Non-Forest Land Cover Area, Gross Regional Domestic Product (GRDP) from the Industrial Sector, and Energy Consumption on the Environmental Quality Index in Indonesia

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Raymond Panuturi Siboro* and Eko Wahyu Nugrahadi
Universitas Negeri Medan, Deli Serdang, Indonesia

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Abstract

Purpose— This study aims to analyze the effects of non-forest land cover area, Gross Regional Domestic Product (GRDP) in the industrial sector, and per capita energy consumption on the Environmental Quality Index (EQI) in Indonesia.

Research Methodology— This study employs a quantitative approach using balanced panel data regression with the Fixed Effects Model (FEM) across 33 Indonesian provinces during the 2018–2024 period.

Results— The results of the study indicate that the area of non-forest land cover has a positive but insignificant effect on the Environmental Quality Index (IKLH). Meanwhile, the industrial sector's regional gross domestic product (PDRB) and per capita energy consumption have a significant negative effect on IKLH. These results indicate that industrial activities and high energy consumption remain the primary factors affecting the environment in Indonesia.

Research limitations/Implications— This study has limitations because it uses only three distinct factors and examines data only from 2018 to 2024. The findings indicate that increased industrial activity and energy consumption are associated with a decline in environmental quality. Therefore, it is necessary to strengthen industrial policies and energy management by improving resource efficiency, controlling environmental impacts, and implementing sustainable development principles.

Originality— This study simultaneously examines the effects of these three factors on the Environmental Quality Index (EQI) using panel data from 33 Indonesian provinces for the period 2018–2024.

Keywords: Environmental Quality Index; Non-Forest Land Cover; GDP; Regional Industrial Sectors; Per Capita Energy Consumption.
Paper type: Research Article

1. Introduction

As we enter an era of increasingly rapid economic development, many countries face the challenge of balancing economic growth and environmental sustainability. Increased production, industrial activity, natural resource use, and energy demand can drive economic growth and improve people's well-being. However, such development can also place greater pressure on the environment through changes in land use, increased production activities, and rising energy consumption. This situation highlights that development cannot be measured solely by increases in economic activity; it must also account for the environment's capacity to sustain its ecological functions over the long term. Baste, (2021) emphasizes that a healthy environment is crucial to achieving sustainable development, as economic growth, social well-being, and ecosystem protection are interlinked.

In Indonesia, environmental quality issues are becoming increasingly critical alongside economic growth and development across various regions. Increased industrial activity, changes in land use, and rising energy demand are part of the development process that can place pressure on the environment if not accompanied by proper management.

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Indonesia uses the Environmental Quality Index (IKLH) to describe environmental conditions more comprehensively as one of its indicators. The IKLH can be used to describe a region's environmental conditions and to support environmental management policies. Aldilla *et al.,* (2024) state that the IKLH is a composite measure that reflects environmental conditions and is influenced by various development activities and patterns of natural resource use. Therefore, changes in the IKLH need to be viewed not only from a single environmental perspective but also from the perspective of the various economic and development activities occurring in each region.

Differences in IKLH conditions across provinces indicate that environmental quality in Indonesia varies widely. Based on data from the Central Statistics Agency (BPS) for the 2020–2024 period, most provinces saw increases in IKLH values, although the rates and patterns of change varied across regions. Southeast Sulawesi Province recorded a relatively high IKLH value, while DKI Jakarta remained at a lower level during the study period. These differences indicate that environmental quality does not develop uniformly, as each province has distinct economic characteristics, land-use patterns, industrial activities, and energy consumption levels. Moreover, changes in the IKLH within a given region do not always follow the same pattern every year. These conditions suggest that environmental quality results from the interaction of various factors that require empirical testing.

One factor related to environmental conditions is the extent of non-forest land cover. Changes in land cover reflect changes in land use that can result from agricultural expansion, development, or other economic activities. Curtis *et al.,* (2018) state that land-use changes are largely associated with agricultural expansion, development, and economic activities that lead to the loss of natural vegetation and trees. In Indonesia, the extent of non-forest land cover varies across provinces. West Kalimantan, for example, experienced an increase in non-forest land cover during the study period, while other regions showed varying changes. Foley *et al.,* (2005) explain that land-use changes are related to resource availability, economic development, and spatial management policies. Thus, changes in the extent of non-forest cover may be linked to changes in environmental quality, but the magnitude of this impact may vary across regions.

In addition to land-use changes, the industrial sector's GRDP may also be associated with changes in environmental quality. The industrial sector's GRDP reflects the scale of economic activity generated by the industrial sector in a given region. Increased industrial activity may indicate rising production, investment, technology adoption, and resource utilization. Based on data from 2020–2024, the industrial sector's GRDP increased in most provinces, with West Java among the regions with the highest industrial sector GRDP. Haraguchi *et al.,* (2017) demonstrated that a region's level of industrialization is associated with investment, production facilities, and economic capacity. However, increased industrial activity does not always result in the same changes in environmental quality. Dinda (2004) explains, using the Environmental Kuznets Curve (EKC), that environmental pressure may rise in the early stages of economic development but can decline as technological advancements, rising incomes, and environmental policies begin to drive more environmentally friendly economic activities.

Another factor is per capita energy consumption, which reflects the amount of energy used by the population to support economic activities and daily life. Increased economic activity, industrialization, and regional development generally increase energy demand. The International Energy Agency (IEA, 2023) explains that economic growth, industrial development, and urban expansion are linked to rising energy demand. In Indonesia, per capita energy consumption varied significantly across provinces during the study period. However, increases or decreases in energy consumption are not always accompanied by corresponding changes in the IKLH. For example, per capita energy consumption in North Sumatra decreased during the study period, while environmental quality actually improved. This indicates that the relationship between energy consumption and environmental quality is determined not only by the amount of energy used but also by energy-use efficiency and the type of energy sources employed. Ahmed & Elfaki, (2024)

demonstrate that the relationship between energy use and environmental conditions can be influenced by efficiency and the characteristics of energy sources.

Theoretically, the relationship between economic activity and environmental quality can be explained through the Environmental Kuznets Curve (EKC). Grossman & Krueger, (1995) explain that in the early stages of economic growth, increased economic activity can intensify environmental pressure due to rising production and resource utilization. However, once a certain level of development is reached, technological progress, rising incomes, and environmental policies can drive improvements in environmental quality. In the context of this study, this framework provides a basis for the argument that increased industrial activity does not necessarily lead to a decline in environmental quality. Meanwhile, changes in land cover and energy consumption can also place pressure on the environment through shifts in land use and increased resource demands. Thus, the relationship between non-forest land cover area, the industrial sector's GRDP, energy consumption, and the Environmental Quality Index (EQI) needs to be substantiated through empirical testing.

Although research on factors related to environmental quality has advanced, there remains scope to examine the relationships among these three factors simultaneously at the provincial level in Indonesia. Changes in land use, industrial sector development, and energy consumption are part of an interrelated development process; however, their impacts on the IKLH may vary depending on the characteristics of each region. Furthermore, the varying patterns of the Environmental Quality Index across provinces indicate that environmental changes cannot be explained by a single factor alone. Therefore, research is needed to examine how the extent of non-forest cover, industrial sector GRDP, and per capita energy consumption relate to changes in the Environmental Quality Index across Indonesian provinces. This study aims to analyze the effects of the area of non-forest land cover, industrial sector GRDP, and per capita energy consumption on the Environmental Quality Index in Indonesia. The study uses provincial panel data from Indonesia over the study period to account for regional differences and temporal changes. The novelty of this study lies in simultaneously testing these three factors within a single empirical model to examine their relationship with the Environmental Quality Index at the provincial level in Indonesia. The results of this study are expected to provide empirical evidence on the relationships among changes in land use, industrial sector economic activity, energy consumption, and environmental quality, and to serve as a basis for formulating development policies that balance economic growth with environmental sustainability.

The remainder of this paper is organized as follows. Section 2 provides a literature review and hypothesis development. Section 3 presents the research method and design. Section 4 provides the results and discussion. Section 5 presents Concluding Remarks and Recommendations.

2. Review of Literature

2.1 Environmental Quality Index (EQI)

The Environmental Quality Index (IKLH) is a tool that combines various factors to indicate the health of environmental conditions in a specific region. This index integrates various aspects of environmental quality—such as water, air, soil, and marine waters—and provides a more comprehensive picture of the environment than relying on a single indicator (Zahro & Tutik, 2025). The IKLH can serve as a general measure for comparing environmental conditions across regions and can help guide environmental management and policy decision-making. Differences in IKLH values among Indonesia's provinces highlight the diversity of ecological characteristics, economic practices, population levels, land use, and environmental management capabilities across various regions. A recent study by Latifa, (2025) shows that across various Indonesian provinces, economic growth, population density, and human development exhibit varying relationships with the IKLH. This indicates that environmental quality is closely linked to the development characteristics of each region. Theoretically, environmental quality can be viewed

through the lens of sustainable development, which focuses on ensuring industrial environmental safety to sustain economic growth. A single factor does not determine environmental quality but arises from the interaction of various factors, such as economic activities, population size, methods of natural resource utilization, and environmental management. This perspective is supported by recent studies conducted through field testing. Hafidhah *et al.,* (2025) state that the IKLH can be used to evaluate environmental improvement programs and as a foundation for environmental protection and management policies. Their spatial analysis highlights the importance of considering the unique characteristics of various regions in explaining differences in environmental quality. Nugroho & Hidayat, (2025) emphasize that economic growth, deforestation, improvements in living standards, and government budget allocation are key factors influencing Indonesia's Environmental Quality Index (IKLH). These results indicate that a combination of various ecological and economic factors shapes the EQI. In this study, the EQI is used as the primary outcome variable to analyze how the area of non-forest land, industrial sector output, and per capita energy consumption influence environmental quality across various provinces in Indonesia.

H1. Non-forest land cover negatively affects Indonesia's Environmental Quality Index.

2.2 Non-Forest Cover Area (LTNH)

Non-forest areas are parts of a region that are not covered by forest and consist of other land cover types. These areas may include agricultural land, large-scale tree plantations, residential settlements, buildings and roads, lakes and rivers, open grasslands, and various other forms of land use. Changes in land cover types—whether forest or other areas—reflect how the landscape is changing. When forests are converted to other land uses, it affects ecosystem functioning, the biodiversity they support, water management, soil conditions, and nature's ability to provide essential environmental services. Recent research by Haneda *et al.,* (2025) shows that differences between forested and non-forested areas are linked to distinct ecological and environmental characteristics. This indicates that land cover types can influence how terrestrial ecosystems function. A study by Rizqullah *et al.,* (2025) shows that rapid changes in land use—driven by urban expansion and deforestation—can harm the environment, water supplies, wildlife, and the land's ability to produce resources. Therefore, non-forest cover is not only related to the amount of available land but can also indicate the extent to which human activities have altered natural areas. Theoretically, the relationship between non-forest cover and environmental conditions can be understood by observing how land use and land cover change over time. This approach views changes in land use and cover as factors that can influence the environment and its functions. An increase in non-forest land cover does not necessarily mean that environmental conditions are deteriorating. The impact on the environment depends on the type of land use occurring, its intensity, and how it is managed. Agricultural land managed responsibly can have a different impact on the environment compared to areas filled with buildings and mining sites. This perspective aligns with research by Assel *et al.,* (2025), which shows that land-cover quality is a crucial component in assessing environmental quality in Indonesia and that environmental conditions vary from one province to another. Furthermore, an analysis of environmental quality in Indonesia indicates that land surface characteristics play a significant role in the overall picture of environmental quality, including water and air quality (Mahmudah & Lola, 2023). In this study, non-forest land cover was treated as a separate factor to examine whether differences in non-forest land area are associated with changes in the Environmental Quality Index across Indonesian provinces.

H2. The industrial sector's GRDP negatively affects Indonesia's Environmental Quality Index.

2.3 Gross Regional Domestic Product of the Industrial Sector (GRDP of the Industrial Sector)

The Gross Regional Domestic Product (GRDP) of the industrial sector reflects the value added generated by industrial activities in a region over a specific period. It is a key indicator of the contribution and intensity of industrial activities to regional economic performance, particularly through manufacturing, processing, and other industrial production. The GRDP of the industrial sector not only reflects a region's economic capacity but also the scale of resource utilization associated with industrial production. In the context of environmental quality, increased industrial output can create additional pressure through rising demand for energy and raw materials, industrial waste, and pollutant emissions. Recent empirical evidence from Indonesia indicates that industrial activity is significantly related to environmental quality, suggesting that industrial expansion can be a key determinant of regional environmental conditions (Kumara, 2025). Similarly, Mire *et al.,* (2024) found that industrial development is one of the socioeconomic factors associated with environmental quality in Indonesia. Theoretically, the relationship between the regional gross domestic product (RGDP) of the industrial sector and environmental quality can be understood through the Environmental Kuznets Curve. This concept suggests that as the economy and industry grow, environmental pressures may increase because production and resource use also rise. However, as development continues and the economy advances, environmental pressures may begin to decline as more environmentally friendly technologies, stricter environmental regulations, and greater awareness of environmental protection become more widespread. Within this framework, the industrial sector's GRDP indicates the scale of economic activity, which generates economic benefits but also causes environmental problems. Samosir *et al.,* (2024) found that industrial sector growth in Indonesian provinces negatively affected environmental quality, as indicated by their spatial analysis. Meanwhile, Pujiati *et al.,* (2023) noted that the industrial sector is one of the key factors explaining differences in environmental quality between Java and other Indonesian islands. In this study, the Industrial Sector GRDP was used as the primary factor to examine whether differences in industrial economic activity are associated with changes in the Environmental Quality Index across various provinces in Indonesia.

H3. Energy consumption negatively affects Indonesia's Environmental Quality Index.

2.4 Energy Consumption

Energy consumption is a key indicator of the amount of energy used for economic and social activities in a given region. The International Energy Agency (IEA, 2024) states that energy use is closely linked to the size of an economy's income. This is because energy is required to produce goods, transport them, carry out household activities, and provide various services. In the context of regional development, increased energy use can signal growing economic activity and improved access to electricity; however, its environmental impact depends on the type of energy used and how efficiently it is utilized. Therefore, energy use is not only an indicator of economic growth but also a critical aspect in understanding the extent of pressure placed on the environment. Theoretically, the relationship between energy use and environmental conditions can be understood through the Energy-Environment Nexus concept. This concept illustrates how energy use, economic activities, and environmental health are interrelated. Energy use from fossil fuels can lead to increased emissions of greenhouse gases and other harmful pollutants, particularly when energy demand grows faster than improvements in energy efficiency. This idea aligns with the Environmental Kuznets Curve (EKC), which states that as economic growth and energy use increase, environmental pressure may initially rise. However, if cleaner technologies and better environmental regulations are implemented, environmental pressures may begin to decrease. Recent studies also indicate that high levels of energy consumption—particularly from fossil fuels—play a major role in environmental degradation, especially in countries where fossil fuels remain the primary energy source (Sarkodie & Strezov, 2019). In this study, energy consumption is treated as

a factor that affects both the economy and the environment. It can influence environmental quality based on how much energy is used, how efficiently it is used, and the type of energy used.

H4. Non-forest land cover, the industrial sector's GRDP, and energy consumption simultaneously influence Indonesia's Environmental Quality Index.

3. Research Methodology

In this study, the panel data regression method was used to analyze the effects of non-forest cover area, industrial sector GRDP, and per capita energy consumption on the Environmental Quality Index (IKLH) in Indonesia. The analysis was conducted across 33 provinces from 2018 to 2024. During data processing, the variables—the Environmental Quality Index (EQI), non-forest cover area, industrial sector GRDP, and per capita energy consumption—were transformed into natural logarithms. The natural logarithmic transformation was applied to scale data with very wide ranges and to reduce unit differences between variables, thereby helping maintain stable data variance and improving the quality and clarity of the regression estimates. Furthermore, the use of natural logarithms facilitates understanding of the elasticities among variables, so that changes in the independent variables can be interpreted as percentage changes in the dependent variable (Gujarati & Porter, 2009).

$$\mathbf{LogIKLH_{it}=\alpha+\beta 1LogLTNH_{it}+\beta 2LogPDRBSI_{it}+\beta 3LogKE_{it}+\varepsilon_{it}}$$

Description:

IKLH	= Environmental Quality Index
LTNH	= Area of Non-Forest Cover
PDRBSI	= Gross Regional Domestic Product (GRDP) of the Industrial Sector
KE	= Per Capita Energy Consumption
Log	= Natural Logarithm
α	= Constants
β_1–β_3	= Regression Coefficient
ε	= Error term
i	= The number of objects is 33 provinces in Indonesia
t	= The years in question are 2018–2024

Data analysis was conducted in three stages: first, the Chow test, Hausman test, and Lagrange multiplier test were used to determine the most appropriate model. The models considered were the Common Effects Model (CEM), Fixed Effects Model (FEM), and Random Effects Model (REM). Next, several standard checks were performed to ensure that the model assumptions were met. These checks included testing for multicollinearity and heteroscedasticity. Next, hypothesis testing was performed using the t-test, F-test, and adjusted R-squared to measure how well the models explained the data. The entire data processing procedure was conducted using EViews 10 software.

4. Results and Discussion

4.1 Research Result

This study examines the impact of non-forest land area, industrial sector GDP, and energy consumption on the Environmental Quality Index in Indonesia, using panel data for 33 provinces from 2018 to 2024. The analysis was conducted using EViews 10 software. Before estimating the regression, the best panel data model was selected using the Chow and Hausman tests.

4.1.1 Selection of a Panel Data Regression Model

Before performing the regression analysis, we first determine the most appropriate panel data model. The models we consider are the Common Effects Model (CEM), the Fixed Effects Model (FEM), and the Random Effects Model (REM). The model is selected

based on the Chow and Hausman tests. The results of the Chow test, as shown in **Table 1**, indicate a cross-sectional chi-square probability value of 0.0000, which is < 0.05; therefore, the Fixed Effects Model (FEM) is selected as the best model. The next step involved the Hausman test to determine the most appropriate estimation method between the FEM and the Random Effects Model (REM). The results of the Hausman test, shown in **Table 2**, yielded a p-value of 0.0005 < 0.05, meaning the Fixed Effects Model (FEM) remains the best model. Therefore, the regression analysis in this study employs the FEM approach.

Table 1. Results of the Chow Test

Redundant Fixed Effects Tests **Equation: Untitled** **Test cross-section fixed effects**			
Effects Test	**Statistic**	**d.f.**	**Prob.**
Cross-section F	16.066800	(32,195)	0.0000
Cross-section Chi-square	298.232552	32	0.0000

Source: Results processed using EViews 10 (2026)

Table 2. Results of the Hausman Test

Correlated Random Effects - Hausman Test Equation: Untitled Test cross-section random effects			
Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Cross-section random	17.869137	3	0.0005

Source: Results processed using EViews 10 (2026)

Table 3. Results of the Multikolinearitas Test

	LOGX1	**LOGX2**	**LOGX3**
LOGX1	1	0.27171231	-0.1398324
LOGX2	0.27171231	1	-0.0041889
LOGX3	-0.1398324	-0.0041889	1

Source: Results processed using EViews 10 (2026)

Table 3 shows that the correlation coefficients between the independent variables are all below 0.80. The highest correlation coefficient is 0.27, observed in the relationship between the variables LogX1 and LogX2. Since all correlation coefficients are less than 0.80, the regression model does not suffer from multicollinearity. Thus, the relationships among the independent variables remain within reasonable limits, making this model suitable for further analysis.

Table 4. Results of the Heteroskedasticity Test

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.152409	0.612202	0.248951	0.8037
LOGX1	0.004191	0.002981	1.405943	0.1613
LOGX2	0.002890	0.001809	1.597932	0.1117
X3	0.022709	0.079894	-0.284242	0.7765

Source: Results processed using EViews 10 (2026)

In **Table 4**, all independent variables have probability values above the significance level of 0.05 (> 0.05). The probability value for the "Non-Forest Land Cover Area" variable is 0.1613, for "Industrial Sector GRDP" is 0.1117, and for "Per Capita Energy Consumption" is 0.7765. Thus, H0 is accepted, meaning that the regression model in this study does not exhibit heteroscedasticity. This indicates that the residual variance in the model is constant, so the regression estimation results can be considered reliable and suitable for use in this study.

4.1.2 Model Analysis

In **Table 5**, the value 12.69843 remains constant, which means that if the area of non-forest land cover, the industrial sector's GRDP, and energy consumption remain unchanged, the logarithm of the Environmental Quality Index is 12.69843. The coefficient for LogX1 is positive (0.003992), indicating that the higher the non-forest land cover, the higher the Environmental Quality Index. However, this relationship is not statistically significant. The LogX2 variable has a negative coefficient of −0.029745, meaning that as the industrial sector's GRDP increases, the Environmental Quality Index tends to decrease. Meanwhile, the LogX3 variable has a negative coefficient of −0.470404, meaning that as energy consumption increases, the Environmental Quality Index tends to decrease.

$$\mathbf{LOGY = 12.69843 + 0.003992\ LOGX1 - 0.029745\ LOGX2 - 0.470404\ LOGX3}$$

Table 5. Results of the Regression Analysis of Panel Data Using the Fixed-Effects Model (FEM)

Dependent Variable: LOGY
Method: Panel Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.69843	1.149908	11.04300	0.0000
LOGX1	0.003992	0.005598	0.713013	0.4767
LOGX2	-0.029745	0.003397	-8.755246	0.0000
LOGX3	-0.470404	0.150066	-3.134653	0.0020
	Effects Specification			
Cross-section fixed (dummy variables)				
R-squared	0.809847	Mean dependent var		8.857669
Adjusted R-squared	0.775716	S.D. dependent var		0.115924
S.E. of regression	0.054900	Akaike info criterion		-2.824339
Sum squared resid	0.587731	Schwarz criterion		-2.287858
Log likelihood	362.2111	Hannan-Quinn criter.		-2.607958
F-statistic	23.72821	Durbin-Watson stat		0.923476
Prob(F-statistic)	0.000000			

Source: Results processed using EViews 10 (2026)

4.1.3 Partial Test (t-Test)

The results of the partial tests shown in **Table 6** indicate that the variable "area of non-forest cover" (LOGX1) has a significance value of 0.4767, which is greater than 0.05. This means that this variable does not have a significant effect on the Environmental Quality Index. The industrial sector GRDP variable (LOGX2) has a probability value of 0.0000, which is less than 0.05. This indicates that this variable has a negative and significant effect on the Environmental Quality Index. Furthermore, the energy consumption variable (LOGX3) has a p-value of 0.0020, which is less than 0.05, indicating a significant negative effect on the Environmental Quality Index.

Table 6. Results of the Partial Test (t-Test)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.69843	1.149908	11.04300	0.0000
LOGX1	0.003992	0.005598	0.713013	0.4767
LOGX2	-0.029745	0.003397	-8.755246	0.0000
LOGX3	-0.470404	0.150066	-3.134653	0.0020

Source: Results processed using EViews 10 (2026)

4.1.4 Simultaneous Test (F-Test)

The results of the simultaneous test presented in **Table 7** show a Prob(F-statistic) value of 0.000000, which is less than 0.05. This indicates that non-forest land use, industrial sector output, and energy use all play significant roles in shaping Indonesia's Environmental Quality Index.

Table 7. Results of the Simultaneous Test (F-Test)

F-statistic	23.72821
Prob(F-statistic)	0.000000

Source: Results processed using EViews 10 (2026)

4.1.5 Coefficient of Determination (R^2)

In **Table 8**, the adjusted R-squared value of 0.775716 indicates that approximately 77.57% of the variation in the Environmental Quality Index is explained by the variables of non-forest land cover area, industrial sector GRDP, and energy consumption in the model. Meanwhile, the remaining 22.43% is influenced by other factors not included in the model, such as the effectiveness of environmental policies, carbon emissions, population density, the extent of renewable energy use, the size of built-up areas, and other factors not examined here.

Table 8. Results of the Coefficient of Determination (R^2) Test

R-squared	0.809847
Adjusted R-squared	0.775716

Source: Results processed using EViews 10 (2026)

4.2 Discussion

4.2.1 The Effect of Non-Forest Land Cover Area on the Environmental Quality Index in Indonesia

The results of the Fixed Effects Model (FEM) show that the variable "non-forest area" has a coefficient of 0.003992 and a p-value of 0.4767. If the p-value is greater than 0.05, it means that the non-forest area does not significantly affect the Environmental Quality Index (IKLH) in Indonesia. Although the result is positive, it implies that as the area of non-forest cover increases, the IKLH also increases by approximately 0.003992 percent, holding all other factors constant. Theoretically, these results can be explained by the Land Use and Land Cover Change (LULCC) Theory. This theory states that human activities and development primarily cause changes in land use. Additionally, the Forest Transition Theory suggests that land-use changes do not necessarily indicate environmental deterioration, as these changes can be offset by efforts such as reforestation, the protection of natural areas, and land management practices that preserve long-term ecological health. Thus, changes in non-forest areas do not always directly affect environmental quality. These findings align with Fahad *et al.,* (2026), who noted that the effects of land-use changes on the environment depend on land use, resource management policies, and the extent to which sustainable development is implemented. This indicates that factors beyond mere land-use changes influence environmental conditions. Other factors, such as industrial activities, air quality, water quality, and waste management, also play a role. Thus, the extent of non-forest land in Indonesia did not significantly affect the Environmental Quality Index during the period covered by this study. These results indicate that environmental improvement requires a comprehensive management approach—one that not only regulates land use but also implements sustainable environmental policies.

4.2.2 The Impact of the Industrial Sector's GRDP on the Environmental Quality Index in Indonesia

The results of the fixed-effects model show that the industrial sector GRDP variable has a coefficient of -0.029745 and a p-value of 0.0000. A p-value below 0.05 indicates that industrial sector GRDP has a significant effect on the Environmental Quality Index in Indonesia. This negative value indicates that if the industrial sector's GRDP increases by 1 percent, the EQI typically decreases by approximately 0.029745 percent, assuming all other factors remain constant. Theoretically, this finding can be explained by the Environmental Kuznets Curve, which posits that in the early stages of economic growth, greater industrial activity typically leads to increased environmental damage due to higher emissions, waste, and greater use of natural resources. Industrial Ecology theory holds that industrial activity is closely linked to the environment, as production processes

require energy and generate various forms of pollution that can harm it. Thus, GDP growth in the industrial sector is one of the factors influencing Indonesia's Environmental Quality Index. This means that as the industrial sector grows, it is also important to adopt more environmentally friendly methods, conserve energy, and improve regulations to control pollution. In this way, the economy can grow without damaging the environment.

4.2.3 The Effect of Per Capita Energy Consumption on the Environmental Quality Index in Indonesia

The results of the fixed-effects model show that the per capita energy consumption variable has a coefficient of -0.470404 and a p-value of 0.0020. A p-value below 0.05 indicates that per capita energy consumption has a significant impact on the Environmental Quality Index (IKLH) in Indonesia. The negative value indicates that if per capita energy consumption increases by 1 percent, the EQI typically decreases by approximately 0.470404 percent, holding all other factors constant. Theoretically, the findings of this study align with the Theory of Sustainable Development, which states that energy must be used wisely to prevent environmental damage. Furthermore, the Environmental Kuznets Curve (EKC) shows that in the early stages of economic growth, increased energy consumption typically leads to greater environmental pollution, especially when most energy is derived from fossil fuels. The findings of this study align with those of Rahmayani *et al.,* (2025), namely that energy use is closely linked to environmental conditions. The more energy is derived from fossil fuels, the greater the likelihood that emissions and environmental pollution will increase, ultimately leading to further deterioration of environmental conditions. Therefore, using energy more efficiently and in a more environmentally friendly way is crucial for maintaining a healthy environment. Consequently, the amount of energy each person uses is one of the factors influencing Indonesia's Environmental Quality Index. This underscores the importance of promoting energy efficiency, increasing renewable energy use, and enacting stricter regulations to reduce emissions—so that energy can continue to support economic growth without harming the environment.

4.2.4 The Effects of Non-Forest Land Cover Area, Industrial Sector GRDP, and Per Capita Energy Consumption on the Environmental Quality Index in Indonesia

A test using the Fixed Effects Model (FEM) showed that the area of non-forest land cover, the industrial sector's GRDP, and per capita energy consumption all have a significant effect on Indonesia's Environmental Quality Index. The Prob(F-statistic) value is 0.0000, which is less than 0.05, indicating that these factors collectively have a strong influence on the EQI. The Adjusted R-squared value of 0.775716 indicates that the three variables in this model explain 77.57% of the variation in the EQI. The remaining 22.43% is attributable to factors not included in this study, such as carbon emissions, waste management, renewable energy use, and environmental policies. The results show that the area of non-forest land cover has a small positive impact on the Environmental Quality Index. However, this effect is not strong enough to be considered significant. These results indicate that changes in environmental quality in Indonesia are largely driven by industrial activities and energy use, rather than by changes in the extent of non-forest land during the study period. The findings of this study are based on the Land Use and Land Cover Change (LULCC) theory, the Environmental Kuznets Curve (EKC), and the concept of sustainable development. LULCC states that changes in land-use patterns can affect the environment. The EKC suggests that as a region begins to develop economically and industrially, it typically places greater initial pressure on the environment. The concept of sustainable development focuses on the intelligent use of energy to enable economic growth without damaging the environment. Thus, environmental conditions in Indonesia are influenced by the extent of non-forested land, the growth of industrial sector output, and per capita energy consumption. However, in this study, the greatest impacts stem from industrial activities and energy use. Therefore, to improve the environment, we need to work toward strengthening environmentally

friendly industrial policies, optimizing resource utilization, and sustainably managing natural resources.

5. Concluding Remarks and Recommendation

This study examines how non-forest land cover, industrial sector output, and average energy consumption affect Indonesia's Environmental Quality Index. The results show that when these three variables are considered together, they all have a significant impact on the Environmental Quality Index (EQI). When examined individually, only the industrial sector's GRDP and per capita energy consumption clearly have a negative impact on the environment. In contrast, non-forest land area does not appear to have a significant effect.

These results indicate that industrial activities and high energy consumption remain the primary drivers of environmental impacts in Indonesia. The government needs to strengthen policies for environmentally friendly industry through energy efficiency, waste management, and emissions reduction. The use of renewable energy also needs to be increased to alleviate pressure on environmental quality. Future research is recommended to include additional variables, such as carbon emissions, renewable energy, and environmental policies. Although the research model explains most of the changes in the IKLH, the findings of this study are limited because it uses only three separate factors and examines data only from 2018 to 2024. Future studies should incorporate other important factors such as carbon emissions, renewable energy use, waste management practices, and environmental policies. Overall, these findings clarify the various key factors that determine environmental conditions in Indonesia.

CONFLICTS OF INTEREST

The author(s) declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DECLARATION OF GENERATIVE AI STATEMENT

During the preparation of this work, the author used generative artificial intelligence tools to support the scientific writing process. Grammarly was used to check grammar, refine writing style, and improve clarity in scientific writing. All interpretations, analyses, and conclusions presented in this study are the sole responsibility of the author.

AUTHOR'S CONTRIBUTION

Raymond Panuturi Siboro: corresponding author, conceptualization, methodology, validation, formal analysis, investigation, data curation, visualization, manuscript writing and revision. **Eko Wahyu Nugrahadi:** conceptualization, methodology, validation, review, editing, and guidance.

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Corresponding Author
Raymond Panuturi Siboro can be contacted at: **raymonsiboro963@gmail.com**