Impact of Palm Oil Industry and Agricultural Growth on Carbon Dioxide Emission in Malaysia: ARDL Approach

MS. Ali[1], Rhm.Radzil[2*], SSS. Safian[3]

[1]Faculty of Plantation and Agrotechnology, University Technology MARA, 26400 Bandar Jengka, Pahang

[2]Faculty of Business and Management, University Technology MARA, 27600 Bandar Raub, Pahang

[3]Faculty of Business and Management, University Technology MARA, 42300 Bandar Puncak Alam, Selangor

***Corresponding author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.906000490

Received: 13 June 2025; Accepted: 19 June 2025; Published: 25 July 2025

ABSTRACT

Palm oil industry has significant contribution towards Malaysian economic and employment creation. However, apart from its massive contribution to economic generation and Malaysian GDP, the palm oil manufacturing is one of the activities that crucially claimed as a pollutant manufacturing and affects the environment. As worldwide consumers are predominantly aware on the importance of sustainability in production of goods, more company and industry are moving towards more sustainable approach in production activities including Malaysian palm oil manufacturing industry. The objectives of the study are to identify the impact from palm oil production, oil palm planted area and GDP towards carbon dioxide emission and to estimate the causality relationships between the determinants of carbon dioxide emission from the Malaysian palm oil industry. The unit root test will be used namely Augmented –Dickey Fuller Test (ADF) and Philip-Perron (PP) test for the initial data test. There is a mixture of stationary and non- stationary variables; the determinants identified by Auto Regressive Distributed Lagged (ARDL) method. Causality test used is Pairwise Granger Causality Test. The results indicate the existence of long run relationship among carbon dioxide emission with all the explanatory variables. Palm oil industry had improved their negative externalities by resulting negative relationship towards carbon dioxide emission through increasing planted area and agriculture output. Instead, the production of palm oil still has direct causality towards the carbon dioxide emission in Malaysia. The results clearly stated that the increase of carbon emission is parallel with the expansion of palm oil. Some action needs to be taken seriously in dampening the impact of this industry towards the environment and making it more sustainable while maintaining the economic viability of palm oil industry. The results also should strengthen the government action to made mandatory of MSPO certification for entire the palm oil supply chain in Malaysia.

Keywords: oil palm plantation, carbon dioxide emission, ARDL, MSPO certification, agricultural growth, sustainability

INTRODUCTION

Within the last few years, environmental issues are increasingly becoming more important to Malaysia and the world over. In Malaysia, palm oil manufacturing is one of the economic activities that crucially claim as pollutant manufacturing and affects the environment. This environmental pollution occurs due to the increasing of population and economic activities such as manufacturing, trading and transportation. The palm oil industry is aware of the environmental pollution and is striving for quality and environmental conservation through sustainable development and cleaner technology approach. Palm oil has played a transformative role in Malaysia's agricultural economy for decades. A key turning point occurred in 1974 with the establishment of

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VI June 2025

the Malaysian Palm Oil Board's predecessor agencies (PORLA and PORIM), which significantly enhanced research, development, and regulatory oversight (Basiron, 2007). By the 1980s, the Federal Land Development Authority (FELDA)had converted vast areas of rubber plantations to oil palm, fostering rural development and increasing agricultural productivity (Simeh & Tengku Ariff, 2007).

The 1990s and early 2000s saw a rapid industrialization of the palm oil sector, with downstream expansion into refining and oleochemicals. Malaysia became a global leader, accounting for over 50% of world exports during this period (Yusof & Bhattacharya, 2004). A major policy milestone occurred in 2004 with the formation of the Malaysian Palm Oil Board (MPOB), consolidating research and industry promotion under one agency (Basiron, 2007).

Between 2013 and 2016, the industry faced increasing global scrutiny over sustainability issues. In response, Malaysia introduced the Malaysian Sustainable Palm Oil (MSPO) certification in 2015, a voluntary initiative that later became mandatory to enhance sustainability and market access (MPOB, 2017). From 2019 to 2024, palm oil remained a vital contributor to agricultural GDP, accounting for about 37% of its total share in 2022 despite challenges from labor shortages and climate events (MPOB, 2023). Research suggests that replanting with higher-yielding varieties and downstream diversification have helped stabilize its contribution (Sharma et al., 2020). Thus, over the last five decades, palm oil has evolved from a land development tool into a cornerstone of Malaysia's agricultural economy, balancing economic output with increasing emphasis on sustainability.

As stated by Lee (2013), oil palm biomass production has been under criticism due to its negative impacts on the environment. The increased in palm oil-based are found to contribute to biodiversity loss, water, soil and air pollution as well as food security problems with it still stands as the most productive and efficient oil crop in the world. During plantation management processes and harvesting of the oil palm, large quantities of wastes including oil palm fronds, oil palm leave, oil palm trunks, and oil palm roots during replanting are generated with about 80 percent not utilized on commercial scale. Continuous environmental improvements are necessary and to remain competitive the oil palm industry must be prepared for new challenges ahead.

Figure 1 below shows production of palm oils in Malaysia increasing from the year 1974 to 2016. The production of palm oil in the year 1974 was only two thousand MT, the production increasing year after year. In the year 2013, the production of palm has reached 20 thousand MT, drops in the year 2014 to eighteen thousand MT but increased back to 21 thousand MT in the year 2016.

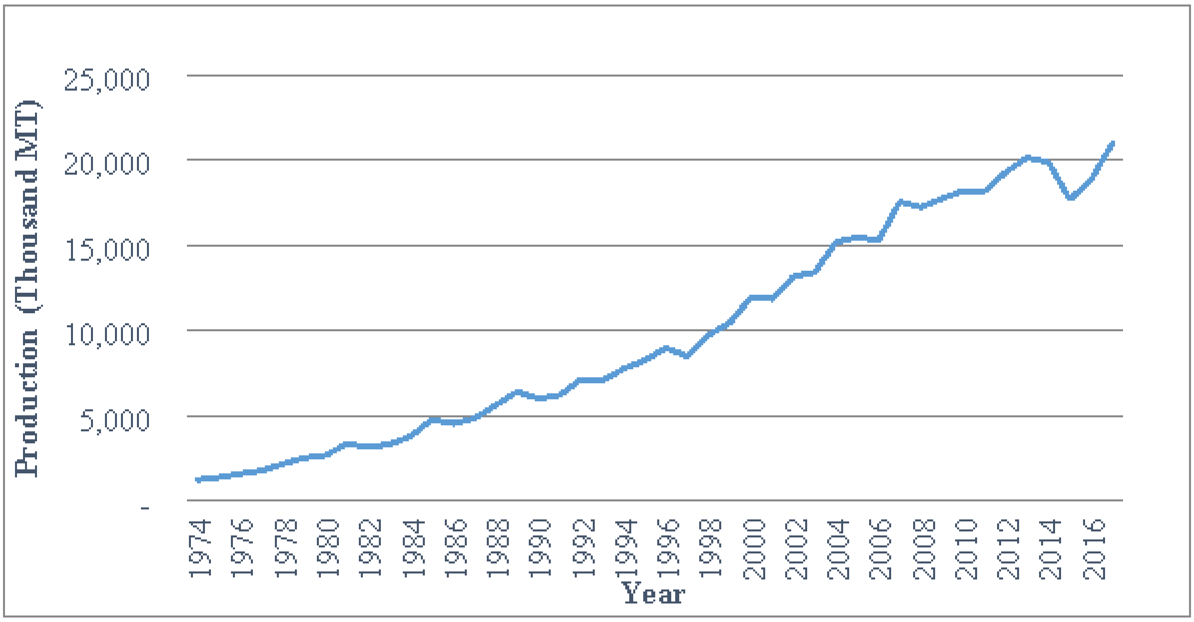

Fig. 1. Production of palm oils in Malaysia from year 1974 to 2016

Increases in carbon dioxide (CO^2) emissions will cause a gap between the ozone layer, which protects the earth from harmful rays coming from the sun. When the harmful rays enter the Earth's atmosphere, it raises the

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VI June 2025

temperature of the planet, which is known as the greenhouse effect. According to Intergovernmental Panel on Climate Change (IPCC) (2014), Electricity and Agriculture sectors are the main contributors to the emission of CO^2 with 25% and 24% respectively. The manufacturing of palm oil affects the environment as the emission of harmful carbon-based greenhouse gases such as CO^2 that dispose towards the mills and burning vegetation. CO^2 emission of Malaysia has been increasing year by year. CO^2 emission is the release of greenhouse gases and their precursors to the atmosphere over a specified area within a period. Moreover, CO^2 known as colorless, odorless, and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms.

Fig. 2. CO^2 emissions in Malaysia from year 1974 to 2014

Fig. 2 shows the CO^2 emissions from the year 1974 to the year 2014. It shows that increasing trend of the CO^2 emissions. From the graph, the emissions of CO^2 from the year 1997 to 1990 are below 10,000 gigagrams. However, the emissions have increased drastically from the year 1991 to eleven thousand gigagrams in the year 1991. The highest emissions of CO^2 were in the year 2009 where the emissions of are 16 thousand gigagrams.

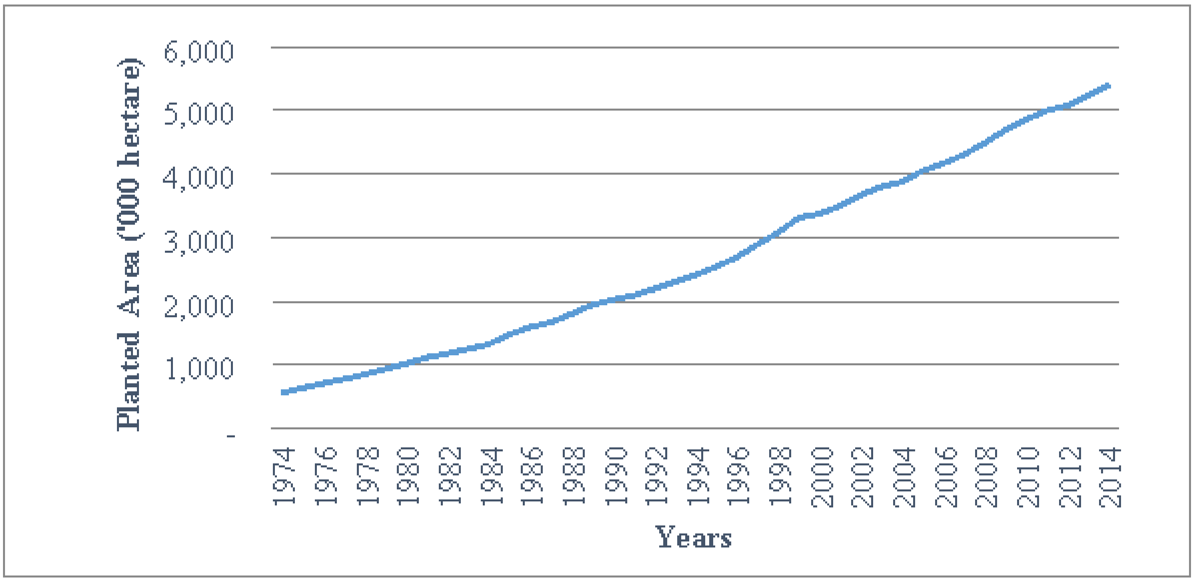

Fig.3. Land usage for oil palm plantation in Malaysia from 1974 to 2014

Fig.3 shows that the land usage to plant palm oil from the year 1974 to the year 2014. From the graph below, we can see that the land usage of palm oil plantation is increasing from year after year without drop. Started

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VI June 2025

from the year 1974 planted area was 8,000 hectares and until the year 2014, the plantation area has reached 5,300 thousand hectares.

Kuznet Curve theory revealed that developing countries tend to have increasing trend of CO^2 emission as increasing to the GDP. It shows the negative trend when countries reach the developed GDP income that denotes by inverted U- Shape curve. In the case of Malaysia as developing country, assumption that increasing to GDP will increase the CO^2 emission might be applicable. Therefore, the linkage of GDP, palm oil production, palm oil land area and CO^2 emission will be discussed in this study. The objectives of the study are to identify the impact from palm oil production, oil palm planted area and GDP towards carbon dioxide emission and to estimate the causality relationships between the determinants of carbon dioxide emission from the Malaysian palm oil industry.

Motivation

As the world second the largest palm oil producer, Malaysia faces a few challenges regarding the sustainability issues in the palm oil production. Transition to forest to oil palm plantation area claimed as a reason for species extinction in the Borneo. Besides, other vegetable oils producer countries claimed that open burning to clear the land for new oil palm plantation caused haze in the Southeast Asia region. To sustain the environment, there are rules and regulation provided to overcome the sustainability problem such as the establishment of Roundtable Sustainability of Palm Oil (RSPO). Due to high demand of sustainable palm oil, Malaysia has established their own certification of sustainable palm oil, which is Malaysian Sustainability of Palm Oil (MSPO) that be mandatory to all palm oil producer in Malaysia starting 1 January 2020. One of the crucial MSPO requirement is practicing environmental management of the plantation including protect riparian zones and biodiversity, properly manage chemical use and waste disposal, monitor, and reduce GHG emissions.

LITERATURE REVIEW

Carbon Dioxide (CO_2) Emissions and Economic Growth in Malaysia

The relationship between economic growth and environmental degradation, particularly carbon dioxide (CO_2) emissions, has been a central focus in environmental economics, especially in rapidly developing economies like Malaysia. Numerous studies have explored this dynamic within the framework of the Environmental Kuznets Curve (EKC), which posits an inverted U-shaped relationship between environmental degradation and economic development (Grossman & Krueger, 1995).

In the Malaysian context, the trend in CO_2 emissions has generally paralleled the country's economic growth since the 1990s. As Malaysia transitioned from an agriculture-based economy to an industrialized one, energy consumption from fossil fuels surged, contributing significantly to greenhouse gas (GHG) emissions (Ang, 2007). Between 2000 and 2020, Malaysia experienced consistent economic growth alongside increasing CO_2 emissions, supporting the early-stage EKC hypothesis where growth leads to environmental degradation. Ang (2007) conducted a time-series analysis and found a long-run unidirectional causality from GDP to CO_2 emissions, implying that economic growth significantly influences environmental outcomes. Similarly, Saboori et al. (2012) applied the autoregressive distributed lag (ARDL) bounds testing approach and confirmed the existence of an EKC in Malaysia, showing that emissions initially increase with GDP growth but decline after a certain income threshold. However, this turning point had not been conclusively reached within the study period, suggesting that Malaysia may still be in the upward phase of the EKC.

Ali et al. (2016) examined sectoral contributions to CO_2 emissions and found that energy-intensive industries, transportation, and agriculture significantly impact emission levels. They emphasized the role of energy policy and renewable energy adoption in flattening the EKC curve. This aligns with Azlina et al. (2014), who noted that energy consumption, especially from non-renewable sources, is a critical mediator between economic growth and CO_2 emissions.

Recent studies indicate a gradual decoupling of emissions from growth. Rahman and Vu (2020) applied the dynamic ordinary least squares (DOLS) method and found that renewable energy usage and energy efficiency improvements had begun to mitigate emissions without significantly affecting GDP. This implies the beginning of the downward slope of the EKC, particularly in sectors undergoing green transitions.

Though evolving, relationship between CO_2 emissions and economic growth in Malaysia. While early economic development was accompanied by rising emissions, recent trends and policy interventions hint at a potential EKC turning point, where environmental sustainability could coexist with continued economic progress.

Carbon Dioxide (CO_2) Emissions and Palm Oil Production

The expansion of palm oil production has been a significant driver of greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2), due to deforestation, peatland conversion, and energy-intensive processing practices. This literature review synthesizes key findings from 2000 to 2025, exploring how palm oil cultivation and processing impact CO_2 emissions, and how sustainable interventions may mitigate those effects.

Numerous studies identify land-use change, especially the conversion of peatland and forest areas into oil palm plantations, as the predominant source of CO_2 emissions. A systematic review by Khasanah et al. (2023) found that tropical peat swamp conversion results in an average carbon loss of 427 t C/ha, with annual emissions around 17 t C/ha. These emissions surpass those from most other agricultural land-use changes. Similarly, field trials in Sarawak, Malaysia, showed that oil palm cultivation on peat soil leads to continuous CO_2 efflux rates between 4.4 and 4.9 $\mu mol\ m^{-2}\ s^{-1}$ (MPOB, 2021). While nutrient-rich peatlands provide up to 40% more fresh fruit bunch (FFB) yield, they also exacerbate soil CO_2 loss.

Palm oil processing contributes significantly to GHG emissions, particularly through palm oil mill effluent (POME) and fossil energy use. Sutardjo et al. (2023) applied RSPO's PalmGHG model to a Cameroonian mill and estimated emissions of 22.3 t CO_2e per ton of crude palm oil (CPO), with land conversion (78%) and POME (21%) as the main contributors. By contrast, mills in Southeast Asia show lower emissions, averaging 1.6 t CO_2e/t CPO. This suggests both regional differences and the importance of technology adoption.

Lifecycle assessments confirm the impact of site-specific practices on CO_2 emissions. Compared to rapeseed, palm oil grown on peat emits more CO_2 (13.8 vs. 3.14 t CO_2e/t oil), but palm on non-peat soils is relatively more efficient (2.37 t CO_2e) (Pratiwi et al., 2022). Biomass utilization, such as producing pellets from empty fruit bunches (EFB) and palm trunks, shows mitigation potential. A study by Zulkefli et al. (2022) reported GHG emissions of 534–732 kg CO_2e/ton pellet, but displacing landfilled waste reduced net GHGs by 62–74%.

Advanced processing and compliance frameworks can substantially reduce palm oil's carbon footprint. A Malaysian roadmap developed by MPOC and Swinburne University (2024) highlights how MSPO-aligned practices like biogas capture from POME and biomass-based combined heat and power (CHP) can cut mill-stage emissions by 68.8%. In some cases, EFB-based solutions could even achieve net-zero operations.

Interestingly, rising atmospheric CO_2 may marginally offset production constraints. Global modeling by Teckentrup et al. (2023) using LPJmL4 showed that elevated CO_2 concentrations enhance palm oil yields, potentially buffering future productivity losses due to climate stress. However, this fertilization effect does not negate the environmental cost of further deforestation.

Overall, the literature consistently emphasizes that land-use change is the main driver of CO_2 emissions in palm oil production. Yet, targeted interventions in milling practices, waste valorization, and site-specific management offer viable emission reduction pathways. The challenge lies in aligning economic goals with ecologically sustainable practices.

Carbon Dioxide (CO_2) Emissions and Palm Oil Planted Area

The expansion of palm oil cultivation has been a major driver of carbon dioxide (CO_2) emissions in tropical regions over the past two decades. Numerous studies highlight that land conversion for palm oil plantations significantly elevates CO_2 emissions. For instance, Carlson et al. (2012) used spatial carbon bookkeeping in

West Kalimantan, Indonesia, and found that although oil palm occupied less than 10% of concession areas by 2008, it accounted for 27% of deforestation-related emissions. This discrepancy underscores how relatively modest expansions in planted area can disproportionately impact emissions when they target high-carbon landscapes such as peatlands and primary forests.

Peatland conversion for palm oil is particularly carbon intensive. Mos et al. (2023) measured CO_2 fluxes in Sarawak and found that drained peatlands emit around 53 t CO_2 per hectare annually for up to 30 years after conversion. These findings are supported by wider reviews (MDPI, 2024), which estimate emission rates between 12 and 76 t CO_2/ha/year on drained peat soils. Thus, increases in palm oil planted area on peatlands contribute significantly to long-term carbon emissions. Danylo et al. (2020) analyzed satellite-derived plantation age and area data across Southeast Asia and reported that over 50% of oil palm in Kalimantan was less than seven years old in 2017. This trend indicates recent expansion into new areas, often accompanied by land clearing, which drives immediate and intense CO_2 emissions. These findings emphasize that not only the size but also the maturity of planted areas affects emission profiles.

Replanting cycles also affect CO_2 flux. A study from Indonesia (JOPR, 2021) showed that newly replanted bare plots emitted around 59 t CO_2/ha/year, whereas intercropped plots with cover crops emitted significantly less. This suggests that land preparation practices during expansion or replanting influence the emissions intensity of a given planted area. In Malaysian Borneo, estimates by Hooijer et al. (2018) suggested that in 2018 alone, planted peatlands in Sabah and Sarawak emitted approximately 0.0166 Gt of carbon annually. Since these regions contain extensive peatland oil palm estates, managing further area expansion is critical to achieving climate targets.

Agricultural Growth, Palm Oil Expansion, and CO_2 Emissions to the Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve (EKC) hypothesis posits an inverted U-shaped relationship between economic development and environmental degradation, suggesting that pollution levels initially rise with economic growth but eventually decline after a certain income threshold is reached (Grossman & Krueger, 1995). This concept has been widely applied to assess CO_2 emissions across various sectors and is particularly relevant for Malaysia's agriculture-driven economy, where palm oil production plays a central role.

Agricultural GDP growth, especially when driven by commodity expansion like palm oil, has historically been linked to rising CO_2 emissions due to land-use changes, deforestation, and peatland drainage. Studies show that Malaysia's agricultural expansion in the early 2000s to 2010s was characterized by large-scale conversion of carbon-rich ecosystems, particularly in Sabah and Sarawak (Hooijer et al., 2018; Carlson et al., 2012). These land conversions led to significant emissions, situating the country on the upward slope of the EKC curve.

Carlson et al. (2012) noted that although oil palm plantations occupied less than 10% of concession areas, they accounted for over 27% of deforestation-related carbon emissions. This suggests that even modest increases in planted area during early development stages can result in disproportionate environmental costs. Mos et al. (2023) corroborated these findings by reporting long-term CO_2 emissions of up to 53 t/ha/year from peatland plantations in Sarawak.

As Malaysia's palm oil industry matured, there was a notable policy shift toward sustainability through mechanisms like the Malaysian Sustainable Palm Oil (MSPO) certification. This reflects a theoretical transition to the EKC's downward phase, where economic growth begins to support environmental improvement. Practices such as intercropping during replanting and reduced reliance on land expansion contribute to this shift (JOPR, 2021).

Furthermore, empirical studies suggest that the EKC framework can be expanded to sector-specific analyses. Jalil and Mahmud (2009) employed cointegration analysis in China and found a long-term EKC relationship for CO_2 emissions. Applying a similar approach to Malaysia, especially within the palm oil sector, could test whether recent GDP growth and increased efficiency have begun to decouple emissions from agricultural output.

Nevertheless, the persistence of emissions from peat-based plantations and continued land expansion indicate that Malaysia may still be on the ascending portion of the EKC curve. Danylo et al. (2020) revealed that over 50% of oil palm plantations in Southeast Asia were under seven years old in 2017, indicating recent expansion and associated emissions.

In conclusion, Malaysia's agricultural and palm oil sector is consistent with the early-to-mid stages of the EKC hypothesis, where economic benefits are accompanied by environmental costs. However, with increasing adoption of sustainable practices and certification schemes, there are signs of a gradual transition toward the turning point of the EKC, where further growth may contribute to environmental improvements rather than degradation.

METHODOLOGY

General Theoretical Framework

The theoretical framework based on the environmental Kuznet Curve (EKC) hypothesis. The environmental Kuznets curve is a hypothesized relationship between various indicators of environmental degradation and income per capita. In the early stages of economic growth, degradation and pollution will increase, but beyond some level of income per capita (which will vary for different indicators), the trend reverses and it became the turning point of the curve, so that at high-income levels economic growth leads to environmental improvement that makes the curve become the inverted U-shape.

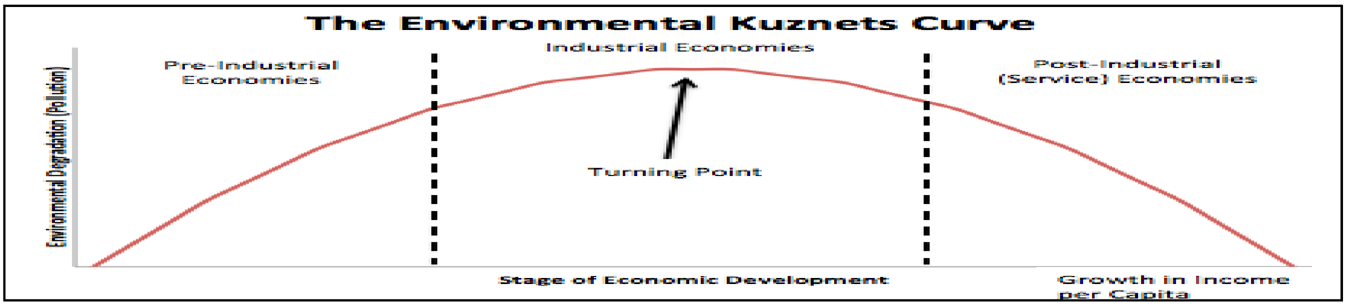

Fig 4. The environment Kuznets Curve

There are proximate factors can explain EKC. According to Stern (2003) , explanatory factors for EKC hypothesis include scale of production implies expanding production at given factor-input ratios, output mix, and state of technology, different industries that have different pollution intensities and typically, over the course of economic development the output mix changes, changes in input mix involve the substitution of less environmentally damaging inputs for more damaging inputs and vice versa, the improvements in the state of technology involve changes in both production efficiency and emission specific changes.

Therefore, the framework that identifies interaction of variables will be as follows:

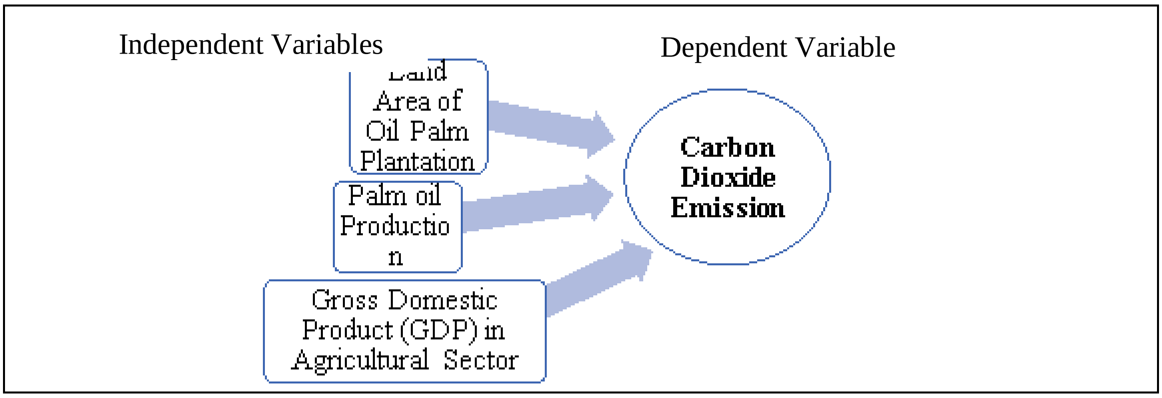

Fig.4. The theoretical framework of carbon dioxide emission from palm oil industry and agricultural output

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VI June 2025

Model Specification

This study attempts to identify the impacts of palm oil industry and agricultural growth towards the carbon dioxide emission in Malaysia and causality relationship between the variables. Therefore, general model specification for the objectives mentioned would be as follows:

$$\ln CO^2{}_t = \alpha_0 + \sum_{i=1}^{m} \beta_{1t} \ln AREA_{t-i} + \sum_{i=1}^{m} \beta_{2t} \ln PROD_{t-i} + \sum_{i=1}^{m} \beta_{3t} \ln GDP_{t-i} + \varepsilon_t$$

Where, $\ln CO^2$ is dependent variable stand for natural logarithm of carbon dioxide emission in Malaysia. Meanwhile, independent variables are $\ln AREA_{t-i}$ for natural logarithm of area planted with oil palm plantation, $\ln PROD_{t-i}$ for natural logarithm of palm oil production and $\ln GDP_{t-i}$ for natural logarithm of GDP in agricultural sector. The α_0 is represent the constant term while ε_t is represent the error term.

Variables Description

Dependent variable in this study is carbon dioxide emissions. Carbon dioxide emission is a harmful gas that emit from the manufacturing activity, planting activities and other natural process. The estimated measurement for carbon dioxide emission in the giga grams. This variable suitable to become a proxy to show the environment degradation as carbon dioxide emission is harmful and poisonous. Independent variables for this study consist of three namely palm oil production, oil palm planted area and GDP of agricultural sector. Palm oil production represent the proxy from the palm oil output as a whole. This variable represents industry output, which caused many activities that lead to carbon dioxide emission. This includes the milling, bulker and distribution process. The estimated measurement for palm oil production is in thousand metric tonnes per year.

Oil palm planted area is one of the proxies that can estimate the impact of land usage change in the palm oil industry. It is keep increasing year by year. Estimated measurement of the area plantation is in thousands hectare. The usage of different type of land for the plantation is suggested by most of the studies in palm oil industry. Therefore, this variable can shows the impact of land usage change in palm oil industry towards the carbon dioxide emission.

GDP from agricultural sector is used as the proxy to shows the agricultural growth in Malaysia. Thus, agricultural output from Malaysia is dominated by palm oil industry. This proxy are able to explain whether the agricultural growth in Malaysia that mostly comes from palm oil gives impact to the environment degradation in Malaysia or not. Estimated measurement for GDP is in USD billion per year.

Table 1. Summary Description of Explanatory Variables

Variables (Malaysia)	**Descriptions**	**Expected Results**
Oil palm planted area	Thousand hectares	Positive
Production of palm oil	Production of crude palm oil, thousand metric ton	Positive
Gross Domestic Product of agriculture sector	USD billion	Positive

EMPIRICAL METHODOLOGY

Unit Root Test is the first test to this research. The purpose of unit root test is to identify whether the data is in stationary or non-stationary trend. This is because the data use is time series data that might be possesses a unit root.

Econometric method of analysis adopted for this study is Autoregressive Distributed Lag Model (ARDL) developed by Pesaran, Shin and Smith (2001). To reached the objectives of this paper, ARDL is the best method because of cyclical components of data that makes standard cointegration technique unsuitable when there is a mixture of stationary or mixture of both I(0) and I(1) which are the result from unit root test. Diagnostic problem such as autocorrelation and omitted variables also could be avoided by adopted ARDL method. In addition, ARDL has a potential to produce an analysis on short run and long run relationship between variables in the model.

The model needs to continue with diagnostic checking. First is autocorrelation will be check by using Breusch Godrey LM Test; to determine the violation of classical assumption that different observations of the error term are not correlated with each other. Secondly, normality test by using Jarque Bera test. Thirdly is specification error test, Ramsey RESET test; to check whether the model is incorrect functional form or not. Fourth, heteroscedasticity test will be check using Breusch Pagan Godfrey; to check whether the error variance is in consistent or volatile for specific of time. Lastly is stability test, which is consists of CUSUM and CUSUMSQ; for checking the stability of the residual's series of data.

The next step is re-parameterization of ARDL Model into Error Correction Model (ECM). In research, there are mainly interested in long-run relationships between the variables under consideration, and to resolve this, the concept of cointegration and the ECM becomes imperative. With the specification of ECM, we now have both long run and short-run information incorporated. Lastly, Pairwise Granger Causality test conducted for analysing the causality between all the variables in a model. It called "pairwise" because the variables will be test in pair for the causality effect. This test is not a grouped test and the variables will be analyse individually.

Data Sources

This research will employ the data from various sources. This research will use time series data from 1974 to 2014 for all variables. In 40 years, it is sufficient for this research to get the outcome for the research objectives. The details of the variables are as follows:

Table 2. Data Sources for Variables

Data of Variables	**Sources**
Carbon dioxide emissions	Food and Agriculture Organization
Palm oil production	www.indexmundi.com
Oil palm planted area	MPOB & Department of Statistic, Malaysia
Gross Domestic Product in Agriculture	www.worldbank.org.com

RESULTS AND DISCUSSION

Descriptive Statistic and Correlation Matrix

Table 3. Descriptive Statistic

Variables	**Mean**	**Std.Dev.**	**Min**	**Max**	**Skewness**	**Kurtosis**	**Obs.**
$lnCO^2$	9.166516	0.405252	8.540057	9.730446	-0.348262	1.406132	40
lnAREA	14.61641	0.657228	13.24594	15.50047	-0.450550	2.053166	40
lnPROD	17.07476	0.933187	15.23930	18.10199	-0.629940	1.920042	40
lnGDP	2.207942	0.643591	1.049530	3.530045	0.417382	2.598365	40

Table 3 indicates the descriptive statistics of the variables included in analysis of carbon dioxide determinants. Four variables were used with the annual data for Malaysia in 40 years period. It is observed that palm oil production (lnPROD) variable have the highest vitality according to the standard deviation value. All data are in the positive range according to the minimum and maximum value. All the variables are negatively skewed except for agricultural growth (lnGDP).

Table 4. Correlation Matrix

Variables	$lnCO^2$	lnAREA	lnPROD	lnGDP
$lnCO^2$	1.000000			
lnAREA	0.936209	1.000000		
lnPROD	0.945737	0.984612	1.000000	
lnGDP	0.822653	0.909159	0.866605	1.000000

Table 4 shows the correlation matrix of the data used. It reveals the explanatory variables are positively correlated with carbon dioxide emission ($lnCO^2$) in a strong linear relationship. Although the variables are highly correlated, this might exist multicollinearity or significant amount of correlation among variables of non-stationary series. However with the ARDL-ECM model, it will considered a robust and dynamic method that designed specifically to reduce the multicollinearity problem. It will increase the reliability and stability of t-ratios in testing for statistical significance.

Estimation Results

Unit Root Test

Table 5. ADF Unit Root Test

Augmented Dickey-Fuller (ADF) Test				
	LEVEL (0)		**LEVEL (1)**	
Variables log ()	**Constant**	**Constant and Trend**	**Constant**	**Constant and Trend**
ln CO^2	-1.220634	-1.717963	-6.178155***	-6.153210***
ln AREA	-9.425105***	-2.987623	-3.229878***	-5.151921***
ln PROD	-2.208258	-1.062101	-7.577742***	-8.370370***
ln GDP	0.720477	-3.086747	-3.061035***	-3.146844

Table 6. PP Unit Root Test

Philip-Perron (PP) Test				
	LEVEL (0)		**LEVEL (1)**	
Variables log ()	**Constant**	**Constant and Trend**	**Constant**	**Constant and Trend**
ln CO^2	-1.209270	-1.792951	-6.180901***	-6.172457***
ln AREA	-9.620613***	-3.038931	-3.136618***	-5.172047***

ln PROD	-2.208258	-0.822699	-7.440961***	-8.370370***
ln GDP	-0.382168	-1.914933	-5.156307***	-5.077431***

Notes: The rejection of null hypothesis is based on Mackinnon's(1996) critical values. AIC is used to determine the lag length while testing the stationary of all variables.***,**,* indicate rejection of the null hypothesis of non-stationary at the 1%,5% and 10% significance level.

From Table 5 and Table 6, the results shows all variables are stationary at the first differentiation. Therefore, it is decided to use ARDL method for the next estimation.

Long Run ARDL Bound Test Cointegration Test

Table 7. ARDL bounds testing approach to co-integration with optimal lag 2,4 (1,4,0,3) K(3).

Test Statistic	**Value**	**Significant level**	**Bound**	**Critical Value**	**Decision**
			I(0)	**I(1)**	
F-statistic	15.10355	1%	3.65	4.66	No cointegration
k	3	5%	2.79	3.67	Inconclusive
		10%	2.37	3.2	Cointegration

Table 7 confirms the existence of long run association (cointegration) among the variables applied. The computed F-Statistic is greater than upper critical bound (15.10355***>4.66) at the 1 percent significant level. This confirms a long run association among the variables. It can be conclude that a long run cointegration exists among the estimated variables in Malaysia during 1974 to 2014.

Diagnostic Test for ARDL Regression

Table 8. Diagnostic test for ARDL regression

Test	**Null Hypothesis**	**Prob. F**
Breusch-Godfrey Serial Correlation LM Test	H_0: There is no autocorrelation	0.9943
Breusch-Pagan-Godfrey	H_0: There is no heteroskedasticity	0.2080
Jarque-Bera test	H_0: The error terms has a normal distribution	0.9814
Ramsey REST test	H_0: Functional form is linear	0.2835

Note : The LM test is used to check for autocorrelation and Ramsey's RESET test for functional form. The test for normality is based on the J-B test and heteroskedasticity is based on the BPG test (all the probability value must be greater than 0.05 value,5% level)

Table 8 shows the diagnostic test for ARDL estimation for the first model variables were conducted. The result shows no evidence of autocorrelation or the heteroskedasticity effect in the estimated model. The model also passes the Jarque-Bera normality test at the 5 percent level , that suggesting the error is normally distributed in the model , and the Ramsey reset specification test that functional form used is linear . All the diagnostic checks for the model reject the null hypothesis that the model is not the best fit against the alternative hypothesis.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VI June 2025

Stability Test

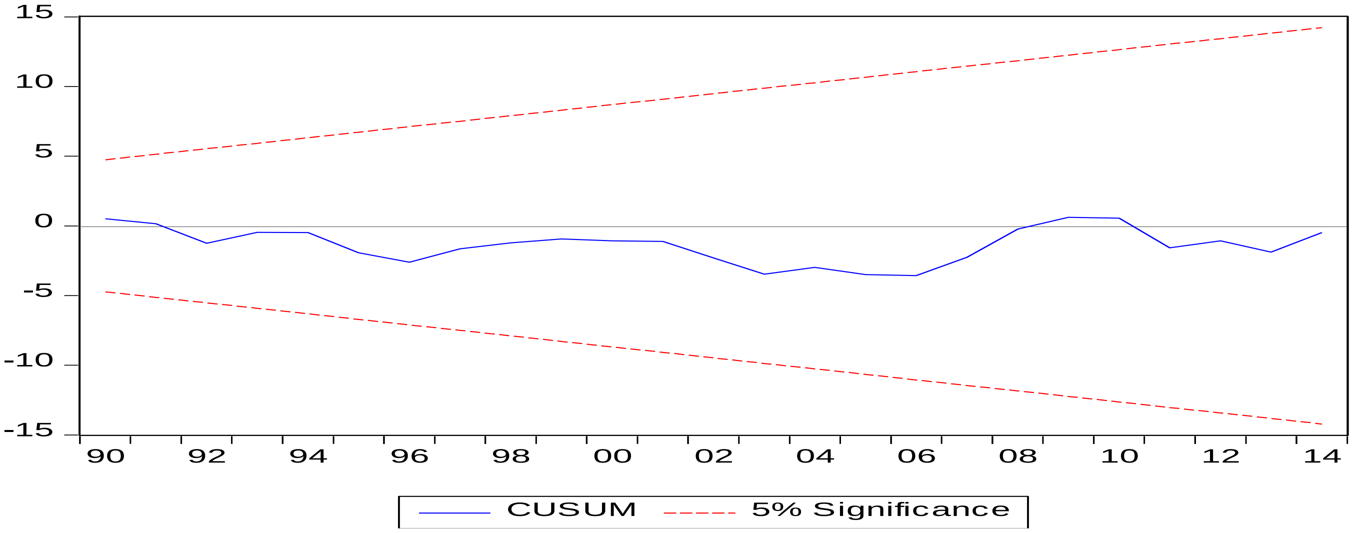

Figure 4.1A Plots for CUSUM and CUSUMQ

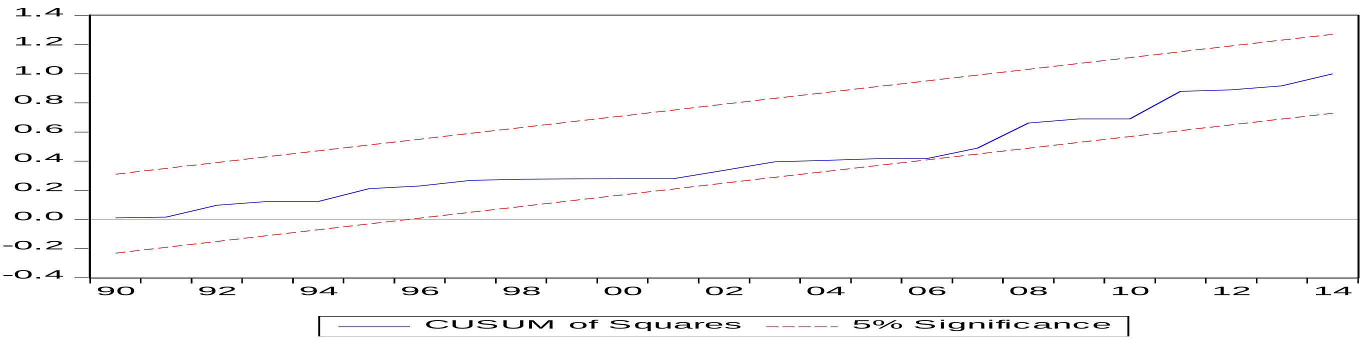

Figure 4.1 B Plots for CUSUM and CUSUMQ

The plots for both CUSUM and CUSUMQ are accounted for in Figure 4.1 A and B. It shows that the plot of CUSUM test did not cross the critical limits. Same goes with CUSUMQ that demonstrates the line did not cross the lower and upper critical limits. It shows that the long and short –run assessments are steady and there is no structural break. Therefore, the results of the estimated model are reliable and efficient.

Error Correction Term Analysis

Table 9. Short run and Error Correction Term (ECT) analysis.

Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Prob.**
D(lnGDP)	-0.103757	0.072761	-1.426005	0.1662
D(lnGDP(-1))	0.169534	0.077797	2.179201	0.0389
D(lnGDP(-2))	0.317346	0.076952	4.123941	0.0004
D(lnGDP(-3))	0.254950	0.077946	3.270845	0.0031
D(lnPROD)	-0.086969	0.072236	-1.203952	0.2399
D(lnPROD(-1))	-0.681688	0.112251	-6.072907	0.0000

D(lnPROD(-2))	-0.536429	0.098600	-5.440484	0.0000
CointEq(-1)*	-0.928554	0.099210	-9.359520	0.0000
R-square	0.781166		Durbin Watson stat	1.9334
Adjusted R-square	0.728344		Akaike info criterion	-2.859012

In the short run, agriculture growth shows the positive relationship meanwhile production of palm oil shows negative relationship towards the carbon dioxide emission. There is no short run impact for the area of oil palm plantation towards carbon dioxide emission. CointEq that denotes as ECTt-1 measures the rate of adjustment from short run disequilibrium towards the long run equilibrium. Any shock that brings the relationship out of the long run equilibrium, the model will adjust back at ECTt-1 rate. The negative sign shown implies that the disequilibrium will converge towards long run equilibrium. The magnitude of ECTt-1 is -0.928554, showed the speed of convergence to the equilibrium of 92.86 percent. In short run, carbon dioxide emission is adjusted by 92.86 percent of the previous year deviation from equilibrium. This implies that it will take approximately 1 years before converging back to the equilibrium path in long run.

ARDL Long Run Estimation

Table 10. Estimated ARDL Long Run Coefficient using ARDL (1,4,0,3) based on AIC.

Dependent Variable : CO^2				
Variable	Coefficient	Std. Error	t- Statistic	Prob.
lnGDP	-0.184724	0.060313	-3.062773	0.0052
lnAREA	-0.295853	0.154078	-1.920144	0.0663
lnPROD	0.685078	0.083639	8.190918	0.0000
C	2.294288	0.941681	2.436376	0.0223

After confirming the long run cointegration relationship among the variables in the Bound Test, the estimation of coefficient for the relationship are reported in Table 10. This result indicates the existence of long run relationship among carbon dioxide emission with all the explanatory variables. As shown above, palm oil production is positively significant as the contributor to the carbon dioxide emission in Malaysia. This finding is consistence with Mendez *et.al* (2017) where they found each ton of oil palm fresh fruit bunches produced; 606 kg of CO^2 emission were fixed. Therefore, the suggestion of using degraded land for environmentally friendly oil palm plantation should be considered (Rejinders, 2008).

In contrast, oil palm planted area and agricultural GDP shows the significant impact to the carbon dioxide emission at the 10 percent significant level, with the unexpected sign. For oil palm plantation, the results support the study by Wicke *et.al* (2008) as they claimed usage of degraded land caused the reduction of carbon dioxide emission. The situation also consistence with the finding by Pant (2009), where he claimed the countries with larger proportions of land under agriculture and forestry emit less carbon per capita as compared to those countries with smaller areas under agriculture and forest. Since the planted area of oil palm plantation in Malaysia increase gradually year by year, the scenario could be the same as the finding mentioned.

For the agriculture GDP, the negative relationship between agriculture output and carbon dioxide emission shows that environment is improved and agricultural sector does not positively cause carbon dioxide emission in Malaysia. This result can be compared with the finding in Pardo *et. al* (2012), where they found that emissions from manufacturing output industry in Mexico depends on the changes of technology and structure of product production. The reduction of emission can be reduced through the structure and real intensity of energy consumption by technology changes. This comparison can support the technology changes in agriculture sector in Malaysia had reduced the environment degradation that caused by this sector. This finding is support by Arouri *et.al* (2012) where they found not all MENA countries need to sacrifice economic growth to decrease their emission levels as they may achieve CO^2 emissions reduction via energy conservation without negative long-run effects on economic growth.

Pairwise Granger Causality Test

Table 11. Pairwise Granger Causality Test

Null Hypothesis	**Obs**	**F-Statistic**	**Prob.**
lnPROD does not Granger Cause lnCO^2	39	7.75778	0.0017
lnCO^2 does not Granger Cause lnPROD	39	1.77426	0.1850

In Table 11 , the result shows there is unidirectional causality between palm oil production and carbon dioxide emission. This means production of palm oil is proven as one of the causes for emission of carbon dioxide in Malaysia. Other explanatory variables are not significantly showing the causality relationship.

In summary, results indicates that objectives of RSPO and MSPO to create less polluted environment that caused by the palm oil industry can be succeed. Agriculture sector especially palm oil industry had improved their negative externalities by resulting negative relationship towards carbon dioxide emission through increasing planted area and agriculture output. But, the production of palm oil still has direct causality towards the carbon dioxide emission in Malaysia.

CONCLUSION

This study has two aims which are first, to identify the impact of palm oil industry and agricultural growth towards carbon dioxide emission in Malaysia. Based on the result, all the selected variables namely land area of oil palm plantation, palm oil production, and GDP in agriculture sector have significant relationship with carbon dioxide emission in Malaysia. Based on the result in the discussion section, in the short run, GDP in agriculture has positive relationship with CO^2 emissions. In contrast, palm oil production has negative relationship with CO^2 emissions. While there is no short run relationship between oil palm planted area and CO^2 emissions. In the long run, there are exist relationship between CO^2 emissions and all the explanatory variables.

Secondly is to estimate the causality relationships between the determinants of carbon dioxide emission from the Malaysian palm oil industry. From the result discussion, there is unidirectional causality between palm oil production and carbon dioxide emission while the other two explanatory variables are not significantly showing the causality relationship.

POLICY RECOMMENDATION

In recent years, green economics has emerged as a critical frontier in global development due to the increase in consumer awareness and concern over environmental issues. In response, many industries are struggling to align their operation with sustainable practice. The same issues faced by palm oil industry in Malaysia which is struggling to overcome widespread misconception and negative perceptions associated with its environmental impact. To support transition towards greener future Malaysian palm oil sector has initiated comprehensive strategies aimed at reducing carbon dioxide emission across all levels of supply chain.

On upstream level, the Malaysian palm oil industry has improved on this matter since 1981 which was in 1981, zero burning policy has been introduced in order to make sure no methane, nitrous oxide and carbon monoxide emit to the environment. Malaysian palm oil industry has adopted zero burning practice and as it has been a requirement in MSPO certification. Malaysian Sustainable Palm Oil (MSPO) Certification is one of the government efforts in order to ensure that Malaysian palm oil industry is able to achieve the balance between the economic development and the protection of the environment through implementation of the MSPO standards. This certification is announced to be mandatory to all palm oil producers in Malaysia by the end of 2019. Thus, to make all smallholders comply with this certification, Malaysian government is suggested to give incentives or subsidies to smallholders who are not afford with this certification.

Furthermore, as early 1990, regulatory measure was introduced to prohibit land clearing and new opening of plantation area reflecting a growing commitment to environmental conservation. Then, sustainability issues come in place in palm oil industry. European Union countries are too demanded when giving pressure to the palm oil industry. They claimed that palm oil industry is the main driver of deforestation and also caused extinction of iconic species such as orang-utans, tigers and elephants. Malaysian government has invested a lot in order to overcome these challenges includes research and development, promotional efforts, marketing and market development and established Malaysian Palm Oil Wildlife Conservation Fund (MPOWCF). All these efforts are to ensure Malaysian palm oil industry's sustainable and able to withstand external pressure in long run.

As the recommendation in midstream and downstream, palm oil industry can strengthen the certification and traceability system. The adoption of blockchain technology in palm oil supply chain especially in midstream and downstream can ensure the sustainability practices are maintained and improve the transparency to promote consumer's trust. The adoption of MSPO certification along the supply chain and integrate it with block chain technology could tremendously improve the overall sustainability of Malaysian palm oil industry into the next level. Apart form that, the implementation or adoption of sustainable practice, periodic measuring and reporting of emission from the production company is also crucial in ensuring the transparency of this industry. This policy is align with the global sustainable development goals (SDG) where its not only ensure the company comply with the sustainable standard, but it also promotes innovation and efficiency in palm oil industry.

REFERENCES

1. Achten, W. M., & Verchot, L. V. (2011). Implications of biodiesel-induced land-use changes for CO_2 emissions: Case studies in tropical America, Africa, and Southeast Asia. Ecology and Society, 16(4), 14.
2. Agus, F., Gunarso, P., Sahardjo, B. H., Harris, N., van Noordwijk, M., & Killeen, T. J. (2013). Historical CO_2 emissions from land use and land use change from the oil palm industry in Indonesia, Malaysia and Papua New Guinea. In Reports from the Technical Panels of the 2nd Greenhouse Gas Working Group of the Roundtable on Sustainable Palm Oil (pp. 65–88).
3. Arouri, M. E., Youssef, A. B., M'henni, H., & Rault, C. (2012). Energy consumption, economic growth and CO_2 emissions in Middle East and North African countries. IZA Discussion Paper No. 6412.
4. Basiron, Y. (2007). Palm oil production through sustainable plantations. European Journal of Lipid Science and Technology, 109(4), 289–295. https://doi.org/10.1002/ejlt.200600223
5. Basiron, Y. (2021). The role of palm oil in Malaysian economic development. Journal of Oil Palm Research, 33(3), 371–380. https://jopr.mpob.gov.my/
6. Carlson, K. M., Curran, L. M., Ratnasari, D., Pittman, A. M., Soares-Filho, B. S., Asner, G. P., Trigg, S. N., Gaveau, D. L. A., Lawrence, D., & Rodrigues, H. O. (2012). Committed carbon emissions, deforestation, and oil palm expansion in West Kalimantan, Indonesia. Proceedings of the National Academy of Sciences, 109(19), 7559–7564. https://doi.org/10.1073/pnas.1200452109
7. Danylo, O., Pirker, J., See, L., & Fritz, S. (2020). Mapping the age and extent of oil palm plantations using remote sensing. Remote Sensing, 12(20), 3412. https://doi.org/10.3390/rs12203412
8. Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. The Quarterly Journal of Economics, 110(2), 353–377. https://doi.org/10.2307/2118443
9. Hooijer, A., Page, S., Canadell, J. G., Silvius, M., Kwadijk, J., Wösten, H., & Jauhiainen, J. (2018). Current and future CO_2 emissions from drained peatlands in Southeast Asia. Biogeosciences, 15(4), 1035–1052. https://doi.org/10.5194/bg-15-1035-2018
10. Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO_2 emissions: A cointegration analysis for China. Energy Policy, 37(12), 5167–5172. https://doi.org/10.1016/j.enpol.2009.07.044
11. JOPR. (2021). Impact of intercropping on carbon dioxide fluxes in replanting phases of oil palm plantations. Journal of Oil Palm Research, 33(2), 329–336. https://jopr.mpob.gov.my/

12. Khasanah, N., Dewi, S., Verchot, L. V., & Murdiyarso, D. (2023). The impact of peatland conversion on carbon emissions in tropical palm oil plantations. Sustainability, 15(6), 11450. https://doi.org/10.3390/su150611450
13. Malaysian Palm Oil Board (MPOB). (2017). MSPO certification scheme overview. https://mpob.gov.my
14. Malaysian Palm Oil Board (MPOB). (2021). Peatland soil CO_2 fluxes and yield potential in Sarawak oil palm plantations. Journal of Oil Palm Research, 33(3), 487–498. https://jopr.mpob.gov.my/
15. Malaysian Palm Oil Board (MPOB). (2023). Palm oil economic review 2022. https://mpob.gov.my
16. Malaysian Palm Oil Council (MPOC) & Swinburne University. (2024). Pathway to decarbonisation of the Malaysian palm oil sector: MSPO innovations and GHG reduction. Malaysian Palm Oil Council.
17. Marjanovic, V., Milovancevic, M., & Mladenovic, I. (2016). Prediction of GDP growth rate based on carbon dioxide (CO_2) emissions. Journal of CO_2 Utilization, 212–217.
18. MDPI. (2024). Carbon emissions from peatland oil palm plantations: A review. Sustainability, 16(4), 2321. https://doi.org/10.3390/su16042321
19. Mendez, Y. R., Rodriguez, D. T., & Romero, H. M. (2017). Carbon footprint of the production of oil palm (Elaeis guineensis) fresh fruit bunches in Colombia. Journal of Cleaner Production, 743–750.
20. Mos, M. A., Tan, H. H., & Ismail, R. (2023). Long-term CO_2 emissions from oil palm on peat: Evidence from Sarawak. Environmental Monitoring and Assessment, 195, 457. https://doi.org/10.1007/s10661-023-11457-8
21. Narayan, P. K., & Narayan, S. (2010). Carbon emissions and economic growth: Panel data evidence from developing countries. Energy Policy, 661–666.
22. Pant, K. P. (2009). Effects of agriculture on climate change: A cross-country study of factors affecting carbon emissions. The Journal of Agriculture and Environment, 10, 72–88.
23. Pardo, C. S., Perez, S. M., & Morales, G. R. (2012). Decomposition of energy consumption and CO_2 emissions in Mexican manufacturing industries: Trends between 1990 and 2008. Energy for Sustainable Development, 57–67.
24. Pratiwi, M., Harsono, S. S., & Thoma, G. (2022). Comparative GHG emissions of vegetable oils using LCA: The case of palm oil versus rapeseed. Sustainability, 14(8), 4230. https://doi.org/10.3390/su14084230
25. Reijnders, L., & Huijbregts, M. (2008). Palm oil and the emission of carbon-based greenhouse gases. Journal of Cleaner Production, 16, 477–482.
26. Saikku, L., Soimakallio, S., & Pingoud, K. (2012). Attributing land-use change carbon emissions to exported biomass. Environmental Impact Assessment Review, 47–54.
27. Sharma, R., Nasir, M., & Saari, M. Y. (2020). Economic impact of palm oil industry in Malaysia: Input-output approach. Malaysian Journal of Economic Studies, 57(1), 1–17.
28. Simeh, A., & Tengku Ariff, T. (2007). The case study of the Malaysian palm oil. UNCTAD Discussion Paper No. 24. https://unctad.org
29. Stern, D. I. (2003). The environmental Kuznets curve. International Society for Ecological Economics.
30. Sutardjo, Y., Fonjong, L. N., & Achondo, R. (2023). Life cycle GHG assessment of palm oil mills in Cameroon. Renewable Agriculture and Food Systems, 38(1), e45. https://doi.org/10.1017/S1742170523000455
31. Teckentrup, L., Pugh, T. A. M., & Bayer, A. D. (2023). Climate change and CO_2 fertilization effects on oil palm productivity: A global modeling approach. Environmental Research Letters, 18(3), 034004. https://doi.org/10.1088/1748-9326/acb123
32. Wicke, B., Sikkema, R., Dornburg, V., Junginger, M., & Faaij, A. (2008). Drivers of land use change and the role of palm oil production in Indonesia and Malaysia. Final Report.
33. Yusof, B., & Bhattacharya, J. (2004). Economic development and the role of palm oil production in Malaysia. Asian Economic Journal, 18(3), 305–317. https://doi.org/10.1111/j.1467-8381.2004.00197.x