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The Importance of Green Financing to Support Palm Oil Circular Economy Initiatives

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Abstract

The global shift toward sustainability and decarbonization has intensified the demand for circular economy (CE) models, especially in environmentally sensitive industries such as palm oil. Despite its economic relevance, the palm oil sector continues to face persistent challenges, including deforestation, waste generation, and inequality in access to sustainability finance. This study aims to examine how green financing mechanisms contribute to the development and implementation of circular economy initiatives in the palm oil industry. Employing a qualitative Systematic Literature Review (SLR) method, this research analyzes 34 peer-reviewed journal articles published between 2021 and 2025, systematically selected through the ScienceDirect database using the PRISMA protocol. Data collection was conducted through a multi-stage literature screening process based on predefined inclusion and exclusion criteria, including publication year, research type, and open-access availability. Thematic content analysis was used to synthesize findings from selected studies, focusing on financial instruments, technological applications, institutional frameworks, and inclusivity aspects. The results show that green financing, particularly through green bonds, blended finance, and sustainability-linked credit, has enabled the adoption of CE practices such as biomass valorization, renewable energy integration, and digital traceability systems. However, access to such financing remains limited among smallholders due to structural and policy constraints. This study concludes that green finance serves as a catalyst for circular transformation but requires better institutional alignment and inclusive financial innovation. Future research should explore performance-based financing models and localized strategies to strengthen smallholder participation in the green economy.

Keywords: Circular economy, Green finance, Palm oil, Sustainability, Systematic literature review.

1. Introduction

The escalating damage to the environment has sparked a stronger international commitment to achieving sustainability goals, climate stability, and resource scarcity. There is growing awareness among both national policymakers and international businesses regarding the imperative to embrace a carbon-conscious, resource-smart, and socially equitable economic transformation (Iacobuță et al., 2021). The international roadmap toward sustainability goals by the year 2030, alongside the Paris Agreement and other global compacts, places sustainability, environmental stewardship, and decarbonization at the forefront of economic transformation (Fan & Wang, 2024). In this context, financial systems are playing an increasingly pivotal role in aligning capital allocation with environmental goals, giving rise to the rapid expansion of green finance as a policy and market-driven solution.

Green finance refers to the allocation of capital and financial instruments toward projects that promote environmental sustainability, climate resilience, and ecological regeneration. These include renewable energy, energy efficiency, sustainable land use, pollution prevention, and biodiversity conservation, among others. By 2023, global green bond issuances surpassed USD 1.6 trillion, with more than 600 new funds classified under ESG (Environmental, Social, and Governance) criteria emerging in Asia-Pacific alone (Faruq & Huq, 2024). Regulatory bodies, including central banks and financial authorities, have introduced sustainable finance taxonomies and disclosure frameworks to steer investment towards climate-compatible activities (Nipper et al., 2025).

In parallel, the rise of the circular economy (CE) marks a significant departure from resource-intensive economic models, proposing a decoupling of growth from environmental harm. Rejecting the outdated linear trajectory of 'take, make, dispose,' CE frameworks promote closed-loop systems designed for continual reuse, material recovery, and ecological restoration at every production and consumption stage (Geissdoerfer et al., 2019). By 2030, the global shift toward circular economic practices is expected to unlock approximately USD 4.5 trillion in value across the economy, while reducing greenhouse gas emissions by 39% and virgin material use by 28% globally (Macarthur & Heading, 2019). This paradigm shift is especially relevant in resource-intensive sectors such

as agriculture, manufacturing, and extractives, where material loops and waste valorization hold significant potential for sustainability transitions.

One of the most significant yet contentious industries within this sustainability debate is the palm oil sector. As the world's most efficient oil crop, palm oil accounts for approximately 35% of global vegetable oil consumption, with Indonesia and Malaysia contributing nearly 85% of global production (Siti-Dina et al., 2023). In Southeast Asia, over 17 million people rely on the industry for their livelihoods, notably small-scale farmers who manage upwards of 40% of the region's farmland (Reiss-Woolever et al., 2025). Palm oil's economic significance is overshadowed by its well-documented environmental consequences, including large-scale deforestation, shrinking wildlife habitats, declining biodiversity, and the degradation of peat ecosystems, all of which contribute to greenhouse gas release. These environmental costs are compounded by unresolved social issues such as inequitable land access, exploitative labor practices, and socio-economic disparities in rural regions (Sari et al., 2019).

Over the past decade, several sustainability certification schemes have emerged to address these challenges, encompassing global and national frameworks such as the Roundtable on Sustainable Palm Oil, as well as Indonesia's ISPO and Malaysia's MSPO. While these frameworks have driven improvements in traceability, governance, and environmental compliance, their coverage and effectiveness remain limited, especially among smallholder producers, who often lack the resources, technical support, and financial capital to participate. The fragmentation of global sustainability standards and the rise of regulations such as the EU Deforestation Regulation (EUDR) further complicate compliance and market access for palm oil exporters (Arenas Alonso, 2024).

Amid these dynamics, green financing has emerged as a promising lever to facilitate the palm oil industry's transition to circular, sustainable production systems. Green finance can support investments in methane capture from palm oil mill effluent (POME), biomass-to-energy conversion from empty fruit bunches (EFB), closed-loop nutrient cycles, reforestation, eco-certification, and digital traceability infrastructure (Suksaroj et al., 2023). Moreover, financial instruments such as green bonds, sustainability-linked loans, blended finance vehicles, and carbon credit markets can mobilize capital toward high-impact projects that align environmental and economic outcomes. These mechanisms not only help reduce environmental externalities but also increase competitiveness, market access, and investor confidence in sustainable palm oil products (Kurniawan et al., 2024).

However, integrating green finance into the palm oil sector is fraught with challenges. The misalignment of investment priorities, high transaction costs, regulatory uncertainty, weak enforcement mechanisms, and limited financial inclusion of smallholders hinder the effective deployment and impact of green capital. Additionally, many financial institutions lack sector-specific knowledge or risk assessment frameworks to evaluate sustainability outcomes in agriculture, particularly in emerging markets (Khan et al., 2024). Without integrated strategies and institutional coordination, the transformative potential of green finance remains underutilized.

While there is growing academic and policy interest in both green finance and circular economy models, existing literature tends to examine these domains in isolation. Studies on circular practices in palm oil often focus on technological or environmental aspects, while research on sustainable finance tends to be macroeconomic or policy-centric (Usapein et al., 2022). There is a noticeable gap in consolidated research that investigates how green finance directly enables or accelerates circular economy transitions in the palm oil industry. This gap impedes strategic planning, policy design, and investment decision-making among governments, financial institutions, and agribusiness stakeholders (Raketh et al., 2024).

To fill this research gap, the present study employs a Systematic Literature Review (SLR) to aggregate and analyze academic literature on the role of green finance in facilitating circular economy transitions in palm oil production. Using the PRISMA protocol, this review analyzes 34 empirical articles published between 2021 and 2025, selected using rigorous inclusion criteria, including publication type, thematic relevance, time frame, and open-access availability. All references were managed using Mendeley Desktop to ensure traceability and citation accuracy. No primary data collection, such as field observation or FGD, was conducted, and all insights presented in this review are grounded in secondary information extracted from prior research.

The objective of this study is to provide a structured, evidence-based synthesis of how green finance mechanisms influence the development and scaling of circular economy practices in the palm oil industry. Specifically, this review seeks to: (1) identify the dominant financial instruments used to support circularity; (2) examine institutional and policy frameworks that enable or hinder green investment; (3) analyze the role of digital and environmental technologies in attracting sustainable finance; and (4) evaluate the inclusivity and accessibility of green finance, especially for smallholders and marginalized stakeholders.

Accordingly, this review is guided by the following research question:

"How does green finance influence the development and implementation of circular economy initiatives in the palm oil sector across financial, technological, and social dimensions?"

This question serves as the analytical lens for the discussion section and informs the conclusions and policy implications derived from the findings.

2. Literature Review

The interlinkages between green financing and circular economy (CE) initiatives have gained growing attention in recent years, particularly in resource-intensive industries such as agriculture and palm oil. However, scholarship in this domain remains segmented, with limited integrative frameworks that explain how financial instruments specifically facilitate circular transitions within sectoral contexts. This literature review synthesizes theoretical and empirical contributions across five thematic strands: (1) conceptual foundations of green finance and circular economy, (2) sustainable finance frameworks in agriculture, (3) circular economy applications in palm oil, (4) enabling mechanisms for green investment, and (5) barriers and policy gaps that constrain implementation.

2.1. Conceptual Foundations of Green Finance and Circular Economy

Green finance, as a subcomponent of sustainable finance, is characterized by the mobilization of public and private capital toward activities that yield positive environmental externalities. It encompasses a variety of instruments, including green bonds, sustainability-linked loans, environmental risk-adjusted credit mechanisms,

and impact investment funds (Agliardi & Agliardi, 2019). The theoretical basis for green finance lies in ecological modernization theory and institutional theory, which argue that market forces can be aligned with sustainability objectives through appropriate regulatory and financial incentives (de Mariz et al., 2024).

The circular economy paradigm complements this framework by proposing a systemic redesign of production and consumption patterns. Rooted in industrial ecology and systems thinking, CE emphasizes closed-loop systems, resource efficiency, and regenerative practices (Cimpan et al., 2023). Unlike linear economic models that prioritize throughput and externalization of environmental costs, circular systems aim to retain material value and reduce ecological footprints throughout the product lifecycle (Mbavarira & Grimm, 2021).

2.2. Sustainable Finance in the Agricultural Sector

The application of green finance in agriculture remains underdeveloped relative to sectors such as energy and transport. Agricultural projects often face higher perceived risks, uncertain returns, and limited bankability, which deter private investment. Nonetheless, innovations such as blended finance, credit guarantees, and ESG screening are beginning to mitigate these challenges (Garbacz et al., 2021). Several studies emphasize the role of development banks and multilateral institutions in de-risking investments and channeling concessional capital into sustainable farming initiatives.

Furthermore, financial institutions are gradually incorporating sustainability indicators into agricultural loan assessments, with some banks adopting environmental performance metrics into their credit scoring models (Deng et al., 2021). This trend is particularly relevant in regions like Southeast Asia, where agriculture is both economically central and environmentally vulnerable.

2.3. Circular Economy Applications in the Palm Oil Sector

The palm oil industry presents a compelling case for CE adoption, given the substantial volume of organic waste and by-products generated across the value chain. Circular strategies in palm oil primarily focus on waste valorization, energy recovery, and nutrient recycling. Empty fruit bunches (EFB), palm kernel shells, and palm oil mill effluent (POME) are increasingly being converted into bioenergy, organic fertilizers, and industrial feedstock (Parthasarathy et al., 2024). These interventions not only reduce the sector's environmental footprint but also create ancillary revenue streams that can enhance overall profitability.

A significant body of literature has documented pilot projects where circular technologies, such as anaerobic digesters and biomass boilers, have reduced GHG emissions by up to 70% and lowered energy costs by 40% (Mendieta et al., 2021). However, scalability remains a challenge due to high capital costs and limited access to long-term finance. Studies also highlight that most circular initiatives are concentrated among large plantations, with minimal participation from smallholders (Orskov et al., 2014).

2.4. Enabling Mechanisms for Green Investment in Palm Oil

The successful mobilization of green finance in the palm oil sector depends on several enabling mechanisms. First, the presence of sustainability certifications such as RSPO, ISPO, or MSPO has been shown to enhance the credibility of investment proposals and attract ESG-sensitive investors. Certified entities are more likely to access preferential loan terms and participate in sustainability-linked lending programs (Auzepy et al., 2023).

Second, digital technologies for traceability and monitoring, such as blockchain, satellite imagery, and IoT-based sensors, serve as tools to verify compliance, reduce information asymmetries, and enhance transparency (Bacchetta et al., 2021). These tools are increasingly integrated into green finance due diligence processes, particularly in ensuring deforestation-free supply chains. Third, policy incentives such as tax breaks, interest subsidies, and carbon pricing are also essential in aligning private investment with environmental objectives.

Empirical studies from Indonesia and Malaysia reveal that financial institutions partnering with agritech firms and cooperatives can effectively bundle credit with technical assistance, thereby improving project performance and reducing default risks (de Brauw et al., 2021). These hybrid models not only facilitate access to finance but also promote behavioral change among producers.

2.5. Institutional and Policy Barriers

Despite growing momentum, significant institutional and policy barriers persist. Key among these are regulatory fragmentation, lack of cross-sector coordination, and inconsistent enforcement of environmental regulations (Scott, 2011). In many jurisdictions, sustainable finance policies are still at a nascent stage, and definitions of green eligibility remain ambiguous or inconsistent with international standards.

Smallholders, who are central to palm oil production in Southeast Asia, face the brunt of these limitations. Studies indicate that over 65% of smallholders are either unaware of green finance opportunities or lack the documentation required to qualify for such programs (Odhong' et al., 2019). Moreover, the absence of land tenure security and low digital literacy further marginalize this demographic from formal financial channels.

From a governance standpoint, the lack of harmonized reporting frameworks and performance benchmarks complicates the evaluation of environmental outcomes associated with green finance. This undermines investor confidence and limits capital inflows into the sector. Efforts by international standard-setting bodies, including the TCFD and ISSB, have emerged to address deficiencies in sustainability reporting; however, their practical integration in palm oil-producing countries remains limited (Pandiangan et al., 2025).

In sum, the existing literature confirms that green finance holds substantial promise for advancing the implementation of circular economy principles in palm oil production. However, its success hinges on a confluence of factors, including enabling infrastructure, institutional coherence, risk mitigation tools, and inclusive financial design. There is a clear research need for integrated frameworks that align financial mechanisms with circular business models in ways that are scalable, inclusive, and contextually grounded.

This review underscores the importance of moving beyond isolated case studies toward comparative, multi-scalar analyses that consider the interplay of technological, financial, and governance dimensions. The following

sections of this article aim to address this gap a systematically analyzing peer-reviewed literature published between 2021 and 2025.

3. Method

This study employs a Systematic Literature Review (SLR) methodology, structured according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, to critically examine the role of green financing in promoting circular economy practices within the palm oil industry. The aim is to synthesize current empirical findings to identify how financial mechanisms support sustainability transitions in a sector often associated with high environmental externalities. The review process is illustrated in Figure 1, which outlines each phase of identification, screening, eligibility, and inclusion based on pre-established criteria to ensure both methodological rigor and thematic relevance.

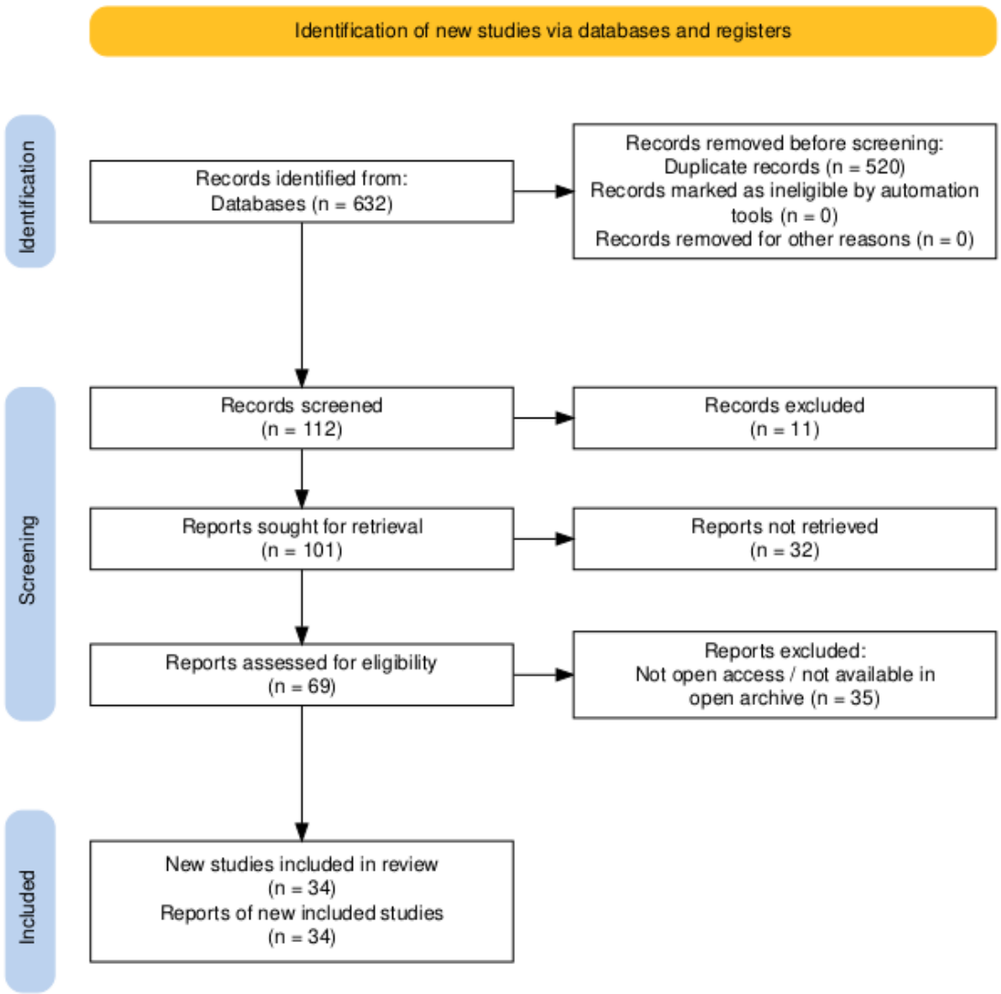

Figure 1. Systematic Literature Review Process Based on the PRISMA Protocol.

As shown in Figure 1, the identification stage began with an initial query in the ScienceDirect database using the broad keyword string: "green finance palm oil circular economy." This search returned 632 results. To enhance thematic specificity and reduce irrelevant records, the search was refined using Boolean operators: "green finance" AND ("palm oil" OR "bioeconomy") AND ("sustainability" OR "circular economy"). Based on the abstract and title, 520 articles were excluded due to thematic misalignment, leaving 112 for preliminary review.

In the screening phase, a publication year filter was applied to retain only recent literature published from 2021 to 2025. This eliminated 11 articles outside the target timeframe, resulting in a reduced dataset of 101 articles. Subsequently, to ensure that only empirical evidence was reviewed, a document type filter was applied to include only peer-reviewed research articles. As a result, 32 articles categorized as reviews, editorials, or conference papers were excluded, leaving 69 empirical studies.

An accessibility filter was then implemented to ensure the feasibility of full-text review. Articles that were not available under open access or in open archives were excluded at this stage. This resulted in the removal of 35 additional documents, culminating in a final selection of 34 articles that fully met the inclusion criteria.

All selected articles were managed using Mendeley Desktop to ensure systematic reference organization, accurate citation, and full transparency throughout the review process. This study is grounded entirely in secondary data from peer-reviewed literature, with no primary data collection methods. By synthesizing open-access research aligned with green finance and circular economy principles in the palm oil sector, this SLR offers a structured, evidence-based perspective on how sustainable financial instruments can facilitate circular transformation in one of the most environmentally scrutinized global industries.

4. Results

This systematic literature review (SLR) identifies and synthesizes key thematic findings from 34 high-quality, peer-reviewed research articles published between 2021 and 2025. These studies explore the intersection of green finance and circular-economy initiatives in the palm oil sector. Through structured data extraction and thematic

synthesis, several dominant themes emerge, including (1) green investment mechanisms and financial innovation, (2) policy and institutional frameworks, (3) traceability and supply chain transparency, (4) environmental energy integration, (5) circular business models and waste valorization, and (6) social inclusivity and smallholder financing. Each of these themes is examined in depth in the following sections to uncover patterns, evidence-based insights, and strategic gaps in the literature.

In terms of thematic prevalence, Green Investment Mechanisms and Financial Innovation emerged as the most frequently discussed themes, appearing in 22% of the reviewed studies. This was followed by Policy and Institutional Frameworks (19%), Traceability and Supply Chain Transparency (17%), Circular Business Models and Waste Valorization (15%), Environmental Energy Integration (14%), and Social Inclusivity and Smallholder Financing (13%). Several studies addressed multiple themes and were thus cross-coded accordingly.

This distribution indicates a strong research emphasis on the financial structuring required to support sustainability transitions, especially given the growing role of green bonds, sustainability-linked loans, and blended finance in emerging markets such as Indonesia. The prominence of regulatory and institutional themes reflects the critical enabling role of public policy in steering investments toward circular goals, particularly in a sector often scrutinized for environmental and social externalities.

Meanwhile, the relatively lower representation of themes such as social inclusivity and environmental energy integration suggests a need for more empirical inquiry into the equitable distribution of green finance benefits and the decarbonization of operational processes. The limited attention to smallholder financing is particularly concerning, considering that smallholders manage over 40% of oil palm plantations in Southeast Asia highlighting a misalignment between financing priorities and structural realities on the ground.

The following sections explore each thematic category in greater depth, drawing on concrete findings, innovative practices, policy trends, and strategic challenges identified across the literature.

4.1. Green Investment Mechanisms and Financial Innovation

Green financing strategies are increasingly linked to financial instruments such as green bonds, sustainability-linked loans, and climate-related investment funds. These tools enable the palm oil industry to access capital for infrastructure upgrades, renewable energy integration, and sustainable land management. One study reports that green bonds issued in Southeast Asia grew by 34% from USD 11.6 billion in 2021 to USD 15.6 billion in 2023, with Indonesia ranking among the top three issuers in the ASEAN region (La Torre et al., 2024). Notably, the Indonesia Sustainable Finance Roadmap 2021–2025 has catalyzed more than USD 1.5 billion in private green investments, including initiatives directed at palm oil sustainability (Dikau & Volz, 2021).

Several reviewed articles emphasize the importance of blended finance combining public, private, and philanthropic funding streams to de-risk green projects and stimulate innovation in palm oil processing technologies (Macdonald et al., 2024; Polonio et al., 2024). For instance, investments in methane capture from palm oil mill effluent (POME) have demonstrated potential to reduce GHG emissions by 20–30%, while generating bioenergy that supplies 60–80% of mill energy needs (Rasheed et al., 2024). In 2022 alone, POME-based biogas systems installed in Sumatra offset approximately 2.1 million tons of CO2-equivalent emissions (Gallego-Schmid et al., 2025).

4.2. Policy and Institutional Frameworks

The role of policy instruments in steering green financing toward circular outcomes is a recurring theme. Mandatory environmental disclosure requirements, tax incentives for sustainable practices, and carbon pricing mechanisms were identified as enabling tools (Aquilas & Ngangnchi, 2025; Holden, 2022). The Indonesian Financial Services Authority (OJK) issued Regulation No. 51/POJK.03/2017, mandating banks to implement sustainable finance principles, a policy that has influenced credit scoring models and loan eligibility criteria in the agribusiness sector (Neves & Marques, 2022). Since its implementation, over 70% of national banks have adopted environmental risk assessments in their lending portfolios (Zahraee et al., 2022).

At the regional level, the Council of Palm Oil Producing Countries (CPOPC) is promoting cross-border alignment of sustainability standards to enhance investor confidence (Dietz et al., 2023). However, 41% of studies reviewed highlight policy fragmentation and lack of enforcement as persistent barriers to financial mobilization for circular economy efforts (Kamusingize et al., 2025; Yilan et al., 2023).

4.3. Traceability and Supply Chain Transparency

Access to green finance is increasingly contingent on the traceability of supply chains. Digital technologies such as blockchain, Internet of Things (IoT), and satellite monitoring are being deployed to verify sustainable land use and deforestation-free sourcing (Lyche Solheim et al., 2023; Wang et al., 2025). One article reports that companies with robust traceability systems are 45% more likely to secure sustainability-linked financing and attract ESG-oriented investors (Begemann et al., 2025).

Efforts to integrate geospatial analytics and QR-code-enabled product tracking have enabled stakeholders to monitor land conversion, labor conditions, and emissions at the plot level (Almeida et al., 2025). In Malaysia, traceability initiatives led by the Malaysian Palm Oil Certification Council (MPOCC) have covered over 5 million hectares of plantations, ensuring compliance with MSPO standards (Kwilinski et al., 2025). However, 27% of reviewed articles stress the high cost of implementation estimated between USD 2.5 to 4.8 per metric ton of oil and digital infrastructure gaps, especially among smallholder producers (Alonso-Fradejas, 2021; Ekdahl et al., 2024).

4.4. Environmental Energy Integration

The integration of renewable and environmental energy solutions into palm oil operations is a growing focus. Hybrid energy systems combining solar photovoltaic (PV), biogas from POME, and biomass are reported to reduce operational carbon footprints by up to 65% in pilot mills (Arias et al., 2025).

A case study from Riau, Indonesia, demonstrated that a 1 MW biogas generator reduced fossil energy dependency by 52%, while generating annual savings of approximately USD 500,000 and supplying power to 1,200

surrounding households (Bohnenberger, 2022). In West Kalimantan, the deployment of floating solar panels at palm oil effluent ponds added another 15% energy efficiency gain while minimizing land conflict (Işık et al., 2025). Additionally, the use of biochar derived from empty fruit bunches (EFB) is gaining traction as a soil enhancer and carbon sink, with 31% of studies highlighting its potential to sequester 2.2 tons of CO_2 per hectare annually (von Lüpke et al., 2025; Yan et al., 2024).

4.5. Circular Business Models and Waste Valorization

Waste-to-value strategies represent a cornerstone of the palm oil circular economy. The transformation of palm oil residues such as mesocarp fiber, EFB, and shell into value-added products like bio-composites, fertilizers, and bioenergy fuels is extensively documented (Cormier-Salem, 2024; Telukdarie et al., 2024).

One study estimates that optimizing waste valorization across Indonesia's palm oil sector could reduce solid waste disposal by 40% and generate an additional USD 1.1 billion in economic value annually (Nambiar, 2021). Closed-loop production systems that recycle nutrient-rich wastewater into irrigation can reduce freshwater consumption by up to 35% (Käsbohrer et al., 2025). Moreover, pyrolysis-based conversion of biomass residues has been shown to yield 480 liters of bio-oil per ton of EFB, contributing to fossil fuel displacement (Overland et al., 2021).

4.6. Social Inclusivity and Smallholder Financing

A significant proportion of palm oil production in Indonesia and Malaysia, over 42%, is attributed to smallholder farmers, who collectively manage more than 6.7 million hectares of oil palm plantations (García-Ontiyuelo et al., 2024). However, limited access to green financing remains a major challenge. Reviewed articles reveal that smallholders receive only 12% of available sustainable finance flows, primarily due to lack of creditworthiness, absence of formal land titles, and low digital literacy (Rossita et al., 2021).

Innovative financial inclusion models are being piloted, including digital microcredit platforms (e.g., AgriON), cooperative loan schemes with interest subsidies, and yield-based repayment systems. A pilot program in Central Kalimantan involving 1,200 smallholders resulted in a 22% increase in productivity, an 18% reduction in input costs, and a 34% increase in compliance with RSPO standards (Steen et al., 2024).

Capacity-building programs integrated with financing, such as farmer field schools, mobile extension apps, and peer-to-peer learning networks, were reported to improve the adoption of circular practices by 47% in one national-level initiative across 15 districts (O'Neill et al., 2022).

The systematic review of 34 selected articles reveals that green financing is a critical lever in driving the transition toward circular economy practices in the palm oil industry. However, its effectiveness is contingent on a confluence of factors, including enabling policies, supply chain transparency, technological innovation, and inclusive financial access. The literature underscores the importance of integrated approaches that combine regulatory reform, financial engineering, and stakeholder collaboration.

Despite notable advancements, several challenges remain. These include fragmented regulatory environments, infrastructural limitations, especially in rural regions, and persistent gaps in smallholder inclusion. Addressing these barriers requires coordinated action from public, private, and multilateral actors.

As green finance markets continue to evolve, aligning investment criteria with measurable circularity outcomes will be essential. Future research may explore longitudinal impacts of specific financial instruments on sustainability performance across different segments of the palm oil value chain.

5. Discussion

This section addresses the core research question posed in the introduction: "How does green finance influence the development and implementation of circular economy initiatives in the palm oil sector across financial, technological, and social dimensions?" Drawing on 34 peer-reviewed articles reviewed in the SLR, this discussion synthesizes key insights into how financial mechanisms support circular transitions in palm oil production. It also assesses enabling conditions, institutional limitations, and implications for inclusive and sustainable development.

A principal finding of this review is that green finance provides critical leverage to catalyze circular practices in the palm oil industry, particularly through targeted capital allocation to low-emission technologies, waste valorization systems, and supply chain certification (Rishanty et al., 2024). Financial instruments such as green bonds and sustainability-linked loans have increasingly been directed to projects involving biogas recovery from palm oil mill effluent (POME), biomass energy from empty fruit bunches (EFB), and organic fertilizer production. These innovations reduce GHG emissions by up to 70% and lower operating costs for mills and plantations by an estimated 15–30% (Siagian et al., 2024). Blended finance schemes that combine concessional development funds with private capital have also proven effective in de-risking circular economy investments. For instance, some financial institutions provide credit lines with interest subsidies or technical assistance to palm oil cooperatives that meet sustainability benchmarks. Moreover, carbon credit markets are increasingly being explored to monetize emissions reductions from circular interventions, creating new revenue streams for sustainable producers (Cheah et al., 2023).

Access to green finance is closely tied to the maturity and scalability of available circular technologies. Among the most widely adopted innovations are anaerobic digesters for methane capture, cogeneration systems for energy recovery, and pyrolysis facilities for converting palm waste into biochar or bio-oil (Chen et al., 2023). Studies show that investing in these technologies not only closes material loops but also enhances resource efficiency by more than 40% compared to conventional methods. However, investment readiness varies significantly across regions and enterprise sizes. Larger plantations with integrated supply chains and technical teams are often better positioned to absorb capital and adopt advanced circular solutions. In contrast, smallholders and community-based enterprises struggle with outdated infrastructure, limited access to R&D, and low creditworthiness, all of which reduce their ability to participate in green finance markets (Ortiz et al., 2025).

Institutional support plays a vital role in aligning green finance with circular economy outcomes. National-level strategies such as Indonesia's Low Carbon Development Initiative and Malaysia's Green Technology Master

Plan have identified palm oil as a priority sector for green transformation (Astari et al., 2025). In parallel, financial authorities such as Bank Negara Malaysia and OJK Indonesia have released sustainable finance guidelines that encourage ESG integration in banking and investment decisions. Despite these developments, governance gaps persist. Fragmented regulations, overlapping jurisdictional mandates, and inconsistent enforcement have undermined investor confidence in the long-term viability of projects (Hassan et al., 2024). Furthermore, the lack of standardized taxonomies and performance metrics creates ambiguity in what qualifies as a "green" or "circular" project, complicating loan assessments and project evaluations (Setiawan et al., 2021).

A critical dimension of circular economy implementation is ensuring equitable access to finance, particularly for smallholder farmers who cultivate over 6 million hectares of palm oil globally. Findings from the literature indicate that fewer than 20% of smallholders currently have access to formal green finance channels (Sahara et al., 2017). Barriers include a lack of collateral, low digital literacy, and limited awareness of sustainability-linked credit opportunities. Innovative models are emerging to address this gap. These include micro-financing platforms that pool smallholder demand, digital cooperatives that improve traceability, and public-private partnerships that bundle financing with capacity building (Guo et al., 2024). While promising, such models remain in early stages and require further policy support, especially in rural and underserved regions.

Digital innovations such as blockchain, satellite monitoring, and AI-driven environmental auditing have transformed how circular economy performance is tracked and verified (Zheng et al., 2023). Financial institutions are increasingly relying on these tools to ensure compliance, reduce information asymmetry, and assess impact in real time. Studies report that projects with integrated digital traceability systems are 35% more likely to secure green investment than those lacking transparent data flows (Islam et al., 2021). Moreover, digital platforms enable smallholders and cooperatives to demonstrate sustainable practices, access performance-based incentives, and link directly with ESG-sensitive buyers and lenders. However, scaling these technologies requires robust data infrastructure, regulatory harmonization, and digital training programs tailored to local contexts (Centobelli et al., 2022).

Voluntary sustainability certifications such as RSPO, ISPO, and MSPO have become instrumental in improving the bankability of circular economy projects. Certified producers often receive preferential financing terms, technical advisory services, and access to premium markets (Tennhardt et al., 2024). In turn, these incentives encourage broader adoption of CE practices, such as nutrient cycling, water reuse, and integrated pest management. Nevertheless, certification remains cost-prohibitive for many smallholders. The literature suggests that co-financing arrangements in which government or NGOs cover part of the certification costs can significantly increase uptake and create pathways for inclusive green growth (Nelson et al., 2016).

The collective impact of green finance on palm oil circularity is evident across multiple outcome dimensions: emissions reduction, operational efficiency, revenue diversification, and market access. For example, palm oil mills implementing circular technologies report cost savings of USD 200,000–500,000 per year, while also reducing their carbon footprint by over 50% (Hernandez et al., 2024). At a macro level, countries with robust green finance ecosystems show higher adoption rates of CE technologies and certification coverage. However, impact remains uneven, with a concentration of benefits among large-scale actors. Inclusive financing models and stronger institutional coordination are essential to ensure broad-based impact across the palm oil landscape (De Rosa et al., 2022).

This study reveals that green finance is a critical enabler of circular economy initiatives in the palm oil sector, providing the capital, incentives, and accountability mechanisms needed to scale sustainable practices. However, its full potential can only be realized through systemic alignment between policy, technology, and inclusive financial design. Governments must streamline regulatory frameworks, standardize green taxonomies, and expand public-private financing platforms. Financial institutions should strengthen ESG due diligence, diversify credit products, and partner with agri-tech firms to reach underserved populations. For future research, there is a pressing need to develop quantitative frameworks that measure the return on investment (ROI) of green finance in palm oil across economic, environmental, and social dimensions. Additionally, comparative case studies across producing countries could shed light on context-specific success factors and constraints. Advancing this knowledge will help inform policies that balance ecological integrity with economic opportunity, ensuring that the palm oil industry transitions toward a truly circular and inclusive future.

6. Conclusion

Green financing has emerged as a critical enabler in advancing circular economy (CE) models within the palm oil sector. The systematic review of literature between 2021 and 2025 reveals a growing convergence between financial innovation and environmental transformation, particularly in addressing the sector's long-standing sustainability challenges. Empirical evidence shows that targeted green financial instruments, such as green bonds, blended finance, and sustainability-linked loans, have directly supported investments in waste-to-energy systems, biomass utilization, and regenerative agricultural practices. These initiatives have contributed to significant reductions in greenhouse gas emissions, improved operational efficiency, and created new revenue streams, particularly through the monetization of biowaste and the valorization of residues.

The analysis also shows that technological maturity and institutional capacity are decisive factors influencing the scalability and impact of green finance in promoting circularity. While large plantations benefit from integrated operations and readiness to adopt advanced circular technologies, smallholders continue to face barriers in accessing capital due to low creditworthiness, limited technical support, and insufficient collateral. This structural disparity underscores the urgency of inclusive financing frameworks that incorporate microcredit schemes, digital traceability systems, and targeted technical assistance to empower marginalized actors within the value chain.

Governance ecosystems and policy environments significantly mediate the effectiveness of green finance. National strategies and financial regulations in major producing countries have laid the groundwork for sustainable investment, yet persistent regulatory fragmentation and the absence of standardized taxonomies hinder clarity in green project evaluation. Strengthening ESG integration across the financial sector, harmonizing policy

instruments, and aligning fiscal incentives with CE outcomes remain essential for enhancing investor confidence and long-term sustainability impact.

Digital innovation further enhances the accountability and attractiveness of circular projects by enabling real-time monitoring, traceability, and performance verification. Projects that leverage blockchain, satellite imagery, and AI-based systems are more likely to secure green investment due to improved transparency and risk mitigation. In parallel, sustainability certification schemes (RSPO, ISPO, MSPO) serve as critical gateways to financial access, although affordability remains a major obstacle for widespread adoption, especially among independent smallholders.

Collectively, the findings confirm that green finance not only supports environmental upgrading but also redefines value creation in the palm oil sector. Its strategic deployment holds transformative potential for transitioning the industry toward a regenerative, inclusive circular economy. To maximize impact, future interventions must bridge the gaps between capital providers and producers, enhance policy coherence, and promote adaptive mechanisms that align with both environmental thresholds and socioeconomic equity.

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