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Article

Environmental Sustainability of Palm Oil Exports in Riau Province: Evidence from Deforestation, Carbon Emissions, and RSPO Certification

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ABSTRACT

The rapid expansion of Indonesia's palm oil industry has raised concerns regarding deforestation and carbon emissions, particularly in major producing regions such as Riau Province. This study aims to examine the relationship between palm oil exports and environmental sustainability by considering deforestation, carbon emissions, and RSPO certification during 2013–2023. The study employs a quantitative approach using secondary data, descriptive analysis, and regression-based assessment. The findings indicate that increases in palm oil export values are not consistently accompanied by higher deforestation, although export growth remains associated with environmental pressure through carbon emissions. Meanwhile, RSPO-certified plantation areas tend to be associated with lower deforestation and carbon emissions. These results suggest that environmental outcomes in the palm oil sector are influenced not only by export performance but also by sustainability governance mechanisms. The study recommends strengthening sustainability certification and environmental governance to support competitive and environmentally responsible palm oil development in Riau Province.

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INTRODUCTION

Palm oil is one of Indonesia's most strategic agricultural commodities and has played a significant role in supporting national economic development over the past two decades. The commodity contributes substantially to food and non-food industries, supports renewable energy development through biodiesel programs, and serves as a major source of foreign exchange earnings through exports. In addition, the palm oil sector provides employment opportunities and contributes to rural economic development, making it an important component of Indonesia's agricultural economy (Direktorat Jenderal Perkebunan, 2024).

Beyond its contribution to the trade balance, the palm oil industry is also a labor-intensive sector that significantly contributes to employment absorption and the improvement of rural livelihoods. As of 2024, Indonesia remains the world's largest palm oil producer, with total crude palm oil production exceeding 50 million tons annually. Palm oil and its derivative products continue to contribute substantially to Indonesia's export earnings and employment generation. According to plantation statistics published by the Directorate General of Plantations and Statistics Indonesia, the palm oil sector remains one of the most important contributors to agricultural output, export performance, and rural livelihoods in Indonesia (Direktorat Jenderal Perkebunan, 2024; BPS, 2024).

This contribution underscores the strategic role of palm oil in gross domestic product (GDP) formation, particularly through the plantation subsector as the backbone of the national agricultural sector.These figures highlight the continuing strategic importance of the palm oil industry to Indonesia's economy, trade performance, and rural development. At the regional level, recent evidence from Riau also highlights the continuing economic importance of oil palm production by demonstrating that diversification involving oil palm remains economically feasible and contributes to farmers' income and value creation, reinforcing the commodity's strategic role in regional rural development (Kusumawaty et al., 2025).

In addition to its role in international trade, palm oil has become an important feedstock for Indonesia's biodiesel program. Through the implementation of mandatory biodiesel blending policies, including the B30 and B35 programs, the government has sought to reduce dependence on fossil fuel imports, strengthen domestic energy security, and support the transition toward renewable energy sources. These policies have further increased the strategic importance of the palm oil sector within Indonesia's broader energy and economic development agenda (Kementerian Energi dan Sumber Daya Mineral, 2024).

Nevertheless, the strengthening of palm oil's economic role has been accompanied by significant environmental challenges. The expansion and intensification of oil palm plantations are often associated with increased pressure on natural resources, particularly deforestation, land degradation, and rising carbon emissions. Riau Province is among the regions with relatively high rates of forest cover loss over the past two decades, particularly within carbon-rich peat swamp forest ecosystems. These peatlands are globally recognized as high-carbon landscapes because drainage, land conversion, and peat fires can generate disproportionately large greenhouse gas emissions relative to the area affected (Global Forest Watch, 2023; IPCC, 2022). This situation highlights a fundamental economic–environmental trade-off between the benefits of export-led growth and the environmental costs associated with deforestation and carbon emissions, particularly in the context of national and global commitments to climate change mitigation.

Recent studies in environmental economics suggest that the relationship between economic growth and environmental degradation is often complex and context-dependent rather than strictly linear. While economic expansion may increase pressure on natural resources through land-use change, energy consumption, and production activities, improvements in environmental governance, technological innovation, and sustainability policies can mitigate these impacts and promote more sustainable development pathways (Ahmed et al., 2022; Wang et al., 2023; UNEP, 2023).

The conceptual logic underlying this perspective is often illustrated by the Environmental Kuznets Curve (EKC), which proposes an inverted U-shaped relationship between economic development and environmental degradation. In the early stages of economic growth, environmental pressure tends to increase as production and resource use expand. However, beyond a certain turning point, improvements in technology, environmental awareness, regulatory quality, and sustainability governance may contribute to reducing environmental degradation. Although the present study does not explicitly test the EKC hypothesis, the framework provides a useful conceptual reference for understanding the potentially non-linear relationship between export-oriented economic activities and environmental outcomes.

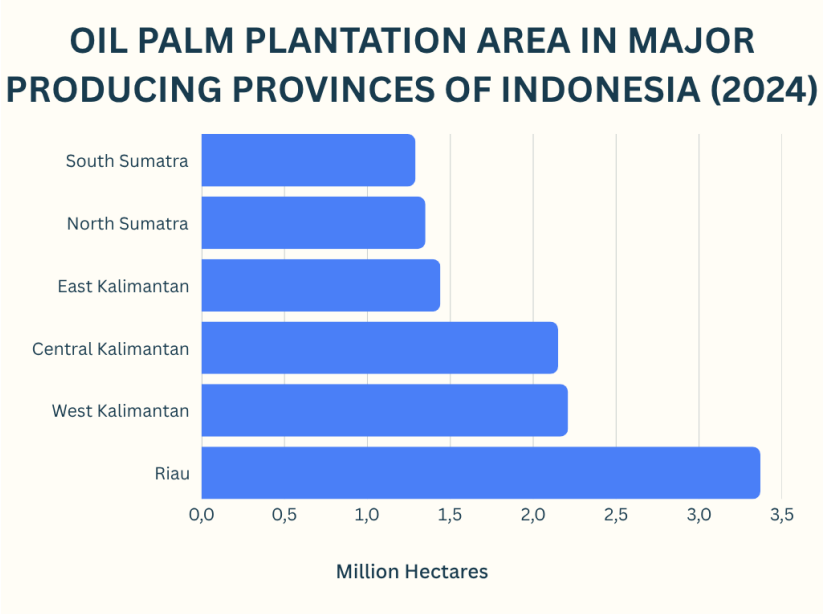


Figure 1
Oil Palm Plantation Area in Major Producing Provinces of Indonesia, 2024
Source: (BPS, 2025)

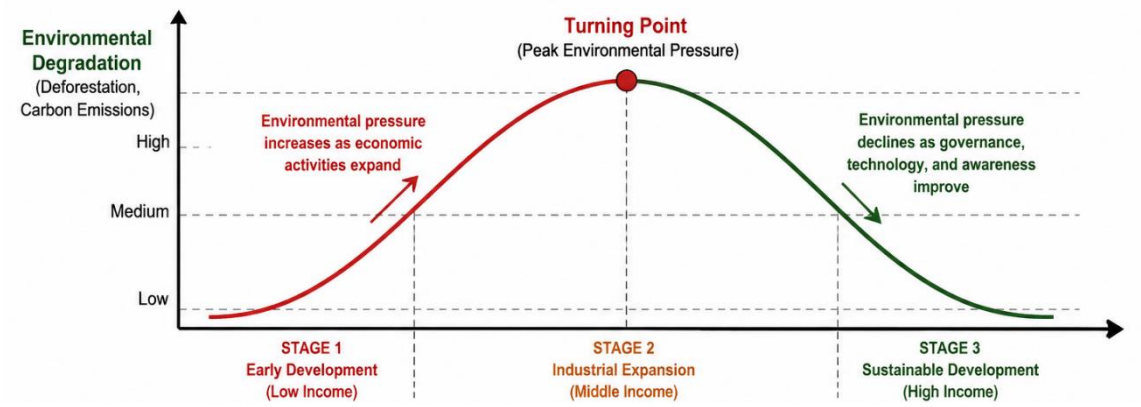


Figure 2
Conceptual Illustration of the Environmental Kuznets Curve (EKC)
Source: (Leal & Marques, 2022)

In the agricultural sector, production expansion remains one of the major drivers of environmental change, particularly through deforestation, biodiversity loss, and greenhouse gas emissions associated with land conversion (IPCC, 2022). In the case of palm oil, several recent studies have reported that plantation expansion may contribute to forest loss and carbon emissions, especially in regions characterized by weak environmental governance and extensive land conversion practices (Meijaard et al., 2020). However, sustainability initiatives, including certification schemes and improved land-use governance, have been increasingly recognized as mechanisms that can reduce environmental pressures while maintaining economic benefits from agricultural exports (Santika et al., 2021).

To address growing environmental concerns associated with palm oil production, sustainability certification has emerged as an important governance instrument. In Indonesia, two major certification schemes are widely recognized: the Indonesian Sustainable Palm Oil (ISPO) and the Roundtable on Sustainable Palm Oil (RSPO). ISPO is a government-led and mandatory certification system designed to ensure compliance with Indonesian laws and sustainability regulations, whereas RSPO is a voluntary multi-stakeholder certification scheme that applies internationally recognized environmental and social standards. While RSPO aims to promote sustainable palm oil production through internationally recognized standards, previous studies have shown that certified smallholder plantations generally demonstrate higher

sustainability performance than non-certified plantations, particularly across environmental and institutional dimensions (Toyyibah et al., 2025; Majid et al., 2021). This suggests that certification may contribute to improving environmental governance within Indonesia's palm oil sector. Consequently, these certification systems are increasingly regarded as important mechanisms for balancing export competitiveness with environmental sustainability.

The differences between ISPO and RSPO can be observed in terms of governance structure, implementation mechanisms, and environmental objectives. Although both certification schemes promote sustainable palm oil production, they differ in regulatory orientation, target actors, and market functions. A conceptual comparison of the two certification systems is presented in Table 1.

Against this background, this study focuses on analyzing the relationship between palm oil export dynamics, deforestation, and carbon emissions in Riau Province the largest palm oil-producing region in Indonesia while evaluating the role of RSPO certification as a sustainability governance instrument in promoting environmental sustainability and supporting access to sustainability-oriented export markets during the period 2013–2023. This study does not explicitly aim to test causal relationships; rather, it seeks to identify patterns of association and interlinkages among economic, environmental, and governance variables in the regional management of the palm oil sector.

In addition to their environmental objectives, sustainability certifications have become increasingly important for maintaining market access, particularly in export destinations where consumers, regulators, and multinational buyers demand compliance with sustainability standards. Consequently, certification is often viewed not only as an environmental governance instrument but also as a strategic mechanism for enhancing the competitiveness of palm oil products in international markets.

The primary contribution of this study lies in its integrated examination of economic, environmental, and governance dimensions of palm oil export development, thereby providing a more comprehensive understanding of the sustainability challenges faced by resource-based regions such as Riau Province.

From an academic perspective, the study contributes to the growing literature on sustainable trade, environmental governance, and the potential decoupling of economic performance from environmental degradation in resource-based commodity sectors. By incorporating deforestation, carbon emissions, and sustainability certification within a unified analytical framework, the research provides empirical evidence on how export-oriented agricultural development can be aligned with environmental sustainability objectives in developing regions.

Table 1
Key Differences between ISPO and RSPO Certification Schemes

Aspect	ISPO	RSPO	Environmental Relevance
Status	Mandatory (national)	Voluntary (international)	Combination of regulatory and market-based governance
Primary focus	Regulatory compliance	NDPE, HCV, GHG standards	Environmental sustainability and emission reduction
Target actors	All palm oil producers in Indonesia	Export-oriented producers and global supply chains	Sustainability compliance and market incentives
Governance approach	Government-led certification	Multi-stakeholder certification	Complementary governance mechanisms
Findings reported in previous studies	Associated with improved legal compliance and land governance	Associated with lower deforestation and emission risks	Enhanced environmental performance
Relevance to Riau Province	Supports peatland and forest governance policies	Supports access to sustainability-sensitive export markets	Green growth transition

Source: Majid et al., 2021; Hutabarat et al., 2023 and Official Certification Documents from RSPO, 2024 and the ISPO Commission, 2024

Table 2
Operational Definition of Variables, Indicators, Units, and Data Sources

Concept	Proxy/Indicator	Unit	Data Source
Palm Oil Export Dynamics	Annual Palm Oil Export Value	Million USD	Statistics Indonesia (BPS)
Deforestation	Annual Deforested Area	ha/year	Forest Watch Indonesia (FWI)
Carbon Emissions	Estimated CO_2e Emissions	ton CO_2e/year	Ministry of Environment and Forestry (KLHK)
Sustainability Certification	Certified oil palm Plantation Area (RSPO)	Hectares (ha)	RSPO

Source: Compiled by the authors from Statistics Indonesia (BPS), Forest Watch Indonesia (FWI), the Ministry of Environment and Forestry (KLHK), and the Roundtable on Sustainable Palm Oil (RSPO).

From a policy perspective, the findings provide evidence-based insights for designing palm oil development strategies that balance export competitiveness, environmental protection, and sustainability objectives. The study also highlights the role of RSPO certification as a governance instrument that can support more sustainable and low-carbon development pathways in Riau Province.

RESEARCH METHOD

This study employs a quantitative approach based on secondary data to analyze the relationship between palm oil export dynamics, deforestation, carbon emissions, and the role of sustainability certification under the ISPO and RSPO schemes in Riau Province. The selection of Riau Province as the study area is motivated by its position as one of Indonesia's major centers of palm oil production and exports, as well as a region experiencing relatively high environmental pressure, particularly in terms of deforestation and carbon emissions. These conditions make Riau Province a relevant empirical setting for examining the interlinkages between the economic performance of the palm oil sector and environmental sustainability issues.

The data used consist of annual time-series observations covering the period from 2013 to 2023. This period is particularly interesting because it captures several important transformations in the palm oil sector, including fluctuations in global commodity prices, evolving sustainability standards in international markets, the expansion of RSPO certification, and policy initiatives aimed at strengthening forest and peatland governance. These developments make the period especially suitable for exploring the associations among palm oil exports, environmental pressures, and sustainability governance in Riau Province.

The dataset includes several key variables. The economic variable is represented by the value of palm oil exports measured in U.S. dollars (USD). Environmental variables include annual deforestation area (hectares) and estimated carbon emissions resulting from land-use change (tons of CO_2e). The governance and sustainability dimension is proxied by the area of oil palm plantations certified under the Roundtable on Sustainable Palm Oil (RSPO) scheme, measured in hectares. RSPO-certified area is used as an indicator of the adoption of sustainability standards because the certification explicitly incorporates environmental, social, and traceability requirements that are relevant to sustainable palm oil production and international market access.

All data were obtained from official and credible sources, including Statistics Indonesia (BPS) for palm oil export and regional economic data, Forest Watch Indonesia (FWI) for deforestation data, the Ministry of Environment and Forestry (KLHK) for carbon emission data, the Food and Agriculture Organization (FAO) and the World Bank for international trade and price information, and annual RSPO reports for sustainability certification data.

The analysis was conducted in two main stages: descriptive analysis and inferential quantitative analysis. Descriptive analysis was used to illustrate trends in palm oil export values, deforestation area, carbon emissions, and the adoption of ISPO and RSPO certification in Riau Province over the observation period. The descriptive results are presented through tables and trend graphs to illustrate temporal dynamics and explore potential associations among palm oil exports, deforestation, carbon emissions, and sustainability certification over the observation period.

The second stage of analysis employs multiple linear regression to examine the associations among the economic, environmental, and governance variables. Multiple linear regression was selected because it enables the estimation of the relationship between one dependent variable and multiple explanatory variables simultaneously, thereby allowing the relative contribution of each factor to be assessed while controlling for other variables in the model. This approach is considered appropriate for the study because the objective is not to establish causality but to identify statistical relationships and patterns of association among palm oil exports, environmental indicators, and sustainability certification over the observation period. In general, the empirical model is specified as follows:

$$DEF_t = \beta_0 + \beta_1 EX\ P_t + \beta_2 RSPO_t + \varepsilon_t \quad (1)$$

$$CO2_t = \beta_0 + \beta_1 EX\ P_t + \beta_2 RSPO_t + \varepsilon_t \quad (2)$$

Where DEF_t represents annual deforestation area, $CO2_t$ denotes carbon emissions resulting from land-use change, $EX\ P_t$ refers to the value of palm oil exports, $RSPO_t$ represents the total area of oil palm plantations certified under the RSPO schemes, and ε_t is the error term. To improve variance stability and allow for elasticity-based interpretation of the relationships among variables, the model is also estimated in its natural logarithmic form.

Two separate regression models are estimated because the study focuses on two environmental outcome variables. The first model evaluates the association between palm oil exports, RSPO certification, and deforestation, while the second model examines the association between palm oil exports, RSPO certification, and carbon emissions. Estimating these relationships separately allows each environmental dimension to be interpreted independently and provides a clearer understanding of the interactions between export performance, sustainability certification, and environmental outcomes within the palm oil sector.

Given the limited number of annual observations (2013–2023), the regression results should be interpreted as indicative associations rather than definitive causal effects. The analysis is intended to provide exploratory empirical evidence regarding the interaction between export performance, RSPO certification, deforestation, and carbon emissions in Riau Province. Due to the limited sample size, the study prioritizes an exploratory regression approach and does not employ advanced time-series procedures such as unit root or cointegration tests, which generally require a larger number of observations to produce reliable results. Consequently, potential issues related to lagged effects, endogeneity, and omitted variable bias cannot be fully addressed and should be considered when interpreting the findings. Therefore, all estimated relationships are discussed as associative rather than causal and are intended to provide preliminary empirical evidence for policy discussion and future research.

Parameter significance is tested using partial (*t*)-tests and a joint significance (*F*)-test at the 5% significance level. The *t*-test is employed to evaluate the individual association of each independent variable with the dependent variable, while the *F*-test assesses the overall goodness of fit of the model. The explanatory power of the model is evaluated using the coefficient of determination (R^2).

Because the analysis is based on a relatively short annual dataset, the statistical results are interpreted as exploratory evidence of association rather than proof of causality. Therefore, the estimated coefficients are discussed primarily in terms of direction and statistical significance, while acknowledging the methodological limitations associated with small-sample time-series analysis.

To assess the robustness of the regression estimates, a series of classical assumption tests is conducted, including tests for residual normality (Kolmogorov–Smirnov), multicollinearity (Variance Inflation Factor/VIF), heteroskedasticity (Glejser test), and autocorrelation (Durbin–Watson). These diagnostic tests help evaluate whether the regression model satisfies the standard assumptions underlying ordinary least squares (OLS) estimation. This analytical approach is consistent with previous exploratory studies examining the interactions between agricultural commodity development, environmental change, and sustainability governance in developing-country contexts (Santika et al., 2021; Meijaard et al., 2020).

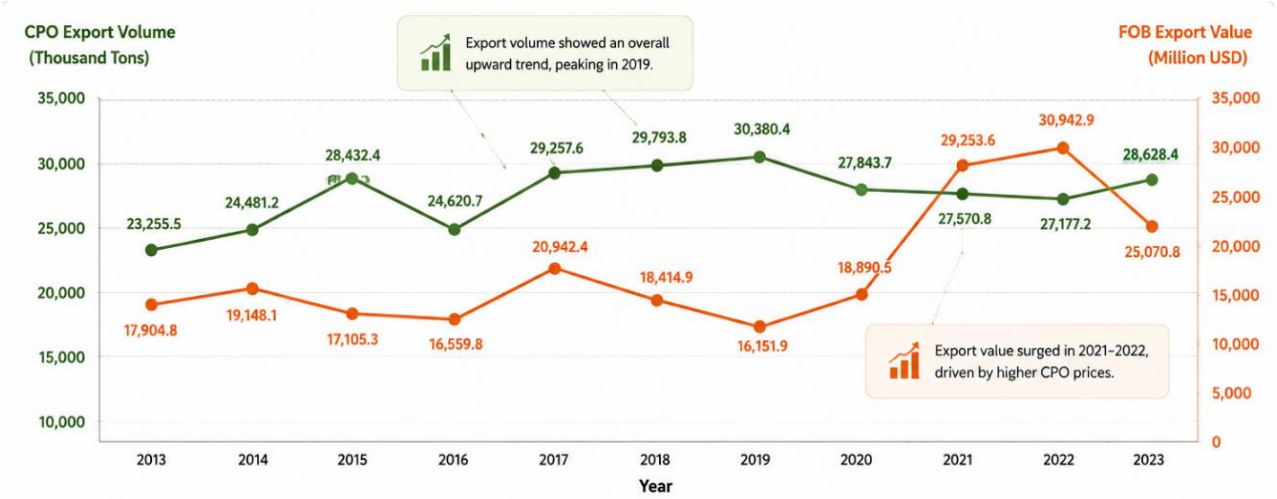


Figure 3
Trends in Palm Oil Export Volume and Value in Riau Province, 2013–2023
Source: (BPS, 2024)

RESULTS AND DISCUSSION

Trends in Palm Oil Exports, Deforestation, Carbon Emissions, and RSPO Certification in Riau Province

To provide an overview of the empirical context, this section first presents the temporal trends in the main variables analyzed in the study, including palm oil export performance, deforestation, carbon emissions, and RSPO-certified plantation area in Riau Province during the period 2013–2023. Examining these trends helps identify patterns of change and potential associations among the economic, environmental, and governance variables before proceeding to the regression analysis.

Over the period 2013–2023, palm oil exports from Riau Province exhibited an overall upward trend, although notable fluctuations were observed. Export volumes increased steadily and reached their highest level in 2019 before experiencing stagnation during the COVID-19 pandemic period. This stagnation can be attributed to disruptions in global supply chains, restrictions on labor mobility, logistical bottlenecks, and weakened demand from major importing countries, all of which affected international trade flows (UNCTAD, 2022; World Bank, 2023). Although global economic activity gradually resumed following the easing of pandemic restrictions, export recovery did not occur immediately during the early post-pandemic period because uncertainties in international markets, shipping constraints, and adjustments in commodity demand continued to affect trade performance (IMF, 2023; UNCTAD, 2023).

Nevertheless, export values increased sharply in 2021–2022 despite relatively stable export volumes. This surge was largely driven by the recovery of global demand following the pandemic, supply chain disruptions in major commodity markets, and rising prices of vegetable oils, which pushed international palm oil prices to historically high levels during this period (World Bank, 2023; FAO, 2023). As a result, export earnings increased substantially even without a corresponding expansion in export volumes.

A more substantial recovery became visible in 2023 as global economic conditions improved, international trade flows stabilized, and demand for vegetable oils strengthened (FAO, 2023; World Bank, 2024). Meanwhile, export values exhibited considerably greater volatility than export volumes, particularly during 2021–2022 when export earnings increased sharply despite relatively modest changes in physical export volumes. This pattern suggests that international price movements played a more important role than production or export volume in determining export revenues during this period. Similar findings have been reported by FAO (2023), which noted that fluctuations in global vegetable oil prices during the post-pandemic period were driven more by supply disruptions, energy market developments, and geopolitical factors than by changes in production volumes alone.

Although Indonesia is the world's largest producer and exporter of palm oil, international palm oil prices are largely determined by conditions in the broader global vegetable oil market. Price formation is influenced not only by palm oil supply but also by fluctuations in soybean oil, sunflower oil, and rapeseed oil markets, as well as energy prices, trade policies, geopolitical events, and demand conditions in major importing countries (World Bank, 2024; OECD & FAO, 2023). Consequently, Indonesia does not possess sufficient market power to unilaterally determine global palm oil prices and generally acts as a price taker

within an integrated international commodity market. This finding is consistent with the analysis of Gbegbelegbe et al. (2022), who argue that agricultural commodity prices are increasingly shaped by global market integration and cross-commodity substitution effects rather than by the production decisions of a single exporting country.

Deforestation data in Riau Province over the study period reveal a fluctuating pattern, with relatively high rates of forest loss during the early years and a tendency to decline following the strengthening of forest governance and land management policies. One of the primary drivers of deforestation in Riau has been the expansion of agricultural land, particularly oil palm plantations, as well as infrastructure development and other land-use conversion activities (Austin et al., 2017; Pendrill et al., 2019). The gradual decline in deforestation observed in several years may be associated with the implementation of forest moratorium policies, peatland protection measures, and stricter monitoring of land conversion practices by the Indonesian government (Gaveau et al., 2022; Ministry of Environment and Forestry, 2023). Nevertheless, renewed increases in deforestation during certain periods indicate that economic incentives, land demand, and pressures from commodity-based development continue to influence forest conversion.

An important characteristic of Riau Province is the extensive presence of peatland ecosystems, which contain exceptionally large carbon stocks. Consequently, reductions in the annual rate of deforestation do not necessarily translate into proportional declines in carbon emissions. Emission levels may remain high when forest loss, drainage activities, or land conversion occur in deep peat areas, where large amounts of stored carbon are released into the atmosphere. This helps explain why carbon emission trends are not always directly proportional to changes in deforestation rates throughout the observation period.

In addition, peatland fires have historically constituted one of the largest sources of carbon emissions in Riau Province. Major fire events, particularly those occurring in 2015 and 2019, generated substantial greenhouse gas emissions and contributed significantly to regional environmental degradation. These episodes illustrate that carbon emissions in peatland-dominated landscapes are influenced not only by deforestation itself but also by peatland degradation and fire occurrence, which can release emissions far exceeding those associated with conventional forest clearing practices (Huijnen et al., 2016; World Bank, 2021).

Carbon emissions exhibit a pattern broadly aligned with deforestation trends because forest clearing and land-use change release carbon stored in above-ground biomass and soil into the atmosphere. Consequently, higher levels of deforestation generally contribute to increased greenhouse gas emissions (IPCC, 2022). However, emission levels are not always proportional to the extent of deforestation. This discrepancy reflects differences in land biophysical characteristics, particularly the presence of peatlands that contain exceptionally large carbon stocks accumulated over thousands of years. The conversion or degradation of peatland areas can therefore generate substantially higher carbon emissions than deforestation occurring on mineral soils, even when the affected area is relatively small (IPCC, 2022). As a result, carbon emission intensity in Riau Province is influenced not only by the scale of forest loss but also by the ecological characteristics of the converted land.

Associations Between Palm Oil Exports, RSPO Certification, and Environmental Outcomes

The regression estimation results indicate that the deforestation and carbon emission models exhibit moderate explanatory power, with coefficients of determination (R^2) of 47.8% and 44.3%, respectively. These values suggest that a substantial proportion of the variation in environmental outcomes remains influenced by factors not included in the models, such as land-use policies, climatic conditions, commodity price fluctuations, and institutional factors. Therefore, the estimated relationships should be interpreted with caution and viewed as indicative associations rather than definitive causal effects.

In the deforestation model, palm oil export values display a positive but statistically insignificant coefficient. This finding suggests that increases in palm oil exports were not systematically associated with higher deforestation during the observation period. In contrast, the carbon emission model shows a positive coefficient that is statistically significant at the 10% significance level. Although this result indicates a possible association between export growth and increased carbon emissions, the relatively weak level of statistical significance suggests that the evidence should be interpreted cautiously.

Table 3
Multiple Log-Linear Regression Results for Deforestation and Carbon Emissions Models

Independent Variables	Model 1: Deforestation		Model 2: Carbon Emissions	
	Coef.	*Sig.*	*Coef.*	*Sig.*
(Constant)	17,996	0,565	-4,080	0,867
Palm Oil Export Value	3,266	0,304	4,453*	0,094
Sustainability Certification	-3,601**	0,029	-2,619**	0,040
Notes: * sig < 0.10; ** sig < 0.05				
R^2	0,478		0,443	
F-statistic	3,656*		3,187*	
Sig F	0,075		0,096	
Observations	10		10	

Source: Primary Data, 2026

RSPO-certified plantation area exhibits negative and statistically significant coefficients in both the deforestation and carbon emission models. These results suggest that greater adoption of sustainability certification is associated with lower environmental pressure. Nevertheless, given the limited number of observations and the correlational nature of the analysis, these findings should be interpreted as evidence of association rather than proof of causality.

In the sustainable export market access model, palm oil export values show a negative and statistically insignificant coefficient, whereas RSPO certification displays a positive coefficient that is statistically significant at the 10% level. This result suggests that sustainability certification may contribute to improved access to sustainable export markets; however, the statistical evidence remains relatively weak. The coefficient of determination (R^2) of 39.3% indicates moderate explanatory power, implying that market access is likely influenced by additional factors beyond those included in the model. Given the short annual time-series dataset (2013–2023), the absence of lag structures, and the potential for endogeneity and omitted variable bias, all regression results should be interpreted as preliminary empirical evidence of association. Table 1 presents the multiple regression estimation results for the three models: deforestation, carbon emissions and sustainable export market access.

Because the variables analyzed exhibit substantial differences in scale and are characterized by positive values, the regression models are also estimated using a natural logarithmic (log-linear) specification. Logarithmic transformation is commonly employed in economic and environmental studies to reduce skewness, improve variance stability, mitigate the influence of extreme observations, and linearize proportional relationships among variables. In addition, the log-linear specification enables the estimated coefficients to be interpreted as elasticities, indicating the percentage change in the dependent variable associated with a one-percent change in the explanatory variable (Wooldridge, 2020; Gujarati et al., 2021). The log-linear models can be expressed as follows:

$$lnDEF_t = \beta_0 + \beta_1 lnEXP_t + \beta_2 lnRSPO_t + \varepsilon_t \quad (3)$$

$$lnCO_{2_t} = \beta_0 + \beta_1 lnEXP_t + \beta_2 lnRSPO_t + \varepsilon_t \quad (4)$$

Where all variables are expressed in natural logarithmic form. The coefficients therefore represent elasticity estimates and describe proportional associations among the variables.

The Role of ISPO and RSPO Certification in Mitigating Environmental Impacts: An Economic–Environmental Transition

To provide a broader perspective on sustainability governance in the palm oil sector, Figure 4 presents a conceptual comparison between the Indonesian Sustainable Palm Oil (ISPO) and the Roundtable on Sustainable Palm Oil (RSPO) certification schemes. Although the empirical analysis in this study focuses on RSPO-certified plantation areas, both certification systems are relevant to understanding the evolving governance framework of sustainable palm oil production in Indonesia. The comparison highlights differences in regulatory orientation, implementation mechanisms, and potential contributions to environmental sustainability and market access.

Figure 4 illustrates contrasting trends between estimated carbon emissions and RSPO-certified plantation area in Riau Province during 2013–2023. While RSPO-certified area increased steadily from 150,000 ha in 2013 to 610,000 ha in 2023, carbon emissions exhibited substantial fluctuations across the observation period. Several emission spikes were observed in 2013, 2018, and 2022, whereas certification coverage expanded continuously throughout the period. This pattern suggests that increases in sustainability certification were not always accompanied by immediate reductions in carbon emissions, reflecting the influence of other factors such as peatland characteristics, forest fires, and historical land-use change dynamics.

The regression results suggest that the association between palm oil exports and environmental outcomes in Riau Province differs across environmental indicators. While palm oil export values do not exhibit a statistically significant association with deforestation, a positive association is observed between export values and carbon emissions. These findings indicate that the relationship between export performance and environmental pressure may be more complex than a simple one-to-one correspondence and may be influenced by additional economic, institutional, and environmental factors not included in the model.

The absence of a statistically significant association between palm oil exports and deforestation during the study period may reflect broader structural changes in Indonesia's palm oil sector, including improvements in forest governance, land-use regulation, and productivity enhancement efforts that reduce dependence on plantation area expansion (Gaveau et al., 2022; Austin et al., 2017). However, given the limited number of observations and the correlational nature of the analysis, this result should not be interpreted as evidence that export growth occurs independently of land-use change. Rather, it indicates that no statistically significant association was detected within the dataset used in this study.

It is also important to acknowledge that the estimated relationships may be affected by methodological limitations, including potential endogeneity, omitted variable bias, and the absence of explicit controls for lagged effects. Furthermore, because the study relies on a relatively short annual time-series dataset and does not employ unit root or cointegration testing, the findings should be interpreted as preliminary evidence of association rather than causal effects. In this context, references to the Environmental Kuznets Curve (EKC) serve only as a conceptual framework for understanding possible interactions between economic activity and environmental outcomes and should not be interpreted as empirical confirmation of a non-linear inverted U-shaped relationship.

In contrast, the weak positive association between exports and carbon emissions suggests that environmental pressure may extend beyond deforestation. Carbon emissions may be associated with indirect mechanisms, such as peatland degradation, production intensification on existing plantations, and lagged effects of past land-use changes. This pattern is consistent with the argument advanced by (Pendrill et al., 2019), who emphasize that emissions associated with land-based commodities are not always fully captured by annual deforestation indicators.

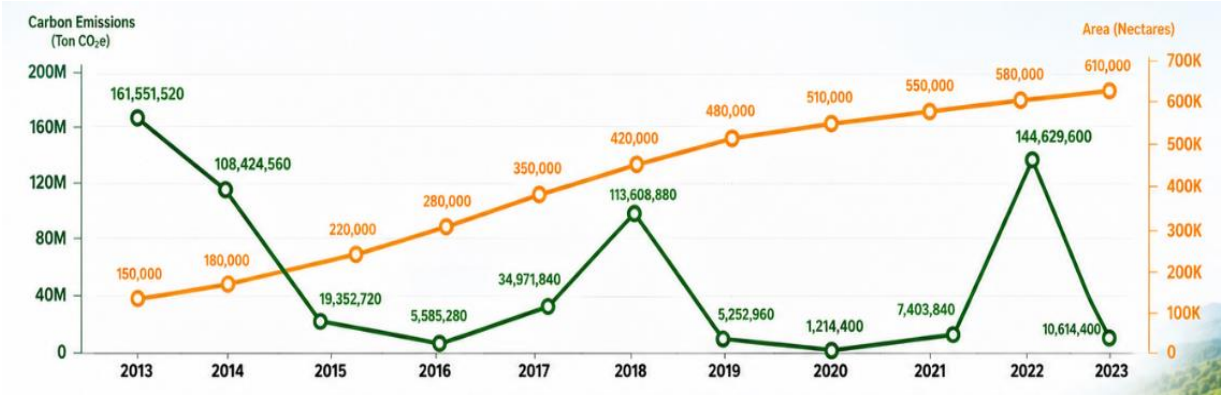


Figure 4
Trends in Sustainability-Certified Palm Oil Area and Deforestation in Riau Province, 2013–2023 (Hectares)
Source: (BPS, 2024)

RSPO certification consistently emerges as a governance factor associated with lower environmental pressure. The negative and statistically significant coefficient of the RSPO-certified plantation area variable suggests that greater adoption of RSPO standards is associated with lower levels of deforestation and carbon emissions in Riau Province. This finding is consistent with previous studies indicating that sustainability certification and zero-deforestation commitments may contribute to improved land management practices and reduced environmental impacts within the palm oil sector (Carlson et al., 2018; Morgans et al., 2022). However, given the correlational nature of the analysis and the limited number of observations, the results should be interpreted as indicative associations rather than evidence of causal effects.

From an environmental economics perspective, these results are consistent with the Environmental Kuznets Curve (EKC) framework, which posits that environmental pressure tends to increase in the early stages of economic growth but may decline as institutions and environmental policies are strengthened (Grossman & Krueger, 1995; Stern, 2004). In the context of Riau Province, the weakening relationship between exports and deforestation, coupled with a persistent association with carbon emissions, suggests a transitional phase from land-expansion–based growth toward a more intensive and regulated production pattern.

Findings related to export market access further indicate that increases in export values do not automatically translate into improved access to markets with high sustainability standards. Instead, sustainability certification acts as a key differentiating factor in strengthening market access. This result is consistent with the green growth and sustainable trade literature, which emphasizes the importance of governance quality and institutional signaling in determining product positioning in global markets (OECD, 2011).

Overall, the results of this study suggest that while trade-offs between palm oil export growth and environmental quality in Riau Province persist, they are not absolute. Strengthening sustainability certification and environmental governance has been shown to narrow these trade-offs, thereby supporting a transition toward greener economic growth.

Discussion of Regression Results and Policy Implications

The regression results provide insights into the complex interactions among palm oil export performance, environmental outcomes, and sustainability governance in Riau Province. Rather than establishing causal relationships, the findings highlight patterns of association that may reflect broader structural changes within the palm oil sector. The differing results across the deforestation and carbon emission models suggest that environmental impacts cannot be explained solely by export dynamics, but are also influenced by land-use characteristics, governance arrangements, and sustainability initiatives.

The absence of a statistically significant association between palm oil exports and deforestation may indicate that export growth during the study period was increasingly supported by productivity improvements and downstream industrial development rather than continuous expansion of plantation area. At the same time, the weak positive association between exports and carbon emissions suggests that economic expansion within the palm oil sector may be associated with environmental pressures through mechanisms other than direct forest conversion, particularly in regions characterized by extensive peatland ecosystems such as Riau Province.

The negative association between RSPO certification and both environmental indicators supports the argument that sustainability governance mechanisms may contribute to improved environmental performance. Although the results do not establish causality, they are consistent with the broader literature suggesting that certification schemes can encourage better land management practices, strengthen compliance with sustainability standards, and reduce exposure to environmentally harmful production practices (Santika et al., 2021; Morgans et al., 2022). Similar evidence has also been reported in the Indonesian context by Hamid et al. (2022), who found that ISPO-certified independent smallholders demonstrated better farm management and stronger compliance with sustainability-related practices. While their study emphasized social and farm-management indicators rather than environmental outcomes, it supports the broader view that sustainability certification may foster improved governance practices within Indonesia's palm oil sector.

CONCLUSION

This study examined the associations among palm oil export performance, deforestation, carbon emissions, and RSPO certification in Riau Province during the period 2013–2023. The results indicate that palm oil export values were not significantly associated with deforestation, suggesting that variations in deforestation during the observation period cannot be explained solely by export dynamics. In contrast, palm oil exports exhibited a weak positive association with carbon emissions, indicating that export-oriented development may still be linked to certain forms of environmental pressure. The study also found that RSPO-certified plantation area was negatively and significantly associated with both deforestation and carbon emissions, representing the most consistent empirical finding and suggesting that sustainability certification is associated with lower environmental pressure during the observation period. Overall, the findings indicate that the relationship between palm oil exports and environmental outcomes in Riau Province is complex and influenced by factors beyond export performance alone, with environmental sustainability appearing to be more closely associated with governance-related factors represented by RSPO certification. Nevertheless, because the analysis is based on a limited annual dataset and a correlational approach, these findings should be interpreted as statistical associations rather than causal relationships. Future studies employing longer time-series data, additional explanatory variables, and more advanced econometric techniques are recommended to provide more robust evidence on the relationships between palm oil exports, environmental sustainability, and governance mechanisms. This study is subject to several limitations. First, the use of province-level time-series data does not fully capture spatial heterogeneity and detailed biophysical characteristics, particularly differences between peatland and non-peatland areas, nor does it account for the aggregate nature of the carbon emission estimates. Second, the linear regression approach employed is intended to identify statistical associations rather than causal relationships; therefore, the results cannot be interpreted causally due to potential endogeneity, omitted variable bias, and long-term structural dynamics. In addition, the certification indicator is measured based on the total certified area and does not fully reflect the quality of implementation or potential leakage effects. Future research is encouraged to employ higher-resolution spatial panel data, integrate remote sensing datasets, and apply causal inference approaches such as difference-in-differences or instrumental variable techniques to more precisely identify the impacts of policy interventions and sustainability certification.

AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used Grammarly to assist with grammar checking, language editing, translation, and improving academic English writing. All outputs generated by these tools were carefully reviewed, verified, and revised by the authors to ensure the accuracy, clarity, and appropriateness of the content. The authors take full responsibility for the integrity, originality, and final content of this manuscript.

DATA AVAILABILITY

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

Ahmed, Z., Ahmad, M., Rjoub, H., Kalugina, O. A., & Hussain, N. (2022). Economic Growth, Renewable Energy Consumption and Ecological Footprint: Exploring The Role of Environmental Regulations and Democracy in Sustainable Development. *Sustainable Development, 30*(4), 595–605. https://doi.org/10.1002/sd.2251.

Austin, K. G., Mosnier, A., Pirker, J., McCallum, I., Fritz, S., & Kasibhatla, P. S. (2017). Shifting Patterns of Oil Palm Driven Deforestation in Indonesia and Implications for Zero-Deforestation Commitments. *Environmental Research Letters, 12*(12), 124012. https://doi.org/10.1088/1748-9326/aa8a2a.

Badan Pengelola Dana Perkebunan Kelapa Sawit (BPDPKS). 2024. *Biodiesel Program and Palm Oil Industry Development Report*. Badan Pengelola Dana Perkebunan Kelapa Sawit.

Badan Pusat Statistik. (2024). *Indonesian Foreign Trade Statistics 2024*. Badan Pusat Statistik.

Badan Pusat Statistik. (2024). *Provinsi Riau dalam Angka 2024*. Badan Pusat Statistik.

Carlson, K. M., Heilmayr, R., Gibbs, H. K., Noojipady, P., Burns, D. N., Morton, D. C., Walker, N. F., Paoli, G. D., & Kremen, C. (2018). Effect of Oil Palm Sustainability Certification on Deforestation and Fire in Indonesia. *Proceedings of the National Academy of Sciences, 115*(1), 121–126. https://doi.org/10.1073/pnas.1704728114.

Direktorat Jenderal Perkebunan. (2024). *Statistik Perkebunan Unggulan Nasional: Kelapa Sawit 2023–2025*. Direktorat Jenderal Perkebunan.

Food and Agriculture Organization of the United Nations. (2023). *FAOSTAT Statistical Database*. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat.

Food and Agriculture Organization (FAO). (2023). *Food Outlook: Biannual Report on Global Food Markets*. Rome: FAO.

Forest Watch Indonesia. (2023). *Potret deforestasi Indonesia*. FWI.

Gaveau, D. L. A., Locatelli, B., Salim, M. A., Husnayaen, Manurung, T., Descals, A., Angelsen, A., Meijaard, E., & Sheil, D. (2022). Slowing Deforestation in Indonesia Follows Declining Oil Palm Expansion and Lower Oil Prices. *PLOS ONE, 17*(3), e0266178. https://doi.org/10.1371/journal.pone.0266178.

Global Forest Watch. (2023). *Forest Loss Data for Indonesia*. World Resources Institute. https://www.globalforestwatch.org.

Hamid, E., Yanita, M., & Alamsyah, Z. (2022). Oil Palm Cultivation and Social Indicators of Independent Smallholders in Pompa Air: A Review. *Agriekonomika, 11*(2), 98–105. https://doi.org/10.21107/agriekonomika.v11i2.11345.

Hutabarat, S., Slingerland, M., Dries, L., & Reed, J. (2023). The evolution of Indonesian Sustainable Palm Oil (ISPO): Challenges and Opportunities for Sustainable Palm Oil Governance. *Journal of Cleaner Production, 398*, 136556. https://doi.org/10.1016/j.jclepro.2023.136556.

Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Mitigation of Climate Change*. Cambridge University Press.

International Monetary Fund (IMF). (2023). *World Economic Outlook 2023: Navigating Global Divergences*. Washington, DC: IMF.

Indonesian Sustainable Palm Oil Commission. (2024). *ISPO Certification System Guidelines*. Indonesian Sustainable Palm Oil Commission.

Kementerian Energi dan Sumber Daya Mineral. (ESDM). 2024. Handbook of Energy and Economic Statistics of Indonesia.

Kementerian Koordinator Bidang Perekonomian (2024). Indonesian Palm Oil Industry Performance Report 2023.

Kusumawaty, Y., Maharani, E., Tiara, R., Edwina, S., & Pebrian, S. (2025). Analysis of Income and Added Value of Oil Palm and Sugar Palm Diversification in Bandar Sei Kijang District, Pelalawan Regency. *AGRIEKONOMIKA, 1*4(1), 1-14. https://doi.org/10.21107/agriekonomika.v14i1.27151.

Leal, P. H., & Marques, A. C. (2022). The Environmental Kuznets Curve, environmental degradation, and energy consumption: A review of the empirical literature. *Environmental Science and Pollution Research, 29*(31), 47011–47036. https://doi.org/10.1007/s11356-022-19723-1.

Majid, N. A., Ramli, Z., Sum, S. M., & Awang, A. H. (2021). Sustainable Palm Oil Certification Scheme Frameworks and Impacts: A Systematic Literature Review. *Sustainability, 13*(6), 1-10. https://doi.org/10.3390/su13063263

Morgans, C. L., Meijaard, E., Santika, T., Law, E., Budiharta, S., Ancrenaz, M., & Wilson, K. A. (2022). Evaluating The Effectiveness of Sustainability Certification in Reducing Environmental Impacts of Palm Oil Production. *Conservation Letters, 15*(1), 1-7. https://doi.org/10.1111/conl.12852.

Meijaard, E., Brooks, T. M., Carlson, K. M., Slade, E. M., Garcia-Ulloa, J., Gaveau, D. L. A., Lee, J. S. H., Santika, T., Juffe-Bignoli, D., Struebig, M. J., et al. (2020). The Environmental Impacts of Palm Oil in Context. *Nature Plants, 6*(12), 1418–1426. https://doi.org/10.1038/s41477-020-00813-w

Meijaard, E., Garcia-Ulloa, J., Sheil, D., Carlson, K. M., Juffe-Bignoli, D., & Brooks, T. M. (2020). *Oil Palm and Biodiversity: A Situation Analysis by The IUCN Oil Palm Task Force*. IUCN Review Series.

OECD & FAO. (2022). *OECD-FAO Agricultural Outlook 2022–2031*. OECD Publishing. https://doi.org/10.1787/f1b0b29c-en.

OECD & FAO. (2023). *OECD-FAO Agricultural Outlook 2023–2032*. OECD Publishing.

Pendrill, F., Persson, U. M., Godar, J., & Kastner, T. (2019). Deforestation Displaced by International Trade: Revisiting The Role of Agricultural and Forestry Commodities. *Global Environmental Change, 56*, 1–10. https://doi.org/10.1016/j.gloenvcha.2019.03.005.

Roundtable on Sustainable Palm Oil (2024). RSPO Principles and Criteria for Sustainable Palm Oil Production.

Santika, T., Wilson, K. A., Law, E. A., St. John, F. A. V., Carlson, K. M., Gibbs, H. K., Morgans, C. L., Ancrenaz, M., Meijaard, E., & Struebig, M. J. (2021). Impact ff Palm Oil Sustainability Certification on Village Well-Being and Poverty in Indonesia. *Nature Sustainability, 4*(2), 109–119. https://doi.org/10.1038/s41893-020-00630-1.

Stern, D. I. (2004). The Rise And Fall of The Environmental Kuznets Curve. *World Development, 32*(8), 1419–1439. https://doi.org/10.1016/j.worlddev.2004.03.004.

Toyyibah, T., Mulyo, J. H., & Jamhari. (2025). Sustainability Status of RSPO-Certified and Non-Certified Smallholder Palm Oil in Kotawaringin Barat Regency. *AGRIEKONOMIKA, 14*(2), 234-243. https://doi.org/10.21107/agriekonomika.v14i2.27487.

United Nations Conference on Trade and Development (UNCTAD). (2022). *Review of Maritime Transport 2022*. Geneva: UNCTAD.

United Nations Conference on Trade and Development (UNCTAD). (2023). *Trade and Development Report 2023*. Geneva: UNCTAD.

United Nations Environment Programme (UNEP). (2023). *Emissions Gap Report 2023*. Nairobi: UNEP.

Vijay, V., Pimm, S. L., Jenkins, C. N., & Smith, S. J. (2021). The Impacts of Oil Palm on Recent Deforestation and Biodiversity Loss. *PLOS ONE, 16*(7), 1-16. https://doi.org/10.1371/journal.pone.0253009.

Wang, X., Zhang, Y., & Li, J. (2022). Environmental Governance, Economic Growth and Carbon Emissions: Evidence From Developing Economies. *Environmental Science and Pollution Research, 29*, 56721–56735. https://doi.org/10.1007/s11356-022-21058-5.

Wang, Z., Chandavuth, Y., Zhang, B., Ahmed, Z., & Ahmad, M. (2023). Environmental Degradation, Renewable Energy and Economic Growth Nexus: Assessing The Role of Financial and Political Risks. *Journal of Environmental Management*, *325*(Part B), 116678. https://doi.org/10.1016/j.jenvman.2022.116678.

World Bank. (2023). *Commodity Markets Outlook: Lower Prices, Little Relief*. Washington, DC: World Bank.

World Bank. (2024). *Commodity Markets Outlook: Outlook for Commodity Markets*. Washington, DC: World Bank.

World Bank. (2023). *World development indicators*. Washington, DC: World Bank.