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Determinants of Indonesia's Environmental Quality Index, Including Human Development, Economic Growth, Deforestation, and Budget Allocation

Rajib Wahyu Nugroho[1], Maryono[1], Jafron Wasiq Hidayat[1]
[1]Environmental Science Master Program, Universitas Diponegoro, Indonesia
Corresponding Author: Rajib Wahyu Nugroho; Email: rajibwnugroho@yahoo.com

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ABSTRACT

Environmental quality in Indonesia remains under sustained pressure due to ongoing deforestation, resource-intensive economic growth, and persistent regional development disparities. This study analyzes the influence of the Human Development Index (HDI), Gross Regional Domestic Product (GRDP), deforestation, and regional government revenue and expenditure budgets on the Environmental Quality Index (EQI) across 33 Indonesian provinces. The analysis employs panel data regression, with a Fixed Effects Model selected based on the Hausman specification test. The results reveal that HDI exerts a positive and statistically significant effect on environmental quality, with a one-point increase in HDI corresponding to a 1.988-point rise in the EQI. Deforestation and regional government budget variables do not demonstrate statistically significant effects on the EQI. These findings suggest that higher levels of human development are associated with improved environmental conditions, whereas economic growth trajectories that are predominantly driven by natural resource exploitation continue to degrade environmental quality. Accordingly, regional development policies should be directed toward strengthening human development performance, integrating environmental considerations into economic growth processes, and enhancing the effectiveness of regional budget allocations for environmental sustainability, in order to achieve inclusive and sustainable development.

INTRODUCTION

Environmental quality is a fundamental indicator of sustainable regional development because it reflects the long-term capacity of ecological systems to support human welfare and economic activities (Setiawan & Primandahan, 2022; Siregar & Hasbi, 2025). In many developing countries, including Indonesia, pressures such as deforestation, land degradation, and pollution continue to intensify alongside economic expansion, resulting in persistent disparities in environmental conditions across regions (Ilham, 2021; Wafiq & Suryanto, 2021). These variations suggest that environmental degradation is not merely an ecological phenomenon but is shaped by socio-economic structures, institutional capacity, and regional development patterns.

From the perspective of human ecology, the relationship between society and the environment is reciprocal. Social and economic activities exert pressure on ecological systems, while environmental resources and ecological functions underpin economic productivity and human well-being (Bentley Brymer et al., 2020; Puspitasari & Yuliawan, 2023). This perspective is consistent with international scholarship emphasizing that development and environmental outcomes are interdependent and mutually reinforcing (Zhang & Wu, 2022). Regions with well-maintained environmental conditions tend to experience higher productivity, better public health, and stronger resilience to ecological shocks, whereas environmental degradation can undermine long-term development prospects (Ramadhan, 2023).

To systematically monitor environmental performance at the regional level, the Government of Indonesia, through the Ministry of Environment and Forestry, introduced the Environmental Quality Index (EQI). The EQI incorporates air quality, water quality, and land cover quality to provide a

composite measure of provincial environmental conditions (Finanda & Gunarto, 2022; Hariyanti et al., 2021; Oladeji et al., 2021). National data indicate notable fluctuations in Indonesia's EQI from 2015 to 2021, declining from 68.05 in 2015 to 66.19 in 2017 before rising to 72.81 in 2021 (BPS, 2023). These dynamics reflect changing ecological pressures, policy interventions, and the uneven implementation of environmental governance across provinces.

Environmental quality at the regional scale is influenced by a complex interaction of social, economic, ecological, and institutional factors (Aldilla et al., 2024; Ramadanti & Suhab, 2023). From a social perspective, improvements in the Human Development Index (HDI) may enhance environmental outcomes by strengthening education, public awareness, and institutional capacity (Li & Xu, 2021). International studies similarly suggest that higher human development supports environmental stewardship through improved governance and environmental literacy (Opoku et al., 2022). Economic growth, typically measured by Gross Regional Domestic Product (GRDP), has a more ambivalent relationship with environmental quality. While higher economic output increases fiscal capacity for environmental programs, growth driven by resource extraction and land conversion often intensifies ecological pressure (Aida et al., 2022; Puspitasari & Yuliawan, 2023). This aligns with the extensive global debate on the Environmental Kuznets Curve hypothesis, which posits a non-linear relationship between income and environmental degradation (Ginting et al., 2023). Yet, empirical findings remain inconclusive, suggesting that the impact of economic growth on environmental quality depends heavily on a region's economic structure.

Ecological pressures, particularly deforestation, represent a critical determinant of environmental quality in Indonesia. High deforestation rates threaten land cover integrity and air quality while reflecting weak land-use governance and limited regulatory enforcement (Perwithosuci et al., 2025; Rahman et al., 2024). Institutional factors also play a central role, particularly regional budget allocations for environmental management. Although environmental budgets increased until 2021, their decline in 2022 partly driven by fiscal reallocation during the COVID-19 pandemic, highlights the vulnerability of environmental spending to broader fiscal pressures (BPS, 2023; Siregar & Hasbi, 2025). These conditions raise concerns regarding the consistency of local government commitment to environmental protection.

Despite extensive discussions on the links between development and environmental quality, existing empirical studies often examine these factors in isolation or treat environmental quality as an explanatory variable rather than an outcome. Research integrating human development, economic growth, deforestation, and environmental budget allocations within a unified analytical framework, particularly using provincial-level panel data in Indonesia, remains limited. This gap restricts a comprehensive understanding of how socio-economic, ecological, and fiscal factors jointly shape regional environmental conditions. Based on this gap, the present study analyzes the effects of human development, regional economic growth, deforestation, and environmental budget allocations on environmental quality, measured by the Environmental Quality Index, across Indonesia's 33 provinces using panel data analysis. By treating environmental quality as the dependent variable and incorporating multiple development-related determinants, this study contributes to the literature by providing integrated empirical evidence on the drivers of regional environmental quality in Indonesia. The novelty of this study lies in its multidimensional approach, the use of updated provincial panel data, and its application of the human ecology framework to explain variations in environmental outcomes at the subnational level.

MATERIALS AND METHODS

This study employs a quantitative approach using panel data regression to examine the determinants of environmental quality across Indonesian provinces. The analysis utilizes annual panel data from 33 provinces over the period 2015–2022. The dependent variable is the Environmental Quality Index (EQI), while the independent variables include the Human Development Index (HDI), Gross Regional Domestic Product (GRDP), deforestation, and Regional Revenue and Expenditure Budget (RREP). To assess the relationship between these variables, the following panel regression model is specified:

$$EQI_{it}=\beta_1 \ln(RREP)_{it}+\beta_2 \ln(GRDP)_{it}+\beta_3\ DEF_{it}+\beta_4\ HDI_{it}+\alpha_i+\varepsilon_{it}$$

Where *i* denotes province, and *t* denotes year. The term α_i captures unobserved, time-invariant provincial characteristics, while ε_it represents the idiosyncratic error term.

A fixed effects estimator is employed to control for unobserved heterogeneity across provinces that may be correlated with the explanatory variables, a condition commonly encountered in regional and environmental studies (Ilham, 2021; Wooldridge, 2010). Model selection is based on the Hausman test, which indicates that the fixed effects specification is more appropriate than the random effects alternative. Logarithmic transformations are applied to GRDP and APBD to reduce skewness and allow for semi-elasticity interpretation of the estimated coefficients (Greene, 2020; Wooldridge, 2010). All estimations are conducted using Stata 17. Robust standard errors are applied to account for potential heteroskedasticity and serial correlation in the panel data, following standard practices in applied econometric analysis (Gujarati, 2003).

RESULTS AND DISCUSSION

Overview of Variable Analysis

Building on the human ecology perspective outlined in the background, environmental quality at the regional level reflects the interaction between human development, economic activities, ecological pressures, and institutional capacity. In Indonesian variations in the Environmental Quality Index (EQI) across provinces indicate that environmental outcomes are shaped not only by natural conditions but also by differences in development patterns, fiscal capacity, and land-use dynamics (Purnamadewi et al., 2019; Soeparno et al., 2024). Human development may enhance environmental quality through improved awareness and governance, while economic growth and deforestation represent potential sources of ecological pressure when driven by resource-intensive activities. Regional government expenditure further reflects institutional commitment to environmental management, although its effectiveness depends on allocation priorities and implementation (Nanda Monika Marpaung & Ni Luh Karmini, 2025; Ramadanti & Suhab, 2023). These interrelated factors provide the analytical basis for examining descriptive patterns and subsequent regression results across provinces.

Table 1. Descriptive Statistics

Variable	Obs	Mean	St. Dev	Min	Max
EQI	271	68.9362	8.69106	35.78	85.69
RREP	257	175374.5	747016.7	1140	7462670
GRDP	272	308985.8	437739	20380	1953489
DEF	247	9550.259	25605.89	-3299	271033
HDI	272	70.45118	4.069789	57.25	81.65

Source: Data Processing

Table 1 presents the descriptive statistics of the main variables used in this study. The dependent variable, the Environmental Quality Index (EQI), has a mean value of 68.93 with a standard deviation of 8.69. The minimum EQI score is 35.78, while the maximum reaches 85.69, indicating substantial variation in environmental quality across provinces. This wide range reflects regional disparities in environmental conditions, including differences in air quality, water quality, and land cover, as comprehensively assessed by the Ministry of Environment and Forestry (Noormalitasari & Setyadharma, 2021; Ushurhe et al., 2024). Similar regional disparities in composite environmental indices have also been documented in developing countries, where uneven development and governance capacity shape environmental outcomes (Masterson et al., 2019; Yahman & Setyagama, 2023).

The Regional Revenue and Expenditure Budget (RREP) shows an average annual regional expenditure of approximately 175,375 million rupiah, accompanied by a very high standard deviation. This pattern highlights pronounced disparities in fiscal capacity among provinces, where more developed regions tend to allocate

significantly larger budgets, including for environmental management. Similarly, Gross Regional Domestic Product (GRDP), as an indicator of economic activity, records a mean value of 308,985 billion rupiah with a large standard deviation of 437,739 billion rupiah, suggesting sharp regional economic inequality between provinces with high economic concentration, such as DKI Jakarta, and less developed regions. Such fiscal and economic asymmetries across regions have been widely observed in decentralized systems and are often linked to uneven development trajectories and policy capacity (Hajad et al., 2025; Ramadanti & Suhab, 2023; Setiawan & Primandahan, 2022).

The deforestation variable exhibits notable heterogeneity, with an average annual forest cover loss of 9,550 hectares and a standard deviation of 25,605 hectares. The presence of negative minimum values indicates that some provinces experienced reforestation or forest cover recovery during the observation period, although large-scale deforestation remains prevalent in several regions. This pattern is consistent with previous studies showing that forest dynamics vary considerably across subnational regions due to differences in land-use policies, enforcement, and economic pressures (Li & Xu, 2021; Walker, n.d.; Wang et al., 2024).

Finally, the Human Development Index (HDI), measured using the updated methodology, has an average value of 70.45, ranging from 57.25 to 81.65. While Indonesia's HDI has improved at the national level, substantial interprovincial disparities persist. Provinces in eastern Indonesia, such as Papua and Nusa Tenggara, generally record lower HDI scores than provinces in Java and Bali, reflecting unequal access to education, health services, and adequate living standards, a pattern commonly reported in regional development studies (Nanda Monika Marpaung & Ni Luh Karmini, 2025; Raihannabil et al., 2025; Rosyid et al., 2025)

Determinants of Environmental Quality Index (EQI)

To ensure the validity and appropriateness of the panel regression model employed in this study, a series of diagnostic tests was conducted. First, the Hausman test was applied to determine the most suitable specification between the Fixed Effects (FE) and Random Effects (RE) models. The test results indicate a probability value (p-value) of 0.0000, which is well below the conventional significance threshold of 0.05. Accordingly, the null hypothesis is rejected, implying systematic differences between the FE and RE estimators. This finding confirms that the Fixed Effects model is more consistent and appropriate, as it accounts for unobserved, time-invariant provincial heterogeneity that may be correlated with the explanatory variables (Baltagi, 2008; Gujarati & Porter, 2009). To examine potential multicollinearity among the independent variables, a Variance Inflation Factor (VIF) test was performed, as reported in Table 2.

Table 2. VIF Test

Variable	VIF
GRDP	1.49
RREP	1.42
HDI	1.19
DEF	1.01

Source: Data Processing

The results show that all VIF values are well below the critical threshold of 10, indicating the absence of severe multicollinearity among the explanatory variables (Greene, 2020; Gujarati, 2003). Furthermore, the Wooldridge test for autocorrelation yields a p-value of 0.0001, suggesting the presence of serial correlation in the panel residuals. In addition, the Breusch–Pagan test for heteroskedasticity reports a p-value of 0.01, indicating non-constant error variance across observations. In response to these diagnostic results, robust standard errors were applied to ensure reliable statistical inference, consistent with best practices in panel data econometrics. Figure 1 illustrates the distribution of the dependent variable, the Environmental Quality Index.

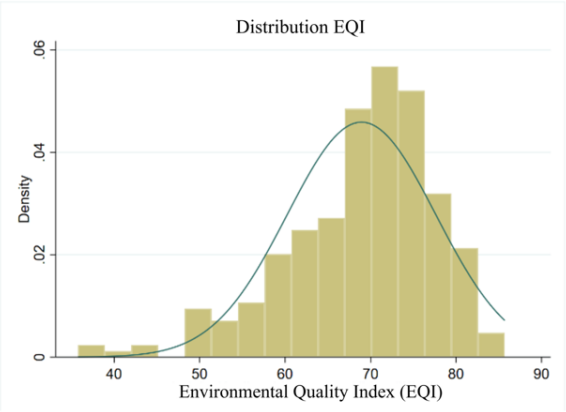

Figure 1. Environmental Quality Index Distribution

The histogram shows that EQI values generally follow an approximately normal distribution, characterized by a relatively symmetric shape and the absence of extreme outliers. This visual evidence suggests that there are no serious distributional issues that could undermine the accuracy of the regression estimates. Overall, the diagnostic tests confirm that the Fixed Effects model is appropriate and that the estimation results can be interpreted with confidence. The estimation results of the main Fixed Effects regression model are presented below.

Table 3. Main Model Regression Results

Variable	Environmental Quality Index (EQI)
ln*GRDP*	0.388
	(0.331)
ln*RREP*	-6.577
	(7.688)
DEF	-0.000
	(0.000)
HDI	1.988**
	(0.818)
Constant	3.794
	(49.893)
Observation	232
R-squared	0.139

Source: Data Processing

The Fixed Effects estimation results indicate that among the four independent variables examined, only the Human Development Index (HDI) exhibits a statistically significant effect on environmental quality at the 5% significance level. The HDI coefficient of 1.988 implies that a one-point increase in HDI is associated with an average increase of 1.988 points in EQI. This finding reinforces the argument that improvements in human welfare, reflected in better access to education, health services, and adequate living standards, are closely linked to enhanced environmental outcomes (Li & Xu, 2021; Zhang & Wu, 2022)

In contrast, the logarithm of Gross Regional Domestic Product (lnGRDP) shows a positive but statistically insignificant coefficient. This suggests that higher economic output does not necessarily translate into better environmental quality, particularly in regions where economic growth is driven by resource-intensive activities. This result aligns with international evidence indicating that the environmental benefits of economic growth depend heavily on structural transformation, technological adoption, and regulatory effectiveness rather than income expansion alone (Stern, 2017; Barbier & Burgess, 2020).

Similarly, the logarithm of regional government expenditure (lnapbd) displays a negative and insignificant coefficient. Although environmental spending is theoretically expected to improve ecological conditions, this result suggests that larger budget allocations do not automatically ensure better environmental outcomes. Previous studies highlight that inefficiencies in budget execution, weak institutional coordination, and limited monitoring can undermine the effectiveness of environmental expenditure, particularly in decentralized governance systems(Purnamadewi et al., 2019; Setiawan & Primandahan, 2022; Yahman & Setyagama, 2023).

The deforestation variable exhibits a very small negative coefficient and remains statistically insignificant. While the direction of the relationship is consistent with theoretical expectations that forest loss degrades environmental quality, its insignificance may reflect high interprovincial variability, time-lag effects, and partial forest recovery in certain regions. Empirical studies emphasize that the environmental impacts of deforestation often manifest over longer time horizons and may not be fully captured in short- to medium-term provincial panel data (Humanita et al., 2024; Indriana et al., 2021). With 232 observations across 33 provinces and the application of robust standard errors, the estimation results demonstrate reasonable reliability. Collectively, these findings underscore the central role of human development in improving environmental quality while revealing the limited standalone influence of economic growth and fiscal expenditure in the absence of effective governance mechanisms.

The results further corroborate national and international panel studies showing that improvements in human capital and social capacity constitute a key driver of environmental sustainability (Ilham, 2021; Long et al., 2020; Siregar & Hasbi, 2025). Conversely, Indonesia's development trajectory reflects a persistent paradox in which industrial expansion, land conversion, and

extractive activities—captured through PDRB growth and deforestation—continue to exert ecological pressure. Empirical evidence from Sumatra and Kalimantan demonstrates that large-scale agriculture, mining, and peatland conversion have contributed to greenhouse gas emissions, water pollution, and ecosystem degradation despite rising regional income levels (Aldilla et al., 2024; Ramadhan, 2023).

Policy and Management Strategies to Improve Regional EQI

From a policy perspective, these results suggest that improving environmental quality in Indonesia requires more than accelerating economic growth or increasing environmental budgets. Strengthening human development emerges as a strategic pathway for enhancing environmental outcomes, as higher HDI levels foster environmental awareness, institutional capacity, and public participation in environmental governance. Therefore, investments in education, health, and social welfare should be regarded as integral components of environmental policy. At the same time, economic expansion must be accompanied by stricter land-use regulation, improved deforestation monitoring, and stronger accountability in environmental spending. By integrating human development, economic growth, deforestation, and fiscal policy within a unified panel data framework, this study contributes empirical evidence to support evidence-based policymaking aimed at balancing regional development objectives with long-term environmental sustainability in Indonesia.

CONCLUSION

This study provides empirical evidence that improvements in the Human Development Index (HDI) exert a significant positive influence on the Environmental Quality Index (EQI). In contrast, deforestation and regional government budget allocations for the environmental sector do not exhibit significant effects. These findings confirm that inclusive human development plays a central role in enhancing environmental quality, whereas unmanaged economic activities may impose additional pressure on ecological systems. Accordingly, Indonesia's development policies should prioritize strengthening human capital and mitigating the environmental impacts of economic growth through improved environmental governance. This includes optimizing regional budget utilization, reinforcing land-use regulation, and adopting sustainable land management strategies to ensure that economic development progresses in harmony with long-term environmental sustainability.

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