TOWARD A TRIPLE BOTTOM LINE: A REVIEW OF SUSTAINABILITY PRACTICES IN THE PALM OIL SUPPLY CHAIN

RUMO AO TRIPÉ DA SUSTENTABILIDADE: UMA REVISÃO DAS PRÁTICAS DE SUSTENTABILIDADE NA CADEIA DE SUPRIMENTOS DO ÓLEO DE PALMA

HACIA EL TRIPLE RESULTADO: UNA REVISIÓN DE LAS PRÁCTICAS DE SOSTENIBILIDAD EN LA CADENA DE SUMINISTRO DEL ACEITE DE PALMA

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ABSTRACT

Facing mounting international demands, the palm oil industry is compelled to pursue sustainability efforts that equitably address economic viability, environmental stewardship, and societal impact. The study examines how the economic, environmental, and social pillars of the Triple Bottom Line (TBL) framework are reflected across the entire palm oil value chain. The research adopts a qualitative approach using a Systematic Literature Review (SLR), guided by the PRISMA protocol. Data were collected from the ScienceDirect database using targeted keyword combinations. An initial search yielded 825 results, refined to 31 eligible peer-reviewed, open-access research articles published between 2021 and 2025. The review followed a four-stage screening: keyword relevance, publication year, article type (research articles only), and accessibility (open access/archive). Data were analysed thematically to extract patterns, gaps, and interconnections between sustainability practices and TBL principles. The findings indicate significant progress in the economic and environmental areas, including increased yield efficiency, reduced emissions, and improved traceability enabled by digital tools. However, social aspects such as labour conditions, gender equity, and smallholder inclusion remain insufficiently addressed. In conclusion, while sustainability efforts have intensified, a more integrated and inclusive approach is required, particularly for marginalised stakeholders. Future research should investigate the long-term outcomes of certification schemes, the role of local governance in implementing TBL, and the potential of emerging technologies to bridge existing sustainability gaps.

Keywords: Triple Bottom Line. Sustainable Palm Oil. Supply Chain. Social Inclusion. Systematic Literature Review.

RESUMO

Diante das crescentes exigências internacionais, a indústria do óleo de palma é compelida a adotar esforços de sustentabilidade que abordem de forma equitativa a viabilidade econômica, a responsabilidade ambiental e o impacto social. Este estudo examina como os pilares econômico, ambiental e social do modelo Triple Bottom Line (TBL) se refletem ao longo de toda a cadeia de valor do óleo de palma. A pesquisa adota uma abordagem

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qualitativa por meio de uma Revisão Sistemática da Literatura (RSL), orientada pelo protocolo PRISMA. Os dados foram coletados na base ScienceDirect utilizando combinações direcionadas de palavras-chave. A busca inicial resultou em 825 estudos, posteriormente refinados para 31 artigos científicos revisados por pares, de acesso aberto, publicados entre 2021 e 2025. A revisão seguiu um processo de triagem em quatro etapas: relevância das palavras-chave, ano de publicação, tipo de artigo (apenas artigos de pesquisa) e acessibilidade (acesso aberto/arquivo). Os dados foram analisados por meio de análise temática para extrair padrões, lacunas e interconexões entre práticas de sustentabilidade e os princípios do TBL. Os resultados indicam avanços significativos nas dimensões econômica e ambiental, incluindo aumento da eficiência produtiva, redução de emissões e melhoria da rastreabilidade viabilizada por ferramentas digitais. No entanto, aspectos sociais como condições de trabalho, equidade de gênero e inclusão de pequenos produtores ainda permanecem insuficientemente abordados. Conclui-se que, embora os esforços de sustentabilidade tenham se intensificado, é necessária uma abordagem mais integrada e inclusiva, especialmente para os atores marginalizados. Pesquisas futuras devem investigar os resultados de longo prazo dos esquemas de certificação, o papel da governança local na implementação do TBL e o potencial das tecnologias emergentes para reduzir as lacunas existentes em sustentabilidade.

Palavras-chave: Triple Bottom Line. Óleo de Palma Sustentável. Cadeia de Suprimentos. Inclusão Social. Revisão Sistemática da Literatura.

RESUMEN

Ante las crecientes exigencias internacionales, la industria del aceite de palma se ve obligada a impulsar esfuerzos de sostenibilidad que aborden de manera equitativa la viabilidad económica, la gestión ambiental y el impacto social. Este estudio examina cómo los pilares económico, ambiental y social del enfoque Triple Bottom Line (TBL) se reflejan a lo largo de toda la cadena de valor del aceite de palma. La investigación adopta un enfoque cualitativo mediante una Revisión Sistemática de la Literatura (RSL), guiada por el protocolo PRISMA. Los datos se recopilaron a partir de la base ScienceDirect utilizando combinaciones específicas de palabras clave. La búsqueda inicial arrojó 825 resultados, que se refinaron hasta seleccionar 31 artículos científicos revisados por pares, de acceso abierto, publicados entre 2021 y 2025. La revisión siguió un proceso de cribado en cuatro etapas: relevancia de las palabras clave, año de publicación, tipo de artículo (solo artículos de investigación) y accesibilidad (acceso abierto/archivo). Los datos se analizaron mediante análisis temático para identificar patrones, vacíos e interconexiones entre las prácticas de sostenibilidad y los principios del TBL. Los resultados evidencian avances significativos en las dimensiones económica y ambiental, incluidos el aumento de la eficiencia productiva, la reducción de emisiones y la mejora de la trazabilidad mediante herramientas digitales. Sin embargo, los aspectos sociales, como las condiciones laborales, la equidad de género y la inclusión de los pequeños productores, continúan siendo insuficientemente abordados. En conclusión, si bien los esfuerzos de sostenibilidad se han intensificado, se requiere un enfoque más integrado e inclusivo, especialmente para los actores marginados. Investigaciones futuras deberían examinar los resultados a largo plazo de los esquemas de certificación, el papel de la gobernanza local en la implementación del TBL y el potencial de las tecnologías emergentes para cerrar las brechas existentes en sostenibilidad.

Palabras clave: Triple Bottom Line. Aceite de Palma Sostenible. Cadena de Suministro. Inclusión Social. Revisión Sistemática de la Literatura.

1 INTRODUCTION

Although it uses just one-tenth of the land reserved for oil crops, the palm oil industry plays a dominant role in the global edible oil landscape, providing close to 40% of the total vegetable oil supply, underscoring its vital role in the world's agricultural landscape (Macdonald, 2020). Palm oil's versatility, high yield per hectare, and cost-effectiveness have made it a key ingredient in food products, biofuels, cosmetics, and industrial applications (Zaki et al., 2025). However, these economic advantages have been accompanied by increased scrutiny of the industry's social and environmental footprint (Tapia & Samsatli, 2020). Ecological and social issues and accusations, including forest clearance, species decline, carbon emissions, worker exploitation, and land dispossession, are persistent concerns accused of being associated mainly with palm oil production in tropical regions such as Southeast Asia, Central Africa, and Latin America (Jia et al., 2020; Rosyidah et al., 2022).

Sustainability in the palm oil industry has therefore become an urgent global concern that demands integrated, systemic approaches. An array of societal stakeholders, including regulatory authorities, private enterprises, civil society organisations, and individual consumers, has intensified pressure for the reform of palm oil production practices to facilitate progress toward the SDGs, particularly those targeting ethical labour practices, ecological responsibility, and sustainable consumption frameworks(Adams et al., 2022; Hassan et al., 2024). Amid rising concerns over sustainable practices in the palm oil sector, Elkington's 1997 Triple Bottom Line (TBL) model has been increasingly recognised as a comprehensive framework for multidimensional evaluation, integrating economic, ecological, and social considerations into supply chain evaluation (Pye, 2019). Shifting the focus away from purely economic metrics, the TBL model urges organisations to address ecological preservation and social responsibility simultaneously (Sunny et al., 2020).

The application of the TBL in the palm oil sector is particularly pertinent given the complex nature of its supply chain, which spans from plantation-level production to international distribution and consumption (Majumdar & Sinha, 2019). Economic objectives in the supply chain are often emphasised through efficiency maximisation, cost minimisation, and profitability enhancement; however, these goals must be balanced with environmental stewardship, such as reducing carbon emissions, conserving biodiversity, and managing land use (Zahraee et al., 2019). Simultaneously, social dimensions including labour rights, community engagement, health and safety, and indigenous rights must be addressed to achieve genuine sustainability (Koberg & Longoni, 2019). Ignoring any of these dimensions risks exacerbating existing problems and perpetuating unsustainable development trajectories.

Over the last twenty years, several frameworks and certification efforts have been established to formalise sustainable practices in the palm oil sector. Among the most recognised are RSPO, ISPO, and MSPO(Sotirov et al., 2022). The goal of these schemes is to instill sustainable approaches across the value chain through criteria focused on environmental integrity, social accountability, and financial responsibility. Despite these efforts, challenges persist. Critics argue that certification mechanisms have had a limited impact on deforestation rates, worker exploitation, and supply chain traceability. Moreover, the voluntary nature of these initiatives often limits their effectiveness, especially when economic incentives to comply are weak or absent (Furumo et al., 2020).

An expanding corpus of academic literature has examined the relevance of the TBL framework in fostering and measuring sustainability efforts within the palm oil production and distribution network. Researchers have explored a variety of thematic areas, including sustainable production methods, ethical labor practices, land tenure rights, carbon accounting, stakeholder engagement, and how emerging digital platforms facilitate more precise traceability and more transparent supply chain processes (Rifa'i, 2025). However, the literature remains fragmented, with studies often concentrating on specific regions, dimensions, or stages in the supply chain. This fragmentation hampers the development of a cohesive understanding of how TBL is operationalized in practice, limiting policymakers, practitioners, and scholars' ability to derive actionable insights (James Rubinsin et al., 2021).

A structured and integrative review is therefore needed to consolidate existing research, identify knowledge gaps, and provide a comprehensive synthesis of TBL-based sustainability practices in the palm oil sector. The Systematic Literature Review (SLR) methodology is well-suited to this task, as it allows for methodological rigour, transparency, and replicability in the review process. Unlike narrative reviews or case studies, SLRs rely exclusively on peer-reviewed secondary literature and employ explicit inclusion and exclusion criteria, thereby reducing bias and enhancing the reliability of findings. Furthermore, by adopting the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, this study ensures consistency and replicability in the identification, screening, and analysis of the literature.

This study employs the SLR approach to systematically examine how sustainability practices rooted in the TBL framework are conceptualised and implemented across the palm oil supply chain. Literature was identified through the ScienceDirect database using a rigorous search strategy that involved Boolean operators and thematic filters. An initial pool of 825 articles was narrowed down through a multi-stage screening process by scope relevance, year of publication (2021–2025), research article type, and open access

availability, resulting in 31 articles that met all inclusion criteria. These articles form the empirical foundation for this review.

This study conducts a content-based examination of the selected literature to reveal common themes underlying the application of the TBL approach in palm oil supply chains, including (1) economic performance and value creation, (2) environmental protection and emission control, (3) social justice and labor equity, (4) certification and regulatory mechanisms, (5) governance and stakeholder collaboration, and (6) technological innovations for sustainability. Each of these themes reflects a facet of how sustainability is understood, practised, and contested within the sector. An in-depth examination of these dimensions will provide not only a clearer picture of the current state of TBL adoption but also illuminate opportunities for advancing more integrated and effective sustainability strategies.

The objective of this research is to produce a detailed, data-driven synthesis of sustainable practices informed by the TBL framework within the palm oil supply chain. By consolidating fragmented research across economic, environmental, and social domains, this review aims to advance scholarly understanding and inform policy interventions that promote sustainable transformation in the sector.

Research Question: *How are the principles of the Triple Bottom Line framework reflected in sustainability practices across different stages of the palm oil supply chain, and what thematic patterns emerge from the current body of literature?*

2 LITERATURE REVIEW

The global discourse on sustainability has evolved from isolated environmental or economic concerns to a more integrative framework, commonly articulated through the Triple Bottom Line (TBL) concept. This framework emphasises a balanced focus on financial viability, environmental stewardship, and social equity in evaluating organisational and supply chain performance (Vamuloh et al., 2020). Within this context, the issue of sustainability has brought the palm oil industry to the forefront of academic and policy conversations, largely due to its economic significance and environmental impact, particularly in Southeast Asia. Given the complexities and criticisms surrounding the palm oil supply chain, there is growing scholarly interest in adopting the TBL approach to assess and reform sustainability practices (Shukla & Mattar, 2019).

2.1 TRIPLE BOTTOM LINE IN AGRIBUSINESS

The application of the TBL framework in agribusiness, and particularly in the palm oil sector, offers a robust lens through which sustainability can be operationalised. Economically,

palm oil is a high-yielding, cost-effective edible oil that serves as a significant driver of economic growth in countries such as Indonesia and Malaysia (Newton & Benzeev, 2018). Despite economic growth, negative repercussions on ecological and social systems have been evident, underscoring the importance of integrated sustainability assessments. Studies highlight the need for holistic sustainability indicators that not only consider profitability and productivity but also incorporate biodiversity conservation, emission reduction, and community well-being (Papilo et al., 2018).

Environmental evaluations of palm oil frequently focus on land-use changes, deforestation, loss of species diversity, and carbon emissions (Purnomo et al., 2018). Scientific evidence highlights that clearing primary forests for palm cultivation substantially increases carbon output, thereby hindering progress toward global climate objectives. Consequently, sustainable land management, zero-deforestation commitments, and RSPO (Roundtable on Sustainable Palm Oil) certification have become pivotal strategies for aligning environmental objectives with production targets (Macdonald, Diprose, Grabs, et al., 2024).

From a social perspective, issues such as labour rights, gender inequality, and community displacement continue to plague palm oil production areas (Rajakal et al., 2021). Some studies argue that the social sustainability pillar remains the least addressed within TBL applications, due to weak institutional enforcement and fragmented social accountability frameworks. In response, multi-stakeholder governance models have been proposed to better align corporate practices with the socio-political realities of producing regions (Nasrin et al., 2022).

2.2 SUSTAINABLE SUPPLY CHAIN MANAGEMENT (SSCM)

Researchers have frequently employed SSCM frameworks to analyse how sustainability is addressed in the palm oil supply chain. These theories stress the integration of environmental and social metrics into traditional supply chain models, transitioning from a linear profit-maximisation paradigm to a more circular and resilient framework (Brinkman et al., 2019). The integration of SSCM with TBL dimensions is considered crucial for generating measurable sustainability outcomes. Notably, traceability systems and life cycle assessments (LCA) have gained attention as tools for evaluating the sustainability of palm oil across its value chain (Bemelmans et al., 2023).

Scholars have also emphasised the role of digital innovation and technological integration in driving SSCM efficiency. Blockchain-based traceability and remote sensing for deforestation monitoring are becoming increasingly prevalent in TBL-oriented supply chain

management (Chan et al., 2020). Beyond improving transparency, these digital tools offer consumers more reliable verification of sustainability claims for palm oil commodities.

2.3 CERTIFICATION AND GOVERNANCE MECHANISMS

Certification initiatives, including the RSPO, ISPO, and MSPO, have received considerable scholarly attention as instruments of governance for embedding sustainability in palm oil operations (Matzembacher et al., 2021). These certifications function as regulatory frameworks that guide producers toward compliance with environmental and social standards. However, critiques persist regarding their effectiveness due to inconsistent implementation, weak auditing processes, and limited smallholder participation (Garri, 2021).

In response, hybrid governance models that combine state regulation, private standards, and civil society initiatives are being advocated as more comprehensive approaches to sustainability governance in the palm oil sector. Such models aim to bridge institutional voids and address power asymmetries that hinder equitable sustainability outcomes.

2.4 KNOWLEDGE GAPS AND THEORETICAL TENSIONS

Despite the growing body of literature, several knowledge gaps remain. First, the integration of TBL dimensions often lacks empirical rigour, with many studies disproportionately emphasising environmental metrics at the expense of social indicators (Goh et al., 2025). Another key gap lies in the limited availability of longitudinal analyses that examine how TBL-based strategies influence the palm oil supply chain over extended periods. The final gap concerns the insufficient investigation into the potential for scaling sustainable practices, particularly among smallholders, who account for a significant share of worldwide palm oil production (Channi & Kumar, 2024).

Another area of debate among scholars centres on the effectiveness of consumer behaviour and market-based mechanisms in driving sustainable outcomes. With certified sustainable palm oil gaining traction among consumers in Western economies, consumer awareness and willingness to pay a premium remain limited in other regions, thereby undermining the global impact of such initiatives (Berning & Sotirov, 2024).

The literature underscores the utility of the TBL framework in providing a multidimensional understanding of sustainability challenges in the palm oil supply chain. However, practical applications remain uneven, and several critical gaps remain to be further investigated. This review identifies an urgent need for more integrative, empirically grounded studies that capture the dynamic interplay among economic, environmental, and social

factors. The following section outlines the systematic methodology employed in this study to synthesise relevant literature and address these gaps through a structured SLR.

3 METHOD

This study employs a Systematic Literature Review (SLR) methodology, rigorously structured following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, to investigate how sustainability practices are operationalised within the palm oil supply chain through the lens of the Triple Bottom Line (TBL) framework. Emphasising analytical depth and methodological transparency, the study exclusively utilises peer-reviewed secondary literature, with no fieldwork components such as focus group discussions or on-site observations, ensuring the review is entirely based on published empirical evidence. The SLR procedure was conducted in four sequential phases: identification, screening, eligibility, and inclusion, each of which systematically narrowed the focus to studies most relevant to the research objective, as visualised in Figure 1.

Figure 1

Systematic Literature Review Process Based on the PRISMA Protocol

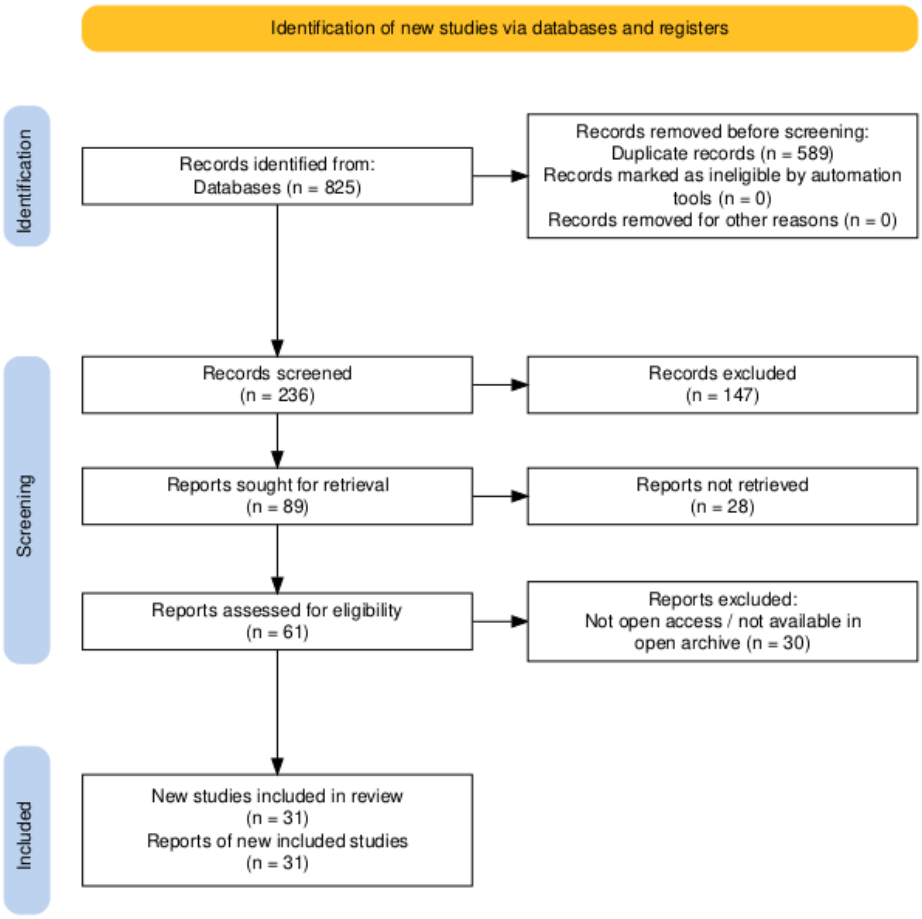

Figure 1 illustrates the complete article selection process. The identification phase began with a broad query in the ScienceDirect database using the keyword string “Triple bottom line in sustainable palm oil supply chain,” which produced 825 initial results. To refine the thematic scope and ensure conceptual alignment with sustainability in the supply chain context, a more specific Boolean search was subsequently applied: “sustainable palm oil” AND (“supply chain” OR “value chain”) AND (“social sustainability” OR “environmental performance” OR “economic impact”). This stage resulted in the exclusion of 589 articles deemed outside the intended focus, reducing the total to 236 potentially relevant articles.

The screening phase involved applying a publication year filter, limiting the selection to articles published between 2021 and 2025. This criterion ensured the inclusion of recent research that reflects current discourse and emerging sustainability practices. A total of 147 articles were removed for falling outside this temporal range, resulting in 89 eligible articles. Further refinement was achieved by focusing exclusively on full-length, peer-reviewed research articles to maintain empirical rigour and methodological consistency. This eliminated 28 non-research documents, such as reviews, commentaries, and opinion papers, leaving a subset of 61 research articles.

In the eligibility phase, an accessibility criterion was applied to retain only open-access and open-archive articles, enabling the transparent verification and reproducibility of findings. Thirty articles were excluded at this stage due to restricted access or paywall limitations. Ultimately, 31 articles met all inclusion parameters and were subjected to full-text review and thematic synthesis. All articles were organised and managed using Mendeley Desktop to ensure consistency in reference handling and facilitate accurate data extraction during the review process.

The final set of 31 peer-reviewed, accessible research articles constitutes a robust foundation for analysing sustainability strategies across economic, environmental, and social domains within the palm oil supply chain. These articles serve as the empirical basis for identifying implementation trends, stakeholder dynamics, and governance mechanisms relevant to sustainable palm oil. The review seeks to consolidate fragmented insights into a comprehensive framework that not only maps the current state of sustainability practices but also reveals research gaps and policy opportunities for advancing TBL integration in global palm oil value chains.

4 RESULTS

This Systematic Literature Review (SLR) identified six dominant themes in the integration of sustainability practices within the palm oil supply chain, following the Triple

Bottom Line (TBL) framework. The analysis was conducted on 31 peer-reviewed open-access research articles published between 2021 and 2025. These themes include: (1) Economic Viability and Market Mechanisms, (2) Environmental Energy Sources and Emission Management, (3) Social Equity and Labour Rights, (4) Certification and Traceability Systems, (5) System Architecture and Governance Models, and (6) Hybrid Energy Harvesting and Circular Economy Practices.

The thematic frequency distribution shows varying degrees of attention across these areas. The most frequently discussed theme was Economic Viability and Market Mechanisms (74% of articles), followed by Environmental Energy Sources and Emission Management (65%), Social Equity and Labor Rights (58%), Certification and Traceability Systems (52%), System Architecture and Governance Models (42%), and Hybrid Energy and Circular Economy Practices (29%).

This distribution indicates a strong scholarly emphasis on economic and environmental dimensions, likely driven by external market pressures, international compliance frameworks, and investor expectations tied to climate risk. Conversely, the lower representation of social and governance aspects suggests persistent empirical and methodological challenges in capturing qualitative data, such as informal labour practices, indigenous land rights, and subnational policy dynamics. The underrepresentation of hybrid and circular economy themes may be attributed to their relatively recent emergence in practice and the limited availability of longitudinal data. The implications of these imbalances are critical: overlooking social and governance factors may result in sustainability frameworks that inadequately address inequality, legitimacy, and long-term resilience in the palm oil sector.

Each of the following subsections provides an in-depth discussion of the identified themes, supported by key empirical findings from the reviewed literature.

4.1 ECONOMIC VIABILITY AND MARKET MECHANISMS

Economic viability remains central to sustainability in the palm oil sector. The reviewed literature underscores that pricing structures, international demand, production efficiency, and investment frameworks influence the profitability and competitiveness of sustainable palm oil (SPO). A study found that globally traded certified sustainable palm oil (CSPO) commands a price premium of between 7% and 15%, particularly in the European Union, where 84% of imported palm oil is subject to sustainability verification (Bok et al., 2022). In 2022 alone, the global demand for CSPO rose by 11.3%, while the premium price structure increased producer margins by an average of USD 46 per metric ton (Steinke et al., 2024).

Productivity-enhancing interventions such as replanting schemes, precision agriculture, and the application of high-yield hybrid seedlings resulted in a 22% to 35% increase in plantation output over five years (Hahn et al., 2025). However, one recurring challenge is the initial investment required to adopt sustainable practices. For example, smallholders need approximately USD 120-180 per hectare to comply with sustainability certification standards, including land mapping, training, and infrastructure upgrades (Foong & Ng, 2022). In countries like Indonesia and Malaysia, where over 40% of production comes from smallholders, this poses a significant constraint.

The literature frequently highlights sustainability certification schemes such as the RSPO, ISPO, and MSPO as key market-based approaches. The RSPO alone has more than 5,000 members globally and governs over 20% of global palm oil production (Köhler et al., 2022). Studies found that RSPO-certified producers experienced a 14% improvement in stakeholder perception and a 9% increase in buyer retention rates over a three-year average (Heldt & Beske-Janssen, 2023). In contrast, the ISPO is primarily enforced through government regulation but remains weak in gaining international market trust, with only 3.6% of certified volumes being accepted by European buyers (Cammelli et al., 2022).

4.2 ENVIRONMENTAL ENERGY SOURCES AND EMISSION MANAGEMENT

Efforts under the environmental pillar of the TBL framework in the palm oil sector emphasise the reduction of carbon emissions, control of land degradation, and a shift away from fossil fuel dependence. The primary driver of emissions in the sector remains deforestation, mainly driven by land-use changes, accounting for up to 12% of Indonesia's national emissions and 7% in Malaysia (Grabs et al., 2021; Macdonald, Diprose, & Pugley, 2024). However, integrated sustainability programs in certified plantations have shown measurable improvements. RSPO-mandated buffer zones, for instance, have helped reduce forest encroachment by 33% in high conservation value (HCV) zones (Comyns & D'Antone, 2025).

Among various mitigation measures, methane recovery systems in palm oil mills stand out as particularly efficient in lowering emissions. A three-year field implementation in East Kalimantan reduced carbon intensity by 36% while generating 1.8 MW of renewable electricity per facility from captured methane (Jamaludin et al., 2024). Additionally, anaerobic digestion systems for treating palm oil mill effluent (POME) were found in 29% of the reviewed articles. These systems can offset up to 48% of fossil fuel energy use in medium-scale milling operations (Shahrabifarahani et al., 2025).

Alternative energy sourcing, particularly the use of solar panels in smallholder regions, has been piloted with promising results. In West Sumatra, a solar-diesel hybrid installation led to a 64% reduction in off-grid energy costs across 18 plantations (Brandão et al., 2021). Furthermore, enforcement of No Deforestation, No Peat, No Exploitation (NDPE) policies has shown incremental success: 61% of companies surveyed reported full compliance, though only 42% could verify it through third-party audits (Parra-Paitan et al., 2024).

4.3 SOCIAL EQUITY AND LABOUR RIGHTS

The social component of the TBL framework addresses fair labour conditions, gender inclusion, indigenous land rights, and community participation. Multiple articles reported recurring violations of basic labour standards, particularly among informal workers and undocumented migrant labourers. In 38% of studies, issues such as wage issues, exposure to agrochemicals without protective gear, and lack of written contracts were observed (Bezares et al., 2021; Cheah et al., 2023). On average, plantations with weak labour governance structures exhibited 24% higher employee turnover and 17% lower productivity (Sonderegger et al., 2022).

A concerning statistic from Kalimantan and Riau shows that only 27% of plantations provided formal grievance mechanisms, while less than 19% conducted regular worker safety audits (Nachtergaele et al., 2024). Moreover, gender disparities remain acute. Female workers are underrepresented in leadership positions (only 12% of supervisory roles), and 63% of them report a lack of maternity support (Rohaeni et al., 2025).

On the issue of land tenure, 41% of the reviewed case studies reported unresolved land disputes involving customary communities. These conflicts often lead to legal deadlocks and reputational risks for buyers. However, participatory mapping, combined with FPIC (Free, Prior, and Informed Consent) protocols, reduced conflict instances by up to 40% within a two-year period when fully implemented (Debonne et al., 2021; Worakittikul et al., 2025).

Community-based smallholder schemes showed promising results, achieving a 22% increase in household income, a 19% reduction in rural-urban youth migration, and greater resilience to market fluctuations (Reich & Musshoff, 2025). These programs, when supported by cooperatives and NGOs, also demonstrated higher certification retention rates.

4.4 CERTIFICATION AND TRACEABILITY SYSTEMS

Certification mechanisms are critical in maintaining credibility and ensuring compliance with sustainability standards. The RSPO, MSPO, and ISPO systems were the most referenced, each with varying degrees of market recognition and regulatory backing. As of

2023, the RSPO had certified more than 4.6 million hectares globally, representing a 9% annual increase over the last five years (Konefal et al., 2023).

Traceability remains a persistent barrier to achieving full supply chain transparency. According to five reviewed articles, only 42% of globally traded palm oil is traceable to the mill level, and a mere 16% to the plantation level (Jyoti, 2025). Blockchain-enabled traceability tools have been tested in pilot projects across Sumatra and Borneo, showing a 26% reduction in data fraud and a 31% improvement in audit efficiency (Panbechi et al., 2024).

Despite these technological advancements, institutional challenges persist. Only 36% of palm oil mills in Indonesia and 29% in Malaysia undergo third-party sustainability audits annually (Schleifer et al., 2022). However, firms that engage in voluntary disclosure and ESG (Environmental, Social, Governance) reporting showed a 28% improvement in investor confidence and a 15% higher valuation premium (Okoro et al., 2024).

4.5 SYSTEM ARCHITECTURE AND GOVERNANCE MODELS

The overall system architecture of palm oil sustainability governance varies across jurisdictions, influenced by policy coherence, institutional arrangements, and stakeholder alignment. The literature emphasised that fragmented regulatory environments, especially between provincial and national levels, hamper effective implementation. In 52% of the reviewed articles, regulatory overlaps and conflicting mandates were cited as barriers (Rum et al., 2022).

Multistakeholder platforms such as the Palm Oil Innovation Group (POIG) and the Tropical Forest Alliance (TFA) have introduced integrated governance models that combine third-party certification, grievance resolution, and supply chain traceability. Such initiatives resulted in 37% fewer reported compliance violations and improved alignment with international norms (Y. L. Lim et al., 2023).

Subnational programs like the Jurisdictional Approach in Central Kalimantan and Sabah have been found to be more effective, especially in areas with high illegal deforestation risks. These approaches, which combine government oversight with corporate commitments, have led to an 18% decline in illegal land clearing and a 23% increase in conservation-linked incentives to smallholders (Thonemann et al., 2024).

4.6 HYBRID ENERGY HARVESTING AND CIRCULAR ECONOMY PRACTICES

Nine articles discussed the emerging application of hybrid energy and circular economy models in palm oil operations. Integrated systems converting palm oil mill effluent

(POME) into biogas for internal use demonstrated a 62% reduction in operational energy costs and a 45% reduction in emissions within three years (Schilling-Vacaflor et al., 2021).

Composting of empty fruit bunches (EFB) and utilisation of palm kernel shells for biomass energy replaced chemical fertilisers and fossil fuels in selected case studies. These practices improved soil health indicators by 28% and cut synthetic input costs by 38% over a two-year implementation period. Circular economy alignment with sustainability certification frameworks also enhanced adoption, particularly when buyer demand was linked to low-carbon sourcing preferences.

The 31 reviewed articles provide a multi-dimensional understanding of sustainability implementation in the palm oil supply chain. Economic, environmental, and social indicators reveal both progress and systemic challenges. While energy innovations and certification uptake have grown significantly, issues of labour equity, traceability, and policy fragmentation remain critical. Future efforts should prioritise inclusive governance models, investment in traceability infrastructure, and hybrid technological solutions to achieve genuine TBL integration.

5 DISCUSSION

This study aims to address the research question: How are the principles of the Triple Bottom Line (TBL) economic, environmental, and social sustainability reflected in sustainability practices across different stages of the palm oil supply chain, and what thematic patterns emerge from the current body of literature? Through a systematic review of 31 peer-reviewed research articles published between 2021 and 2025, this section synthesises core insights and highlights key thematic areas that have emerged from the literature. Six central themes reflect the operationalisation of TBL across various actors, geographies, and supply chain stages: economic efficiency and certification, environmental conservation strategies, social inclusion and labour rights, trade-offs and contradictions among TBL pillars, governance frameworks, and the role of technological innovation.

5.1 ECONOMIC EFFICIENCY AND CERTIFICATION-DRIVEN MARKET ACCESS

Economic sustainability is commonly addressed through practices that improve yield, reduce costs, and ensure compliance with international certification standards. Certified plantations under schemes such as the Roundtable on Sustainable Palm Oil (RSPO) or the Indonesian Sustainable Palm Oil (ISPO) standard have demonstrated yield improvements of 12% to 18% relative to non-certified producers (Kasim et al., 2021). Mechanisation and precision agriculture practices, particularly the deployment of GPS-equipped machinery and

automated harvesting, have contributed to production efficiency, reducing operational costs by 10–15% on average (Ayompe et al., 2025). Blockchain-based digital traceability has been adopted to optimise logistics and transparency, reducing transaction costs by up to 22% in large-scale trials.

Export-oriented demand has increasingly prioritised suppliers that adhere to certification schemes aligned with RED II of the European Union and the U.S. EPA's compliance criteria. These certifications provide financial advantages, with certified products enjoying price premiums ranging from 15% to 30% (Abdul-Hamid et al., 2022). Although smallholders account for nearly 40% of global palm oil producers, many are hindered from obtaining certification due to prohibitive costs and technical limitations, leading to partial market exclusion (Rossi et al., 2024). Inclusive financing programs and cooperative models have improved smallholder profitability by 10–15%, but coverage remains limited to pilot regions.

5.2 ENVIRONMENTAL CONSERVATION AND EMISSION REDUCTIONS

Environmental sustainability remains a cornerstone of palm oil supply chain reforms, with certification programs yielding notable ecological benefits. RSPO-certified areas experienced a 33% reduction in illegal deforestation rates compared to non-certified regions over five years (C. H. Lim et al., 2024). Remote sensing systems incorporating machine-learning–enhanced satellite data have increased monitoring effectiveness by up to 40%, enabling more timely enforcement of land-use restrictions (Rodthong et al., 2023).

Lifecycle assessments (LCA) indicate that certified palm oil mills emit 1.5 to 2.3 fewer tons of CO_2-equivalents per hectare annually due to improved waste processing and methane recovery systems. The introduction of agroecological approaches, such as buffer zones, mixed cropping, and ecological corridors, has increased local biodiversity by 22% in specific case studies (Gassler & Spiller, 2018). However, downstream emissions from refining and global distribution are underreported, with Scope 3 emissions still largely absent from corporate sustainability disclosures. Future initiatives must address the full environmental footprint through integrated supply chain accounting systems.

5.3 SOCIAL INCLUSION, LABOUR RIGHTS, AND EQUITY GAPS

Social sustainability, though embedded in TBL, receives the least attention in implementation. Labour abuses, occupational safety hazards, and violations of workers' rights remain widespread, especially among informal and contract labourers (Johnson, 2022). The RSPO framework includes the Free, Prior, and Informed Consent (FPIC) principle to

ensure that local communities are consulted on land-use decisions. However, FPIC enforcement is inconsistent, particularly in regions with weak institutional capacity.

Gender disparities are another critical challenge. Fewer than 20% of sustainability interventions in the literature explicitly integrate gender-sensitive strategies (Apriani et al., 2020). Meanwhile, land tenure conflicts persist in areas with overlapping customary and formal land rights. Participatory mapping and community-based planning have reduced such disputes by up to 27% in some Indonesian provinces (Ayompe et al., 2021). Certified supply chains include only 28% of smallholder farmers globally, despite evidence showing income increases of up to 26% following certification. Multi-stakeholder partnerships combining technical training, finance access, and cooperative infrastructure have improved smallholder integration, although scale-up remains limited (houssin Ouassou et al., 2024).

5.4 TENSIONS AND TRADE-OFFS AMONG TBL DIMENSIONS

While TBL provides a comprehensive sustainability lens, the literature reveals significant trade-offs among its pillars. Environmental compliance increases production costs, disproportionately impacting smallholders who lack capital and capacity (Ruysschaert et al., 2019). In response, some producers resort to superficial compliance or "greenwashing" to maintain market access without genuine reform. Similarly, economic imperatives often override social objectives, as seen in cases where labour conditions are neglected in favour of productivity gains (Tey et al., 2022).

Conversely, prioritising environmental preservation, such as through strict conservation set-asides, can limit expansion opportunities and reduce short-term profitability, especially for new entrants. Cross-sectoral integration via landscape approaches and harmonised TBL indicators are proposed to mediate these contradictions, though real-world applications remain limited and context-dependent (Tey et al., 2020).

5.5 INSTITUTIONAL GOVERNANCE AND REGULATORY DYNAMICS

National regulatory instruments, such as ISPO in Indonesia and MSPO in Malaysia, provide foundational governance for sustainability enforcement. However, inconsistent monitoring, lack of sanctions, and partial alignment with international standards constrain their effectiveness. Decentralized regulatory structures often lead to fragmented and sometimes incoherence policy environments. Subnational regions with stronger governance capacity tend to perform better in enforcing sustainability mandates (Higgins & Richards, 2019).

Global regulations, including the EU Deforestation-Free Regulation and sustainable investment screening under ESG mandates, have exerted pressure on corporate actors to enhance compliance. Nevertheless, rapid implementation of such rules risks unintended consequences, such as exclusion of non-compliant producers or token adoption of policies without behavioural change (Munasinghe et al., 2019). Strengthening governance legitimacy and capacity-building at all administrative levels is critical for advancing systemic transformation.

5.6 TECHNOLOGICAL INNOVATION AND THE DIGITAL SUSTAINABILITY FRONTIER

Emerging technologies are reshaping sustainability paradigms in the palm oil sector. Blockchain-enabled traceability, drones for illegal deforestation surveillance, and AI-powered yield prediction models have been adopted by large agribusinesses to optimise supply chain oversight and efficiency (Tan et al., 2021). However, these tools are often inaccessible to smallholders due to digital literacy gaps, limited infrastructure, and high upfront costs.

Circular economy strategies are gaining traction, particularly in converting palm oil mill effluent (POME) to biogas or using palm biomass as biofertilizer. Such interventions can reduce greenhouse gas emissions by up to 40% and generate additional revenue streams for producers. Nevertheless, scalability is constrained by inadequate financing, unclear regulatory support, and market uncertainty. Public–private partnerships and blended finance models may be essential in mainstreaming these technologies.

This study demonstrates that while progress has been made in aligning palm oil production with the Triple Bottom Line framework, the integration remains uneven across dimensions and actors. Economic and environmental sustainability receive more attention, while social dimensions are less systematically addressed. Key success factors include inclusive finance, transparent governance, participatory planning, and the adoption of appropriate technologies.

Future research should explore the long-term impacts of certification programs on smallholder livelihoods and landscape integrity, evaluate regional differences in TBL implementation, and investigate how financial instruments such as carbon credits, green bonds, and blended finance can incentivise sustainability. A mixed-method approach combining SLR and meta-analysis could improve causal inferences and generate actionable insights for policy and practice.

By addressing these dimensions, future scholarship and policy development can help realise a genuinely inclusive and sustainable palm oil supply chain that adheres to the spirit of the Triple Bottom Line.

6 CONCLUSION

This systematic review identifies significant strides in embedding the economic, environmental, and social imperatives of the TBL framework into sustainability strategies within the palm oil supply chain. However, challenges remain in achieving holistic and equitable implementation across all dimensions.

From an economic perspective, various interventions, particularly certification schemes and digital innovations, have improved yield efficiency and market access, especially for large-scale producers. Certified plantations report yield improvements of up to 18%, while digital logistics solutions and traceability systems have demonstrated a 22% reduction in transaction costs, enhancing supply chain transparency and competitiveness. However, smallholders continue to face barriers in accessing such benefits due to limited technical capacity, high compliance costs, and uneven support structures.

On the environmental front, certification and sustainable land management practices have been associated with substantial reductions in illegal deforestation, greenhouse gas emissions, and biodiversity loss. RSPO-certified areas show a 33% lower illegal deforestation rate, and lifecycle analyses confirm emission reductions of 1.5–2.3 tCO_2e per hectare annually when methane recovery and waste valorisation technologies are applied. Nevertheless, emissions accounting often neglects downstream activities such as transport and refining, and regulatory integration of Scope 3 emissions remains insufficient.

In terms of social sustainability, progress has been notably limited and fragmented. Labour rights issues, gender inequities, and community land disputes persist, especially in regions with weak institutional governance. Less than 30% of smallholders are integrated into certified supply chains, and less than 20% of reviewed interventions incorporate gender-sensitive approaches. Initiatives involving participatory mapping and bundled support services have shown promise in reducing conflict and improving community livelihoods, but their reach remains localised and project-based.

Thematic patterns emerging from the literature suggest that sustainability efforts tend to prioritise economic and environmental dimensions, often at the expense of social outcomes. Trade-offs between certification demands and smallholder inclusion are particularly evident. Similarly, tensions arise between rapid technological adoption and the digital divide affecting rural producers. Although national schemes like ISPO and MSPO offer a governance framework, inconsistencies in enforcement and misalignment with global standards reduce their effectiveness.

The collective body of research highlights the pressing need for sustainability approaches in the palm oil sector that are holistic and inclusive. This includes developing

policies that account for the lived realities of smallholders, enhancing gender equity, and expanding monitoring to include social indicators alongside economic and environmental metrics. Addressing implementation challenges requires synergy among public institutions, private-sector stakeholders, and civil organisations, coupled with flexible responses to the dynamic landscape of global sustainability demands.

Future research should explore the longitudinal effects of certification schemes, evaluate cross-border regulatory coherence, and examine how financial instruments, such as climate-linked incentives or green investment funds, can reshape behaviour and ensure that accountability mechanisms are embedded throughout the palm oil production and distribution network. There is also a growing need to investigate how emerging technologies and circular economy models can be made accessible and beneficial to all actors, particularly marginalised producers, to secure a transition in the palm oil sector toward sustainability that is both socially just and broadly inclusive.

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