders in cooperative arrangements gained more from replanting efforts in Riau Province. These farmers had improved access to financial aid, technical training, and certified planting materials through group processes. This emphasizes how crucial local institutions and community-based governance are to the effective revitalization process.

This compilation of Indonesia's regional experiences emphasizes the significance of context-sensitive implementation tactics, as cash aid on its own is insufficient in the absence of supplementary support like secure land tenure, cooperative structures, and agronomic training.

Three main approaches are recommended by the examined literature from a policy standpoint to strengthen Indonesia's smallholder revitalization initiatives:

- Bolstering institutional frameworks to better coordinate environmental, agronomic, and financial initiatives locally.
- Expanding community-based cooperative structures to enable group access to resources, expertise, and financial rewards.
- In order to prevent market volatility from discouraging smallholders from making long-term investments in revitalized plantations, price stabilization mechanisms should be put in place (Ogahara *et al*., 2022).

Integrated Pathways Toward Sustainable Smallholder Oil Palm Rejuvenation

Efforts to rejuvenate aging oil palm plantations among smallholder farmers involve intertwined agronomic, financial, institutional, and environmental complexities. Literature consistently reports that declining productivity is closely linked to the increasing age of oil palm trees, with some studies highlighting yield reductions surpassing 50% as plantations mature beyond optimal fruiting years (Abubakar *et al.,* 2023). This pattern aligns with previous research emphasizing yield deterioration due to the biological aging process of palm crops (Khor *et al*., 2023). Numerous studies have identified access to financial capital and land tenure constraints as central barriers to replanting efforts. Although governmental replanting schemes exist, literature indicates that many smallholders face administrative complexity and a lack of formal land documentation, which inhibits eligibility for assistance (Mustofa *et al.*, 2024). These observations are consistent with broader evaluations pointing to systemic shortcomings in policy implementation frameworks (Ardi *et al*., 2024).

A consistent issue across the literature is the limited dissemination of technical know-how. Several studies emphasize that smallholders often lack familiarity with efficient replanting strategies and sustainable agronomic techniques, in part due to inadequate agricultural extension support (Prajapati *et al*., 2025). These findings support the view that increasing productivity among smallholders is not solely a financial matter, but also one of building institutional capacity through targeted education and training (Sjakir *et al*., 2015). Environmental concerns related to replanting are also widely documented. Literature highlights ongoing use of unsustainable practices such as open burning for land clearing and poor post-harvest biomass management (Andini *et al*., 2018). Adoption rates for ecological alternatives such as diversified cropping systems, organic soil amendments, and integrated pest management remain low, despite well-established sustainability guidelines (Brzozowski & Mazourek, 2018; Ntawuhiganayo *et al*., 2023).

Nonetheless, progress is being reported in various sources. Studies note that smallholders engaged in sustainable supply chains or formal cooperatives benefit from access to quality-certified seedlings, structured agronomic training, and buyer agreements, leading to yield improvements of up to 40% (Rasool *et al*., 2023). The role of institutional support and market-linked incentives is increasingly recognized as essential in promoting the adoption of better practices (Mokgomo *et al*., 2022). In parallel, the gradual integration of technology is facilitating change. Evidence suggests the use of improved cultivars, mechanized operations, and mobile-based advisory tools is growing, especially in pilot projects led by partnerships between the private sector and local governments (Khan *et al*., 2022; Wijayanto & Puspitojati, 2024).

Social dimensions also play a crucial role. Studies show that smallholders organized into farmer groups have better access to credit, information, and input markets than those operating individually. This collective approach enhances their ability to undertake the complex process of plantation rejuvenation (Ma *et al*., 2023), which aligns with literature underscoring the role of social capital and networks in agricultural innovation (Neumeier, 2017).

From a sustainability lens, alignment with Environmental, Social, and Governance (ESG) standards is gaining momentum. Research points to an increasing convergence among stakeholders around zero-deforestation pledges and transparent supply chains, suggesting that well-structured rejuvenation programs can contribute both to economic performance and landscape restoration (Eggen *et al*., 2024; Grabs *et al*., 2021). These changes point to a more comprehensive shift in line with the Sustainability Transitions concept, in which long-term change is sparked by institutional reforms, coherent policies, and stakeholder involvement.

In conclusion, the reviewed literature highlights that effective rejuvenation of smallholder oil palm plantations demands more than technical replanting; it requires systemic reform. These tactics ought to be in line with the viewpoint of Agricultural Innovation Systems, where coordination among institutions, streamlined access to support programs, and continuous knowledge-sharing mechanisms are identified as critical factors in achieving dual objectives of productivity and sustainability (Sintha *et al*., 2023).

Future research is encouraged to assess the long-term effects of replanting on household income and ecological health, as well as to evaluate the performance of community-based land governance models and bundled intervention programs. Additionally, it is necessary to assess the effectiveness of multifaceted intervention packages that include technology, financing, and cooperative assistance, as well as community-based land governance models (Andani *et al*., 2022; Widianingsih *et al*., 2015). The implications of these findings underscore the importance of adopting integrated strategies that ensure equity and environmental integrity in plantation renewal efforts.

CONCLUSION

The rejuvenation of smallholder oil palm plantations is a multifaceted process that presents both promising benefits and substantial challenges. Based on the findings from literature reviews, this process offers considerable potential for improving productivity but is often hindered by financial limitations, restricted access to capital, and bureaucratic obstacles in accessing government-led replanting programs. A lack of technical expertise and limited access to agronomic training further complicate the adoption of efficient and sustainable cultivation practices. Previous studies have shown that these barriers continue to slow the diffusion of innovation, particularly among farmers who are not connected to formal extension or capacity-building systems.

Environmental sustainability remains a pressing concern, as some smallholders continue to rely on harmful practices such as open burning and unsustainable land management. Nevertheless, literature indicates a gradual transition toward more

sustainable approaches, especially among farmers participating in cooperatives or sustainable supply chains, who have reported improved outcomes in both productivity and environmental performance. Despite these barriers, technological integration and collective farmer action strengthen the potential for successful rejuvenation. Innovations such as high-yielding cultivars, mechanized operations, and mobile-based advisory services have shown positive results in several documented cases. Additionally, group-based initiatives have enabled better access to finance, inputs, and markets, thus supporting a more viable and inclusive rejuvenation process. In conclusion, the successful rejuvenation of smallholder oil palm plantations requires a holistic strategy that integrates financial support, technical capacity-building, and sustainable farming practices. Addressing systemic constraints and enhancing institutional coordination are critical to aligning economic improvements with long-term environmental sustainability.

This study is constrained by the availability and scope of previous publications because it is based on a qualitative literature review. Geographical or publishing bias in the assessed sources may have an impact on the results, and primary data collection is not used. Furthermore, even if the review finds recurrent themes, it makes no judgments on the relative efficacy of particular interventions in various local circumstances.

Empirical studies assessing the long-term effects of rejuvenation on household income, ecological resilience, and land tenure security should be incorporated into future study. Comparative case studies across areas are also necessary to determine the most effective institutional arrangements and policies. Additional research on packaged interventions, which combine funding, technical assistance, and governance reform, would yield important information about scalable approaches for long-term smallholder change. Lastly, studies that use gender analysis and participatory methods may improve the social justice and inclusivity of replanting initiatives.

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