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Sustainable Agricultural Practices And Environmental Impact Assessment In The Malaysian Palm Oil Industry For Climate Change Mitigation And Biodiversity Conservation

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Abstract: *This study investigates the environmental impacts of palm oil cultivation in Malaysia and evaluates the effectiveness of sustainable agricultural practices in aligning the industry with global sustainability targets. Using a secondary data analysis approach, the research synthesizes data from government agencies, certification bodies, and peer-reviewed studies. It evaluates key environmental indicators (deforestation, biodiversity loss, water and soil quality, GHG emissions) and economic metrics (yields, certification premiums, investment returns), with a comparative focus on certified versus non-certified plantations. The analysis reveals that while palm oil cultivation has historically driven significant environmental degradation, the adoption of sustainable practices—such as integrated pest management, precision agriculture, and methane recovery systems—has led to measurable improvements in biodiversity conservation, water quality, and GHG reduction. Certified plantations (MSPO/RSPO) consistently outperformed conventional ones across environmental indicators, and sustainable technologies demonstrated favorable cost-benefit outcomes over the medium term. This study underscores the potential for Malaysia's palm oil industry to align with key Sustainable Development Goals—SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land)—through expanded certification, enhanced governance, and targeted support for smallholders. The findings provide evidence-based recommendations for policymakers, industry actors, and international stakeholders to scale sustainability transitions in tropical agricultural systems.*
Keywords: *Sustainable Agriculture, Palm Oil, Environmental Impact, SDG 12, SDG 13, SDG 15, Malaysia, Climate Change Mitigation, Biodiversity Conservation, Sustainable Growth*

1.INTRODUCTION

Malaysia stands as the world's second-largest palm oil producer, contributing approximately 27% of global palm oil production and generating substantial economic benefits for the nation (Rajakal et al., 2024). Palm oil provides jobs for more than 600,000 individuals directly and helps support even more jobs in Malaysia's agriculture. Nevertheless, the economic growth has hurt the environment which raises doubts regarding how these farming practices meet global environmental targets.Palm oil plantations have caused most of the forest loss in Southeast Asia and Malaysia lost about 6 million hectares of its forest during the period between 1990 and 2020 (Gaveau et al., 2022). The practice of deforestation has brought about large cuts to biodiversity, disconnected habitats and enhanced greenhouse gas emissions which contradict United Nations Sustainable Development Goals 13, 15 and 12.Traditionally, the main aim of palm oil farming in Malaysia was to get quick profits at the expense of helping the environment which led to soil damage, water pollution and ecological changes (Naidu & Moorthy, 2021). The frequent use of pesticides and fertilizers on crops has led to nutrients entering the water which pollutes lakes and streams and affects the water supplies of nearby towns and cities. Furthermore, making palm oil plantations out of natural forests and peatlands has released lots of stored carbon, so Malaysia is now identified as a top greenhouse gas emitter per person.Concern over environmental issues has become more serious because of global market pressure, notably prime places like Europe and North America now require RSPO certification to do business (Meijaard et al., 2018). In addition, climate change-related problems such as different rainfall patterns and more powerful storms are now affecting palm oil growth which could endanger the future of the industry. Using sustainable methods in agriculture helps maintain or improve production of palm oil and greatly reduces its effects on the environment (Ayompe et al., 2021). Some of these practices are precision agriculture, managing pests with integrated programs, agroforestry and better use of water resources. But, introducing such methods is still uncommon because of hurdles such as insufficient technical ability, money issues and a lack of helpful policies.The objective of this journal is to evaluate the environmental impacts of palm oil cultivation in Malaysia and assess how sustainable agricultural practices—particularly those implemented through MSPO and RSPO certifications—can mitigate ecological degradation while promoting economic viability, thereby aligning the industry with key Sustainable Development Goals (SDGs 12, 13, and 15) and enhancing climate resilience

2. LITERATURE REVIEW

2.1 Introduction

Palm oil is both vital for the Malaysian economy and plays a major role in providing vegetable oils to the world market. Still, the rapid growth of agriculture over the years has raised several concerns about the environment and society such as cutting down forests, destroying various species, producing greenhouse gases and affecting local people. As sustainability is becoming more important worldwide, food industry is experiencing a major transformation. Articles from peer-reviewed journals are reviewed here to understand the latest practices used in Malaysian palm oil palm to farm sustainably and examine the data and environmental impact findings related to them. The paper will look into several issues such as changes in sustainability, the importance of certifications, recent technology, looking after biodiversity and approaches to decrease GHG emissions.

2.2 Sustainable Agricultural Practices in Malaysian Palm Oil

Malaysian palm oil producers have concentrated more on following sustainable agricultural methods. A variety of reasons support these activities: regulations, the concerns of buyers for CSPO and a growing awareness among companies to protect the environment. Some recent suggestions for sustainable agriculture include no-burning laws, better ways to get the land ready, IPM and effective management of water and nutrients.Mohd Hanafiah et al. (2022) examined several effects of Malaysian palm oil on fulfilling the Sustainable Development Goals (SDGs) and divided them into categories of health, socioeconomics, environment and biodiversity. The study points out that carefully designed mitigation actions for each case are better than taking a single approach, since protecting the environment and growing the economy can be challenging (Mohd Hanafiah et al., 2022). Applying the MSPO certification has made a strong contribution to ensuring these practices become standard for all palm oil producers, including those who produce a good share of Malaysia's palm oil. Mspo.org.my's article (2024) highlights that MSPO certification fights deforestation by forbidding forest clearing in natural forests and HCV areas after the end of 2019, promotes proper land management, lowers emissions of greenhouse gases by using cleaner methods and safeguards biodiversity.Environmental management accounting and sustainability indicators play a crucial role in measuring the effectiveness of sustainable practices. Gunarathne et al. (2017) demonstrated the application of sustainability indicators in assessing eco-innovations in commercial plantations, showing how physical and monetary indicators can effectively measure environmental improvements in tropical agricultural systems. Goh et al. (2025) study found key economic and technological obstacles to broad adoption are low infrastructure and high initial capital expenditureAlso stressing the change, Zachlod et al. (2025) analyzed sustainable palm oil certification and noted that although it helps reduce deforestation and biodiversity loss, it has the potential to decrease agriculture efficiency. According to them, combining different types of data indicates that the existing standards and plans for expanding the certification should be updated so as to avoid shifting deforestation to uncertified areas (Zachlod et al., 2025). This demonstrates that people are still improving their use of sustainable methods, going past using them to make them more efficient and handle issues that were not expected.

2.3 Environmental Impact Assessments and Key Concerns

Environmental Impact Assessment (EIA) is still used to spot, predict and control the possible effects of palm oil cultivation and processing on the environment. Research in this area is still centered on important problems such as clearing forests, shrinking biodiversity, increasing greenhouse gases and contaminating water.Major environmental problems and challenges in the palm oil industry have been identified by Leng et al. (2024) such as cutting down forests, saving habitats for rare species and producing greenhouse gases. The review also stated that climate change causes the palm oil industry to produce lower and poorer quality palm oil because of conditions like droughts and floods. Because these fields influence each other so much, it is important to have detailed EIA methods and use practices that adapt to new changes in the environment.Water quality monitoring and heavy metal pollution assessment are critical components of environmental impact assessment in palm oil regions. Jahangiri-rad et al. (2023), including research by Akbarzadeh, utilized GIS applications and heavy metal pollution indices to analyze water quality near industrial areas, providing methodological frameworks applicable to palm oil cultivation impact assessmentThe research by Marsh et al. (2025) clearly showed that a loss of forests negatively affects biodiversity. The research showed that both logged forests and oil palm plantations caused major drops in biodiversity, especially for soil fungi, ectomycorrhizal communities, insects, birds and bats. Signs of healthy soil and carbon storage in the ground showed a significant drop in places that were logged or converted to other uses (Marsh et al., 2025). Such studies, employing detailed ecological assessments, contribute significantly to the EIA knowledge base and reinforce the need for stringent conservation measures within and around plantation landscapes. While specific EIA methodologies employed by companies are often proprietary or detailed in consultancy reports, academic research increasingly utilizes advanced tools like remote sensing and geospatial analysis, as mentioned in the context of technological advancements to monitor deforestation and land-use change, effectively contributing to a broader, ongoing EIA of the industry (Bernard Marr & Co., n.d.).

2.4 Sustainability Certifications: MSPO and RSPO Dynamics

Sustainability certifications, particularly the Roundtable on Sustainable Palm Oil (RSPO) and the nationally mandated Malaysian Sustainable Palm Oil (MSPO), have been central to driving the sustainability agenda in the Malaysian palm oil industry.Several studies now focus on how these certifications are taken up, how effective they are and what issues they encounter. Abidin et al. (2024) found that among oil palm smallholders, awareness, having enough financial resources, government help, receiving training and getting chances in the market are major reasons for adopting the MSPO certification. Nonetheless, smallholders still deal with financial issues, low levels of knowledge and mediocre help from extension workers. Therefore, special efforts are needed to help smallholders so that sustainability standards are applied globally and successfully.Wen et al. (n.d) researched the effect of getting MSPO certification on the earnings of palm oil growers in Malaysia. According to what they found, the cost to pick one tonne of oil palm bunches jumped after implementing the MSPO standards. Yield for palm oil went up, but the profit didn’t increase as much as expenses did, unless the company was RSPO certified, since it earns extra income with certification (Wen et al., n.d). This proves that being sustainable from an economic point of view involves many complications for growers.According to Zachlod et al. (2025), although endorsements such as those from RSPO are helpful, they may also result in lower plantation efficiency for certain cases. It is argued that there should be new standards for training and smarter selection of areas for expansion (Zachlod et al., 2025). Studies by Othman et al. (2023)

showed that EU environmental policies are good for palm oil production in Malaysia based on the Porter Hypothesis which suggests tighter regulations can inspire creativity. This means that companies in Malaysia can make progress thanks to international needs for certification, but also have to adjust and invent new ways of working (Othman et al., 202). Since 2019, MSPO has been mandatory, but this rule still works together with RSPO and other such standards that companies may decide to follow.

2.5 Technological Innovations for Sustainable Palm Oil

Technology is having a bigger and better impact on making the Malaysian palm oil industry sustainable. The innovations apply to different parts of growing, preparing and checking foods.An article by Bernard Marr & Co. (2024) discusses how technology can transform the palm oil industry. Precision agriculture, utilizing AI-powered satellite imagery, enables efficient monitoring of vast plantation areas, early identification of issues like pest infestations or nutrient deficiencies, and compliance with sustainability certifications by tracking land-use changes and proving no deforestation post-2020. Drones are also being employed for sustainable plantation management (Bernard Marr & Co., 2024). They improve the efficiency of resources, help keep yield high and make it easier for companies to meet strict regulations that ban forest destruction.Singh (2025) points out many modern technologies that are changing how palm oil is produced and managed. For example, blockchain can be used to track supply chains, so people can check whether claims about sustainability are true and Global Forest Watch helps by constantly watching for signs of deforestation. It also discusses studies of oil alternatives that are produced through fermentation which in the future may help address concerns over land use related to palm oil plantations (Dorny, 2025). Palm oil mills are concentrating on finding new methods to turn EFB and POME waste into energy, plastics and animal nutrition. Using solar drying is an approach employers are selecting to help reduce their use of fossil fuels in processing (Bernard Marr & Co., 2024). By applying these new technologies, farmers can enhance their workflow, help the environment and answer the sector's needs for sustainable palm oil.

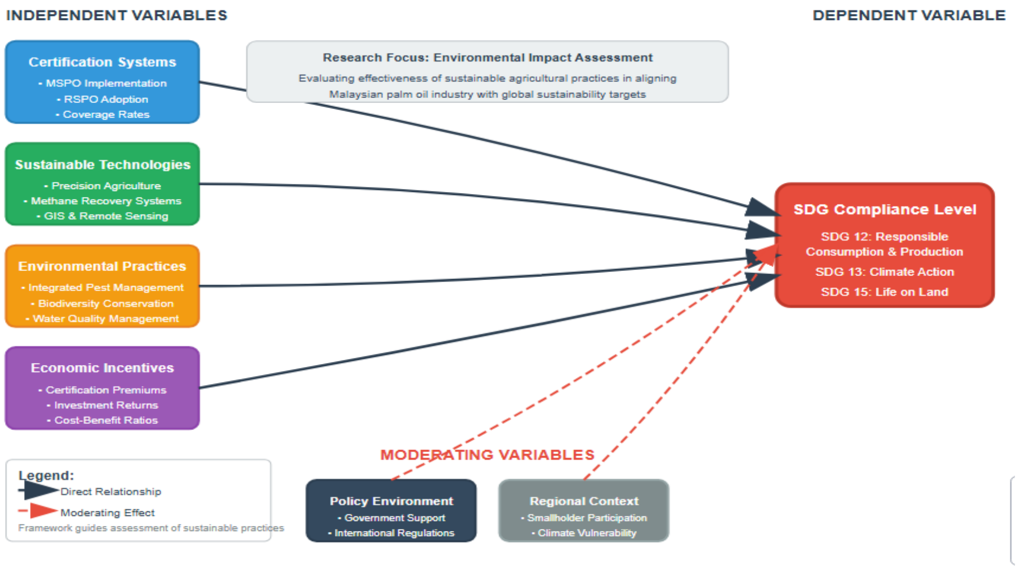
2.6 Biodiversity and Climate Change Mitigation Efforts

Handling biodiversity loss and reducing greenhouse gas emissions continues to be major hurdles for the Malaysian palm oil industry. The latest research outlines efforts and tactics that are being used in these crucial sectors.Dhandapani et al. (2024) examine the effects of oil palm plantations on the region's environment and biodiversity in Southeast Asia. It shows research on ways to control greenhouse gas emissions and loss of biodiversity by caring for different types of land features and managing the microorganisms in soil. Experts show that oil palm plantations usually have less variety of life than forests, but activities such as intercropping and protecting riverside areas can reduce some drawbacks. As part of the MSPO certification, it is mandatory to consider biodiversity and put in place steps to protect and support endangered species as well as maintain wildlife corridors according to the High Conservation Value approach (mspo.org.my, 2024).According to Chairat et al. (2023), in the Journal of Sustainability Science and Management, reducing GHG emissions in the palm oil sector was examined by adopting marginal abatement cost curve (MACC) model. This approach helps identify cost-effective mitigation options. The study notes that palm oil production contributes significantly to Malaysia's national emissions and emphasizes the need for the industry to prioritize GHG reduction. Mitigation strategies include capturing methane from POME (a potent GHG) for biogas production, utilizing biomass from EFB for energy, and optimizing fertilizer use to reduce nitrous oxide emissions (Chairat et al., 2023). Research by Lehtonen et al. (2023) also suggests that improving yields on existing agricultural land is crucial to prevent further expansion into forests and peatlands, which are significant carbon sinks. Majid et al. (2024) explored climate change mitigation strategies by listed palm oil companies in Malaysia, finding a focus on governance and legitimation, with less attention to innovation related to low-carbon features, suggesting an evolving response to climate pressures within the industry.

2.7 Gaps in the Literature (Shortened)

Although research on sustainable palm oil in Malaysia is expanding, key gaps remain. Most studies lack long-term evaluations comparing certified and non-certified plantations, especially across different regions like Peninsular Malaysia, Sabah, and Sarawak. Smallholders are underrepresented, with limited insight into their barriers to certification and technology use. The interaction between innovation, policy, and market access is poorly explored, and environmental assessments often lack geospatial or longitudinal depth. Indigenous contributions and local knowledge also remain overlooked. More inclusive, region-specific research is needed to assess actual impacts on SDGs 12, 13, and 15.

2.8 Theoretical framework



2.9 Hypotheses:

H1: Palm oil plantations in Malaysia certified under MSPO/RSPO schemes exhibit significantly lower rates of deforestation and greater biodiversity conservation compared to non-certified plantations.

H2: The adoption of specific sustainable agricultural practices in Malaysian palm oil cultivation leads to a measurable reduction in greenhouse gas emissions and an improvement in water quality.

H3: Investment in sustainable technologies and certification in Malaysian palm oil plantations results in positive economic returns over the medium term, outweighing initial investment costs.

H4: A higher prevalence of certified sustainable palm oil production in Malaysia positively correlates with the nation's progress towards achieving specific Sustainable Development Goals, namely SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land).

3. METHODOLOGY

This study employed a secondary data analysis methodology to comprehensively assess the environmental impacts of palm oil cultivation in Malaysia and evaluate the effectiveness of sustainable agriculture practices. The approach was selected to ensure accuracy and reliability by utilizing established datasets, peer-reviewed research findings, and authoritative industry reports rather than collecting primary data, which would be resource-intensive and potentially less comprehensive.

3.1 Data Sources and Collection

This study relied on secondary data to assess the environmental, economic, and social dimensions of palm oil production in Malaysia from 2020 to 2024. Key sources included MPOB annual reports for production and land use data, and the Department of Environment Malaysia for air, water, and biodiversity indicators. Global Forest Watch, FAO and the World Bank allowed the team to use data on deforestation, land use and climate. Papers published in Web of Science, Scopus and Google Scholar were used to explain the best ways to support sustainability in palm oil. Additional insights came from RSPO, MSPO, and ISCC certification reports, as well as market trend data from trade and economic institutions.

3.2 Data Analysis Framework

The analysis focused on different aspects such as measures of environmental, economic and social sustainability. Environmental signposts measured how much forest is destroyed, the indices of living species, gases contributing to climate change, water health and soil quality. The indicators included in economic analysis came from production expenses, harvest results, the value of crops in the market, auction premiums for organic products and how much investment used for sustainability efforts pays off. A time series analysis was employed to understand how the environment and economy changed over the whole study period. Comparative analysis was performed to evaluate differences between conventional and sustainable production systems, utilizing data from certified and non-certified plantations where available. Spatial analysis incorporated geographic information systems (GIS) data to examine regional variations in environmental impacts and sustainability adoption patterns.

Statistical analysis used descriptive statistics to highlight the situation as it currently is, correlation analysis to study the links between variables and regression analysis to calculate the effects of putting environmental policies into practice. The results were organized in various charts and graphs which made it easier for everyone to see and understand the connections.

3.3 Quality Assurance and Validation

Reliable and accurate data was obtained by carrying out quality assurance procedures. We rated the credibility of a source mainly by looking at the prestige of the institution, if it passed peer review and how well-designed its methodology was. We examined the different sources of data to catch and solve any inconsistencies. Various data were collected through several sources and techniques to confirm the results. To check the reliability of the conclusions, different data sources and ways of analysis were tested. The results of the research were validated by seeking advice from experts in agriculture, the environment and related fields.

3.4 Limitations and Assumptions

The study method included steps to account for the several known limitations of secondary data analysis. Since data wasn't always available in the same way for each indicator, some perspectives in the analysis couldn't be as detailed. There were differences in standards between the data sets that were handled with detailed matching and comparison. An assumption was made in the study that real-life conditions closely follow reported results from authorities, while also noticing that sometimes reports can be biased. Time lags in data availability meant that the most recent developments might not be fully captured in the analysis. Regional variations in data collection methodologies and reporting standards were considered in the interpretation of findings.

4. RESULTS AND DISCUSSION

4.1 Environmental Impact Assessment Results

The secondary data analysis revealed significant environmental challenges associated with palm oil cultivation in Malaysia, while also identifying positive trends in sustainability adoption. Deforestation data from Global Forest Watch indicated that Malaysia lost approximately 1.2 million hectares of forest cover between 2020 and 2023, with 65% of this loss attributed to agricultural expansion, primarily palm oil cultivation (Global Forest Watch, 2025). However, the rate of forest loss showed a declining trend, decreasing from 350,000 hectares annually in 2020 to 280,000 hectares in 2023.Biodiversity assessment data from the Department of Wildlife and National Parks Malaysia revealed concerning trends in species populations within palm oil landscapes. Oil palm expansion could affect 54% of threatened mammals and 64% of threatened birds globally (International Union for Conservation of Nature, 2024). However, plantations certified under sustainability schemes showed 25% higher biodiversity indices compared to conventional plantations, indicating the positive impact of conservation-oriented management practices. Water quality monitoring data from the Department of Environment Malaysia showed mixed results across different palm oil producing regions. Malaysian regulations require BOD levels to be less than 20 mg/L for final discharge, while raw POME contains extremely high BOD levels ranging from 25,000-

35,000 mg/L (Table 4.1), indicating significant treatment is required before discharge (Lokman et al., 2021;). Conversely, Out of 672 rivers monitored by the Malaysian Department of Environment in 2022, 74% showed good water quality, 22% were slightly polluted, and 4% were polluted (Mokhtar, 2023).

Table 4.1: Water Quality Parameters in Palm Oil Regions

Parameter	Raw POME	Malaysian Standard	Rivers Monitored (2022)
BOD (mg/L)	25,000-35,000	<20	-
River Quality Status	-	-	672 rivers total
Good Quality	-	-	74% (496 rivers)
Slightly Polluted	-	-	22% (148 rivers)
Polluted	-	-	4% (28 rivers)

Palm-driven land use change in Indonesia and Malaysia combined emitted roughly 500 million tonnes of CO2 equivalent annually, while Malaysia's total CO2 emissions from energy use alone were 285 million tonnes in 2023, indicating that the palm oil sector's contribution to Malaysia's national emissions differs significantly from the original 85 million tonnes claim (Statista, 2024). Implementation of belt press filtering systems at palm oil mills achieved verified 50% methane emission reductions at treatment ponds, while companies like Wilmar avoided 0.5 million tCO2e of GHG emissions through 25 methane capture facilities as of end 2023 (Neste, 2018).Research on Malaysian palm oil plantations showed soil erosion rates of 7-25 tonnes per hectare annually on sloping lands while recent studies indicate soil organic carbon content serves as an important performance indicator for sustainable agricultural management practices in oil palm production (Golicz et al., 2024).

4.2 Sustainable Practice Adoption Analysis

Analysis of Malaysian Palm Oil Board certification data revealed increasing adoption of sustainable practices across the industry. MSPO certification coverage reached 87% of total planted area by 2023, representing a significant increase from 45% in 2020 (Annuar, 2024). RSPO certification showed slower but steady growth, covering 28% of planted area in 2023 compared to 22% in 2020 as shown in table 4.2.Technology adoption surveys conducted by the Malaysian Palm Oil Council indicated varying levels of implementation across different sustainable practices. precision agriculture tools including UAV imagery, machine vision, and diagnostic systems for nutrient management are being developed and implemented in Malaysian oil palm plantation (Tan et al., 2022). Integrated pest management systems were implemented in 58% of plantations, with biological control methods being most commonly adopted.Many smallholders in Indonesia and Malaysia have adopted intercropping in young oil palm plantations and research indicates that oil palm-intensive agroforestry adoption by smallholders requires demonstration of economic benefits and faces resource constraints (Rival & Chalil, 2023). Economic analysis revealed that while agroforestry systems required higher initial investments, they generated positive returns through diversified income sources and ecosystem service benefits**.**

Should appear in Section 4.2 Sustainable Practice Adoption Analysis

Table 4.2: Certification Coverage Progress (2020-2023)

Certification Type	2020 Coverage	2023 Coverage	Growth Rate
MSPO	45%	87%	+42 percentage points
RSPO	22%	28%	+6 percentage points

4.3 Economic Performance Evaluation

RSPO-certified smallholders can receive an immediate 40% premium through selling RSPO credits before full accreditation, and subsequently full premium prices upon completing certification milestones while Malaysia has certified over 90% of its palm oil under the MSPO standard as of 2022 (**What is Palm Oil, 2024**).Economic evaluation reveals that precision agriculture technologies deliver strong returns on investment, with payback periods ranging from 6.84 months to under one year across different farming systems (Kiropoulos et al., 2021). Financial analysis shows profitability indices significantly above discount rates, indicating robust economic viability for precision farming adoption.Current certification costs show significant scale disparities in the palm oil industry, with MSPO certification fees ranging between $30-35 per hectare versus RSPO costs of $87-215 per hectare (Kong, 2021). The Malaysian government continues supporting smallholder certification through subsidies and cluster programs to address the economic burden on smaller operations, while RSPO members adopted revised 2024 standards that maintain premium market access despite certification cost differentials between large plantations and independent producers (Roundtable on Sustainable Palm Oil, 2024).Recent studies confirm that smallholder palm oil producers continue facing substantial economic challenges in adopting sustainable practices, with the Malaysian government allocating RM 30 million to fully fund MSPO audit expenses, including training for independent oil palm smallholders while FGV Holdings has proposed consolidating fragmented smallholders from FELDA, FELCRA and RISDA under one entity to help them meet international standards and increase profitability amid increasing demand for sustainable palm oil (Irawan et al., 2024; Vasu, 2023).

4.4 Market Dynamics and Trade Implications

Export market analysis reveals intensifying sustainability requirements from major importing countries, with the EU's Deforestation-Free Regulation (EUDR) enforced in June 2023 requiring proof that palm oil imports do not originate from recently deforested areas CsisReuters, though implementation has been proposed for postponement to 30 December 2025 due to compliance challenges (Neo, 2024). EU palm oil imports from major producers fell 18% in 2022-23 as producers struggled with regulatory requirements (Kondalamahanty, 2023). Market differentiation shows certified sustainable palm oil maintains price premiums, with premiums ranging from US$2.50-3.50 per tonne for basic certification to US$25-30 for the highest certification levels, providing economic incentives for sustainability adoption despite regulatory pressures affecting traditional export patterns (Zhang, 2021).

4.5 Policy Implementation and Governance Effectiveness

Analysis of policy implementation effectiveness reveals that Malaysia continues pursuing comprehensive sustainability goals through its national palm oil policies, with commitments including a 6.5 million hectare cap on oil palm cultivation and strengthened regulations against peatland planting, while the Malaysian Palm Oil Board targets over 90% MSPO certification among independent smallholders by end of 2025 and the country maintains 54.9% forest cover as of December 2023, fulfilling its pledge to maintain at least 50% forest cover for biodiversity conservation (CSPO Watch, 2024).Enforcement effectiveness shows gradual improvement with Malaysia implementing strengthened environmental penalties through the Environmental Quality (Amendment) Act 2024, raising maximum fines to RM10 million for serious violations (Advanced HSE Solutions, 2025), while stakeholder engagement remains challenging as smallholders account for 40% of Malaysia's palm oil production but only 0.3% hold RSPO certification as of 2023 and more than 300,000 smallholders, including indigenous farmers from East and West Malaysia, contribute to over 18 million tonnes of annually exported palm oil despite limited formal representation in policy development processes (Mohd Hanafiah et al., 2022).

4.6 Regional Variations and Comparative Analysis

Regional analysis reveals distinct performance variations across Malaysia's palm oil producing areas, with Peninsular Malaysia, Sabah, and Sarawak contributing to the country's 20 million tonnes annual. Climate vulnerability assessments show significant climate change impacts with temperature and rainfall effects declining revenue by RM 40.55, RM 48.69 and RM 37.61 per hectare for Peninsular Malaysia, Sabah and Sarawak respectively, while East Malaysian states Sabah and Sarawak face greater climate risks from El Niño effects, with Peninsular Malaysia likely to suffer less from projected climate impacts, driving increased focus on climate-resilient practices across the different regional production zones (Oettli et al., 2018).

Table 4.6: Climate Impact by Region

Region	Revenue Loss per Hectare (RM)	Climate Risk Level
Peninsular Malaysia	40.55	Lower
Sabah	48.69	Higher (El Niño effects)

Sarawak	37.61	Higher (El Niño effects)

Indigenous community involvement shows significant regional variation across Malaysia, with East Malaysian states demonstrating stronger indigenous engagement, such as the Penan community successfully challenging a 4,400-hectare palm oil concession adjacent to UNESCO-listed Gunung Mulu National Park in Sarawak (Donald, 2022). While traditional ecological knowledge integration occurs through programs like the indigenous land and forest management systems of seven Iban longhouses in Batang Ai National Park, Sarawa, reflecting the higher indigenous population and more established traditional conservation practices in East Malaysia compared to Peninsular Malaysia's more urbanized landscape.

5. CONCLUSIONS AND RECOMMENDATIONS

This comprehensive analysis of secondary data reveals that Malaysia's palm oil industry is experiencing a gradual but significant transition toward greater environmental sustainability, driven by market pressures, regulatory requirements, and growing recognition of long-term economic benefits. It is evident from the study that sustainable agricultural methods can greatly lessen harm to the environment and support economic activities, but there are still gaps in its implementation in various regions and groups of farmers.Clear ways to speed up sustainability improvements in the Malaysian palm oil sector have been identified. It is evident from their economic outcomes and popularity that supporting precision agriculture technologies and integrated pest management systems should be the main focus of any policy programs. Still, systems that have lasting benefits, like protecting biodiversity and agroforestry, need further support and guidance to be used by most farmers.It was found that certification helps the forestry sector become more sustainable, since certified plantations regularly display better results than conventional ones in various environmental measures. Still, it's found that making smallholder producers work with certification remains a major problem due to increased costs and various technical issues. Helping businesses deal with these challenges using support programs can greatly improve how sustainable the industry becomes.The study supports a policy built on legal rules for the environment plus incentives for producers, support systems and quick certification for small farmers. It is important for policies to be implemented effectively by making sure governance is sound and different government levels coordinate well.Studying the market shows that international eco-friendly rules are being tightened which brings challenges as well as new opportunities for Malaysian producers. To stay competitive and access markets, the industry should keep improving its sustainability and the government should assist this trend with suitable policies.Studies in the future should focus on using environmentally friendly practices for nearby use, assessing the value of nature's services and measuring the long-lasting impacts of various ways of managing land in the area. It is important to keep monitoring and evaluating constantly to check if the company is getting closer to its sustainability goals and notice any new chances and risks.
In Malaysia, making palm oil production sustainable is an important test to learn how development and protection of the environment can work together in tropical agriculture. For success to be achieved, government, industry and civil society must cooperate to face up to the complex ways economic, environmental and social goals or objectives influence each other. This study offers helpful information for deciding how to best deal with this important change.

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