

Environmental Quality and Sustainable Development in Indonesia: The Role of Socioeconomic Determinants During 2019–2023

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Abstract: Environmental quality is an important indicator of sustainable development because it reflects the interaction between economic, social, and environmental dimensions. This study examines the relationship between socioeconomic determinants and environmental quality across Indonesian provinces during 2019–2023. A quantitative approach was employed using balanced panel data from 34 provinces, comprising 170 observations obtained from Statistics Indonesia (BPS) and the Ministry of Environment and Forestry (KLHK). Panel data regression was applied, with the Fixed Effect Model (FEM) selected based on the Chow and Hausman tests. Diagnostic testing indicated heteroscedasticity, serial correlation, and cross-sectional dependence; therefore, Driscoll–Kraay robust standard errors were employed for statistical inference. The results show that GRDP per capita is positively and significantly associated with environmental quality, while poverty has a negative and significant association. Population density also shows a positive and significant relationship with environmental quality. In contrast, unemployment has a positive coefficient but is not statistically significant at the conventional 5% level. The model explains 94.72% of the variation in environmental quality. These findings highlight the importance of integrating economic development, poverty alleviation, sustainable urban management, and environmental protection into regional development policies in Indonesia.

Keywords: Environmental quality; Indonesia; Panel data; Socioeconomic determinants; Sustainable development

Introduction

Environmental quality is a crucial indicator of sustainable development because it reflects the balance between economic growth, social welfare, and environmental sustainability. Sustainable development emphasizes the integration of economic, social, and environmental dimensions to ensure that development activities meet present needs without compromising the ability of future generations to meet their own needs (Halişçelik & Soytaş, 2019). In this context, environmental quality serves as an essential measure of ecological sustainability and societal well-being, alongside economic performance (Zhang et al., 2024).

The transition from the Millennium Development Goals (MDGs) to the Sustainable Development Goals (SDGs) further highlights the growing recognition of environmental protection as a fundamental component of sustainable development strategies worldwide (Halişçelik & Soytaş, 2019). Therefore, maintaining environmental quality has become a global priority to support long-term economic prosperity, social equity, and ecosystem resilience.

Despite global commitments to the Sustainable Development Goals (SDGs), rapid urbanization, industrialization, and population growth continue to exert significant pressure on environmental quality worldwide. These processes have accelerated resource

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consumption, land-use change, pollution, and environmental degradation in both developed and developing countries. Previous studies have shown that economic expansion and urban growth are often associated with increasing ecological footprints and environmental pressures (Sarwar et al., 2024). Although green innovation, environmental policies, and sustainable development initiatives have been implemented to address these challenges, their effectiveness varies across countries and regions (Ma et al., 2025). Therefore, balancing economic development with environmental sustainability remains a major challenge for achieving long-term sustainable development goals (Li & Hassan, 2026).

Indonesia faces increasing environmental challenges, including air pollution, water degradation, land-use change, and resource depletion, which affect environmental quality across provinces. Rapid economic development, urbanization, and population growth have intensified pressure on natural resources and ecosystems, creating disparities in environmental conditions among regions. Although the government has implemented various sustainable development and green growth policies to improve environmental performance, significant challenges remain in balancing economic growth with environmental sustainability (Anderson et al., 2016). These conditions highlight the importance of continuously assessing environmental quality to support effective and evidence-based policy interventions across Indonesia.

The Environmental Quality Index (EQI), known as Indeks Kualitas Lingkungan Hidup (IKLH) in Indonesia, is a comprehensive indicator used to assess environmental conditions and monitor sustainable development performance (Ministry of Environment and Forestry of the Republic of Indonesia, 2024). The index incorporates key environmental dimensions, including air quality, water quality, and land quality, to provide an overall measure of environmental sustainability (Lyu et al., 2024). As an important policy instrument, IKLH helps evaluate environmental performance and supports evidence-based decision-making for sustainable development in Indonesia (Badan Pusat Statistik, 2024).

Environmental quality is closely influenced by socioeconomic factors, including economic growth, poverty, population density, and unemployment. While economic growth can generate environmental pressure through increased resource consumption, it may also contribute to environmental improvement through innovation and investment (Adejumo, 2020). At the same time, poverty and demographic pressures can affect environmental sustainability through resource utilization patterns (Perrings & Ansuategi, 2000). Therefore, integrating socioeconomic and

environmental considerations is essential for sustainable development.

Previous studies have shown that economic growth has a dual relationship with environmental quality. Economic expansion may increase environmental degradation through higher production, consumption, and resource utilization, but rising income levels can also improve environmental quality through technological innovation, cleaner production systems, and environmental investment (Hunjra et al., 2024). This dual relationship is also consistent with the Environmental Kuznets Curve perspective, which suggests that the relationship between economic development and environmental pressure may vary across different stages of development (Pincheira & Zuniga, 2021). In addition, the adoption of renewable energy and sustainable technologies has been found to strengthen environmental resilience and support sustainable development goals (Han et al., 2024; Wang et al., 2025). These findings indicate that the environmental effects of economic growth largely depend on the effectiveness of environmental policies, technological progress, and sustainability-oriented development strategies (Mutakim et al., 2025).

Previous studies have reported that poverty, population density, and unemployment are important determinants of environmental quality, although their effects vary across regions and periods. Poverty may contribute to environmental degradation through excessive dependence on natural resources, while population pressure can increase resource consumption and environmental stress (H. Khan et al., 2009; S. Khan & Yahong, 2021). On the other hand, unemployment has been found to reduce environmental degradation in some cases due to lower levels of industrial and economic activity (Sahin et al., 2025). Studies in Indonesia also report mixed findings, where economic growth significantly improves environmental quality, while population density and poverty often show insignificant effects (Navila & Cerya, 2025; Soeparno et al., 2024). These inconsistent findings indicate that the relationship between socioeconomic factors and environmental quality remains context-dependent and requires further investigation to support sustainable development policies.

Although previous studies have examined the relationship between socioeconomic factors and environmental quality, several important gaps remain. First, existing evidence in Indonesia is still fragmented, as previous studies have generally focused on specific regions, individual socioeconomic determinants, or limited observation periods. Second, the empirical findings remain inconclusive, particularly regarding the effects of economic growth, poverty, population density, and unemployment on environmental quality. Third,

limited evidence is available from a unified provincial-level panel framework that simultaneously evaluates these socioeconomic determinants while controlling for time-invariant regional heterogeneity. To address these gaps, this study integrates four key socioeconomic determinants GRDP per capita, poverty, population density, and unemployment within a balanced panel of 34 Indonesian provinces over 2019–2023. The novelty of this study lies in providing an integrated provincial-level assessment of these determinants using a fixed-effects panel framework, thereby offering updated evidence on how socioeconomic disparities are associated with environmental quality across Indonesia. This approach contributes to the literature by reconciling previously mixed findings within a common empirical framework and providing regionally relevant evidence for sustainable development policy.

Therefore, this study aims to analyze the influence of socioeconomic determinants, including economic growth, poverty, population density, and unemployment, on environmental quality across Indonesian provinces during the 2019–2023 period. In addition, this study seeks to provide empirical evidence on the role of socioeconomic factors in shaping environmental sustainability at the regional level. The findings are expected to enrich the literature on environmental quality and sustainable development and provide insights for evidence-based environmental policymaking in Indonesia.

Method

This study employed a quantitative approach with an explanatory research design to examine the influence of socioeconomic determinants on environmental quality in Indonesia. The study utilized balanced panel data consisting of 34 provinces observed during the period 2019–2023, resulting in 170 observations. Secondary data were obtained from Statistics Indonesia (BPS) and the Ministry of Environment and Forestry of the Republic of Indonesia (Badan Pusat Statistik, 2024; Ministry of Environment and Forestry of the Republic of Indonesia, 2024)

Table 1. Operational Definition of Variables

Variable	Symbol	Measurement
Environmental Quality Index	EQI	Index (0–100)
GRDP per Capita	GRDP	Rupiah
Poverty Rate	POV	%
Population Density	PD	Persons/km ²
Open Unemployment Rate	OUR	%

Source: Statistics Indonesia (BPS, 2024) and Ministry of Environment and Forestry of the Republic of Indonesia (KLHK, 2024).

The dependent variable in this study was the Environmental Quality Index (EQI/IKLH), while the independent variables included Gross Regional Domestic Product (GRDP) per capita, poverty rate, population density, and open unemployment rate. The operational definitions and measurements of the variables are presented in Table 1.

Descriptive statistics were first employed to describe the characteristics of the variables. Furthermore, panel data regression analysis was conducted to examine the influence of socioeconomic determinants on environmental quality. Panel data analysis combines cross-sectional and time-series data, allowing for more comprehensive estimation and greater variability of observations (Baltagi, 2008). Model selection was determined through the Chow test, Hausman test, and Lagrange Multiplier test to identify the most appropriate model among the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM). The panel regression model is specified as follows:

$$EQI_{it} = \alpha + \beta_1GRDP_{it} + \beta_2POV_{it} + \beta_3PD_{it} + \beta_4OUR_{it} + \varepsilon_{it} \quad (1)$$

where EQI represents the Environmental Quality Index, GRDP denotes Gross Regional Domestic Product per capita, POV represents the poverty rate, PD represents population density, OUR represents the open unemployment rate, α is the intercept, β is the regression coefficient, and ε is the error term. All analyses were performed using EViews 13 software.

To assess the reliability of the panel regression estimates, additional diagnostic tests were conducted. Multicollinearity among the explanatory variables was evaluated using the Variance Inflation Factor (VIF). Heteroscedasticity was assessed using the Breusch–Pagan test, while serial correlation and cross-sectional dependence were examined using residual-based serial correlation diagnostics and the Pesaran cross-sectional dependence (CD) test, respectively. The diagnostic results indicated the presence of heteroscedasticity, serial correlation, and cross-sectional dependence. Therefore, the Fixed Effect Model was re-estimated using Driscoll–Kraay robust standard errors to obtain statistical inference that is robust to these disturbances.

A dynamic panel specification was not employed because the objective of this study was to estimate the contemporaneous associations between socioeconomic determinants and environmental quality rather than the persistence or adjustment dynamics of environmental quality over time. The empirical specification did not include a lagged dependent variable, and the relatively short time dimension of the panel ($T = 5$) further supported the use of a static fixed-effects framework.

Accordingly, the static FEM with robust inference was considered more consistent with the research objective and data structure.

Result and Discussion

The substantial interprovincial variation observed across the socioeconomic and environmental indicators reflects the heterogeneous development conditions of Indonesian provinces. The wide range of the Environmental Quality Index indicates that provinces differ considerably in their capacity to maintain environmental conditions, while disparities in GRDP

per capita demonstrate uneven levels of economic development. Similarly, the broad variation in population density reflects contrasting demographic pressures across provinces, ranging from relatively sparsely populated regions to highly concentrated urbanized areas. Differences in poverty and unemployment further indicate unequal socioeconomic conditions that may influence environmental pressures, resource use, and regional capacity for environmental management. These variations provide an important empirical basis for employing a provincial panel-data approach, as the relationship between socioeconomic development and environmental quality is unlikely to be homogeneous across Indonesia.

Table 2. Descriptive Statistics

Variable	Mean	Minimum	Maximum	Std. Dev.
EQI	72.543	43.180	85.930	6.485
GRDP per Capita	70,914.224	21,353.000	322,651.000	54,560.046
Open Unemployment Rate	5.194	1.570	10.950	1.736
Population Density	747.447	9.000	16,159.000	2,692.014
Poverty Rate	9.858	3.420	27.530	5.775

Source: Processed secondary data (2025)

Table 3. Panel Model Selection Results

Test	Statistic	Probability	Decision
Chow Test	267.504	0.0000	FEM
Hausman Test	540.249	0.0000	FEM

Source: Authors' calculation using EViews 13 (2025)

Model selection was conducted using the Chow and Hausman tests. The results showed that both tests were significant ($p < 0.05$), indicating that the Fixed Effect Model (FEM) was more appropriate than the

Common Effect Model (CEM) and Random Effect Model (REM). Therefore, FEM was selected as the final model for further analysis.

Before interpreting the final FEM estimates, diagnostic tests were conducted to assess potential violations of the regression assumptions. The results of the multicollinearity, heteroscedasticity, serial correlation, and cross-sectional dependence tests are presented in Table 4.

Table 4. Panel Diagnostic Test Results

Diagnostic Test	Statistic/Result	p-value	Interpretation
Multicollinearity (VIF)	1.108-1.995	-	No serious multicollinearity
Breusch-Pagan heteroscedasticity test	LM = 73.381	<0.001	Heteroscedasticity detected
Serial correlation diagnostic	$\rho = 0.337$	<0.001	Serial correlation detected
Pesaran CD test	CD = 11.789	<0.001	Cross-sectional dependence detected

Source: Authors' calculation using EViews 13 (2025)

As shown in Table 4, the VIF values ranged from 1.108 to 1.995, indicating no serious multicollinearity among the explanatory variables. However, the Breusch-Pagan test indicated heteroscedasticity (LM = 73.381, $p < 0.001$). The residual-based serial correlation diagnostic also indicated significant within-panel serial correlation ($\rho = 0.337$, $p < 0.001$), while the Pesaran CD test revealed significant cross-sectional dependence (CD = 11.789, $p < 0.001$). These findings indicate that conventional FEM standard errors may not provide reliable statistical inference. Therefore, the final FEM estimates were evaluated using Driscoll-Kraay robust

standard errors to account for heteroscedasticity, serial correlation, and cross-sectional dependence.

Table 5. Fixed Effect Model Estimation with Driscoll-Kraay Robust Standard Errors

Variable	Coefficient	Robust SE	t-Statistic	Probability
GRDP	0.000059	0.0000126	46.800	<0.001
POV	-0.8746	0.2592	-3.3737	0.0007
PD	0.0445	0.0050	88.640	<0.001
OUR	0.6598	0.3654	18.057	0.0710

Source: Authors' calculation based on processed secondary data (2025). $R^2 = 0.9588$; Adjusted $R^2 = 0.9472$; Note: Statistical inference is based on Driscoll-Kraay robust standard errors.

The robust FEM estimates presented in Table 5 show that GRDP per capita has a positive and statistically significant association with environmental quality ($\beta = 0.000059$, $p < 0.001$). Poverty has a negative and statistically significant association with environmental quality ($\beta = -0.8746$, $p = 0.0007$), indicating that higher poverty levels are associated with lower environmental quality. Population density also exhibits a positive and statistically significant relationship with environmental quality ($\beta = 0.0445$, $p < 0.001$). In contrast, the unemployment rate retains a positive coefficient ($\beta = 0.6598$), but its effect is not statistically significant at the conventional 5% level ($p = 0.0710$). The model demonstrates strong explanatory power, with an R^2 of 0.9588 and an adjusted R^2 of 0.9472. Overall, the robust estimates provide consistent evidence that GRDP per capita, poverty, and population density are significantly associated with provincial environmental quality, whereas the evidence regarding unemployment is comparatively weaker after accounting for heteroscedasticity, serial correlation, and cross-sectional dependence.

Table 6. Results of Linear Regression Analysis

Statistic	Value
R^2	0.9588
Adjusted R^2	0.9472
F-statistic	830.204
Prob(F-statistic)	0.0000

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$
Source: Authors' calculation using EViews 13 (2025)

Overall Regression Results

The robust estimation results indicate that socioeconomic conditions are associated with environmental quality through different mechanisms across Indonesian provinces. Rather than suggesting a uniform effect of socioeconomic development, the findings reveal that economic capacity, poverty conditions, demographic concentration, and labor-market conditions operate through distinct pathways. Higher economic capacity may strengthen provincial resources for environmental infrastructure and governance, whereas poverty may constrain both household and governmental capacity to adopt environmentally sustainable practices. Population concentration may generate environmental pressures, but it may also facilitate more efficient provision of environmental services and infrastructure. Meanwhile, the weaker statistical evidence for unemployment suggests that labor-market conditions may not directly translate into environmental outcomes once regional heterogeneity and disturbances in the panel error structure are taken into account. These mechanisms are

discussed separately in the following subsections and compared with previous empirical findings.

Effect of Poverty on Environmental Quality

The robust estimation confirms a negative and statistically significant relationship between poverty and environmental quality ($\beta = -0.8746$, $p = 0.0007$). This relationship may operate through several interconnected socioeconomic mechanisms. Households facing persistent economic constraints tend to prioritize immediate livelihood needs and may depend more heavily on locally available natural resources, potentially increasing pressure on forests, land, and other environmental assets. At the regional level, high poverty may also coincide with limited access to environmentally friendly technologies, adequate sanitation, waste-management services, and other environmental infrastructure. These constraints can reduce the capacity of communities to adopt sustainable practices and may intensify environmental degradation. This mechanism is consistent with previous studies linking poverty to environmental degradation through resource dependence and limited environmental management capacity (S. Khan & Yahong, 2021; Perrings & Ansuategi, 2000).

From a sustainable development perspective, the finding suggests that poverty reduction and environmental improvement should be pursued as mutually reinforcing objectives. Improvements in household welfare, education, access to basic environmental services, clean technologies, and sustainable livelihood opportunities may reduce dependence on environmentally harmful activities while strengthening adaptive capacity. The provincial-level evidence in this study further suggests that the poverty-environment relationship remains significant after controlling for time-invariant regional heterogeneity and applying robust inference. Differences from studies reporting weaker or different poverty-environment relationships may reflect variations in geographic coverage, environmental indicators, observation periods, and socioeconomic structures. Therefore, poverty alleviation policies should be integrated with investments in sanitation, waste management, environmental infrastructure, and sustainable livelihood development rather than being implemented independently of environmental policy.

Effect of Population Density on Environmental Quality

The robust estimation confirms a positive and statistically significant relationship between population density and environmental quality ($\beta = 0.0445$, $p < 0.001$). Although population concentration is commonly associated with greater pressure on land, energy, transportation, and waste-management systems, the

positive relationship observed in this study suggests that density may also generate environmental efficiency when accompanied by adequate infrastructure and institutional capacity. In more densely populated provinces, the concentration of residents may facilitate more efficient provision of public transportation, sanitation, waste collection, water services, and other environmental infrastructure because these services can be delivered to a larger population within a relatively concentrated area. Stronger administrative capacity and environmental governance in more urbanized regions may further offset some of the environmental pressures associated with population concentration.

This finding indicates that population density should not be interpreted as an inherently detrimental factor for environmental quality. Compact settlement patterns may reduce extensive land conversion and enable more efficient utilization of transportation networks and public utilities when supported by appropriate spatial planning and sustainable urban management. The result is consistent with Soeparno et al. (2024), who indicate that demographic concentration can contribute positively to environmental quality under supportive governance conditions. At the same time, the positive relationship found in this study may differ from studies associating population density with environmental degradation because the environmental consequences of density depend on differences in infrastructure provision, urban form, institutional capacity, and environmental management. Thus, the findings emphasize that the environmental effect of population concentration is conditional on how effectively regional development and urban services are managed.

Effect of Unemployment on Environmental Quality

The robust estimation shows that the unemployment rate has a positive coefficient ($\beta = 0.6598$), but the relationship is not statistically significant at the conventional 5% level ($p = 0.0710$). This finding indicates that unemployment does not independently provide sufficiently strong evidence for explaining variations in environmental quality across Indonesian provinces during the study period. One possible mechanism underlying the positive coefficient is that weaker labor-market activity may coincide with lower industrial production, transportation intensity, energy consumption, and resource exploitation, thereby reducing certain forms of environmental pressure. However, unemployment may simultaneously reduce household income and regional economic capacity, potentially constraining investment in environmental services, infrastructure, and sustainable technologies. These opposing mechanisms may explain why the

estimated relationship becomes statistically weaker after robust correction.

Accordingly, the positive coefficient should not be interpreted as evidence that higher unemployment improves environmental quality. Rather, the result highlights the complex and potentially indirect relationship between labor-market conditions and environmental outcomes. Sahin et al. (2025) reported evidence linking economic and labor-market dynamics to environmental pressure in emerging economies. In comparison, the present study finds weaker statistical evidence for unemployment after accounting for heteroscedasticity, serial correlation, and cross-sectional dependence. This difference may reflect variations in geographic scale, economic structure, study period, environmental indicators, and econometric specification. The finding therefore suggests that employment policies should not be evaluated solely in terms of their direct environmental effects; instead, employment creation should be accompanied by cleaner production, resource-efficient technologies, and environmentally sustainable regional development strategies.

Implications for Sustainable Development

The findings have several practical implications for sustainable development policy in Indonesia. First, the positive relationship between GRDP per capita and environmental quality suggests that regional economic growth should be accompanied by green fiscal policies that direct public expenditure and investment toward pollution control, renewable energy, low-carbon infrastructure, waste management, and environmental restoration. Provincial governments can strengthen this linkage by integrating environmental performance criteria into regional budgeting and development planning and by prioritizing fiscal incentives for cleaner production and resource-efficient technologies. Such measures are important to ensure that economic expansion generates sufficient fiscal and technological capacity to improve environmental quality rather than increasing environmental pressure.

Second, the negative relationship between poverty and environmental quality indicates the need for environmentally based poverty-alleviation strategies. Poverty-reduction programs should be integrated with access to adequate sanitation, clean energy, community-based waste management, environmental education, and sustainable livelihood opportunities. Programs that increase household income while reducing dependence on environmentally damaging resource extraction can generate simultaneous social and environmental benefits. This approach is particularly relevant for provinces where socioeconomic vulnerability and

limited environmental infrastructure occur simultaneously.

Third, the positive association between population density and environmental quality emphasizes the importance of effective urban and spatial planning. Densely populated provinces should prioritize compact and transit-oriented development, accessible public transportation, efficient waste collection and wastewater treatment, adequate green open spaces, and environmentally efficient public utilities. Population concentration can generate environmental benefits only when supported by sufficient infrastructure and strong environmental governance. Therefore, regional planning should focus not merely on controlling population density but on managing urban concentration through sustainable infrastructure and land-use policies.

Finally, because unemployment does not show a statistically significant relationship with environmental quality after robust correction, employment creation should not be treated as a direct environmental policy instrument. Instead, labor-market policies should be aligned with the transition toward environmentally sustainable economic activities through green-job development, cleaner production, renewable-energy activities, circular-economy initiatives, and environmentally responsible small and medium-sized enterprises. Collectively, these policy directions support a more integrated approach in which economic development, poverty reduction, urban management, employment creation, and environmental protection are incorporated into regional development strategies.

Conclusion

This study examined the relationship between socioeconomic determinants and environmental quality across 34 Indonesian provinces during 2019–2023 using a Fixed Effect Model with Driscoll–Kraay robust standard errors. The findings show that GRDP per capita is positively and significantly associated with environmental quality, whereas poverty has a negative and significant association. Population density also exhibits a positive and significant relationship with environmental quality. In contrast, unemployment shows a positive coefficient but is not statistically significant at the conventional 5% level after robust correction. These findings indicate that provincial environmental quality is more consistently associated with economic capacity, poverty conditions, and demographic concentration than with unemployment during the study period. Theoretically, this study contributes to the socioeconomic–environmental quality literature by demonstrating that regional development

factors do not operate through a uniform pathway. Economic capacity may support environmental improvement through greater fiscal, technological, and institutional resources, while poverty may constrain access to environmental infrastructure and sustainable practices. The positive relationship between population density and environmental quality further indicates that demographic concentration does not necessarily result in environmental deterioration when supported by efficient infrastructure, spatial planning, and environmental governance. The weaker evidence for unemployment also suggests that labor-market conditions may influence environmental outcomes indirectly rather than constituting a stable independent determinant. These findings reinforce the importance of incorporating regional heterogeneity into explanations of socioeconomic–environmental relationships. Several limitations should be acknowledged. First, the analysis covers a relatively short period of five years (2019–2023), which limits the assessment of long-term environmental dynamics. Second, the study relies on provincial-level aggregate data and therefore cannot capture socioeconomic and environmental variations within provinces. Third, the model focuses on four socioeconomic determinants and does not incorporate other potentially relevant factors such as industrial structure, energy consumption, renewable-energy utilization, environmental expenditure, urbanization, or institutional quality. Finally, the observational panel design identifies statistical associations and should not be interpreted as establishing definitive causal relationships. Future research should extend the observation period and incorporate additional environmental, economic, energy, and institutional indicators to provide a more comprehensive explanation of regional environmental quality. Studies using district- or city-level data could also identify spatial heterogeneity that is obscured by provincial aggregation. In addition, future research may employ spatial panel models to examine environmental spillovers across neighboring regions and, where longer time-series data become available, dynamic panel approaches to investigate persistence and adjustment in environmental quality. Comparative analyses across Indonesian regions or other emerging economies may further clarify the conditions under which socioeconomic development supports or constrains environmental sustainability.

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Adejumo, O. O. (2020). Environmental quality vs economic growth in a developing economy: complements or conflicts. *Environmental Science and Pollution Research*, 27(6), 6163–6179. <https://doi.org/10.1007/s11356-019-07101-x>
- Anderson, Z. R., Kusters, K., McCarthy, J., & Obidzinski, K. (2016). Green growth rhetoric versus reality: Insights from Indonesia. *Global Environmental Change*, 38, 30–40. <https://doi.org/10.1016/j.gloenvcha.2016.02.008>
- Badan Pusat Statistik. (2024). *Indeks Kualitas Lingkungan Hidup Menurut Provinsi*. Badan Pusat Statistik. Retrieved from <https://www.bps.go.id/id/statistics-table/2/MjUzMMSMy/indeks-kualitas-lingkungan-hidup-menurut-provinsi.html>
- Baltagi, B. H. (2008). *Econometric analysis of panel data* (Vol. 4). Springer.
- Halisçelik, E., & Soytas, M. A. (2019). Sustainable development from millennium 2015 to Sustainable Development Goals 2030. *Sustainable Development*, 27(4), 545–572. <https://doi.org/10.1002/sd.1921>
- Han, S., Li, C., Li, M., Lenzen, M., Chen, X., Zhang, Y., Li, M., Yin, T., Li, Y., Li, J., Liu, J., & Li, Y. (2024). Prospects for global sustainable development through integrating the environmental impacts of economic activities. *Nature Communications*, 15(1), 8424. <https://doi.org/10.1038/s41467-024-52854-w>
- Hunjra, A. I., Bouri, E., Azam, M., Azam, R. I., & Dai, J. (2024). Economic growth and environmental sustainability in developing economies. *Research in International Business and Finance*, 70, 102341. <https://doi.org/10.1016/j.ribaf.2024.102341>
- Khan, H., Inamullah, E., & Shams, K. (2009). Population, environment and poverty in Pakistan: linkages and empirical evidence. *Environment, Development and Sustainability*, 11(2), 375–392. <https://doi.org/10.1007/s10668-007-9119-y>
- Khan, S., & Yahong, W. (2021). Symmetric and Asymmetric Impact of Poverty, Income Inequality, and Population on Carbon Emission in Pakistan: New Evidence From ARDL and NARDL Co-Integration. *Frontiers in Environmental Science*, 9. <https://doi.org/10.3389/fenvs.2021.666362>
- Li, T., & Hassan, A. (2026). Urbanization, Education, and Resource Efficiency: Empirical Insights Into Environmental Sustainability in <scp>G20</scp> Nations. *Sustainable Development*, 34(S1), 364–378. <https://doi.org/10.1002/sd.70182>
- Lyu, X., Li, X., Wang, K., Dang, D., Cao, W., & Lou, A. (2024). Using a pattern-process-service-sustainability framework to clarify the relationship between regional ecosystem quality and sustainable development. *Ecological Indicators*, 165, 112174. <https://doi.org/10.1016/j.ecolind.2024.112174>
- Ma, X., Ben-Salha, O., & Choukaier, D. (2025). Beyond economic growth: the synergistic effects of globalization, environmental policies, and the triple green strategy on environmental sustainability in OECD countries. *Frontiers in Environmental Science*, 13. <https://doi.org/10.3389/fenvs.2025.1649166>
- Ministry of Environment and Forestry of the Republic of Indonesia. (2024). *Indeks Kualitas Lingkungan Hidup Indonesia 2023*. Retrieved from <https://www.bps.go.id/id/statistics-table/2/MjUzMMSMy/indeks-kualitas-lingkungan-hidup-menurut-provinsi.html>
- Mutakim, J., Komar, O., Sudiapermana, E., Pramudia, J. R., & Nuraeni, L. (2025). Community-Based Learning Model to Support Environmental Sustainability and Community Empowerment in Sukamakmur Regency. *Jurnal Penelitian Pendidikan IPA*, 11(3), 599–608. <https://doi.org/10.29303/jppipa.v11i3.10371>
- Navila, Y., & Cerya, E. (2025). Pengaruh Pertumbuhan Ekonomi, Kepadatan Penduduk dan Kemiskinan Terhadap Kualitas Lingkungan Hidup Di Indonesia. *Jurnal Ilmiah Pendidikan Lingkungan Dan Pembangunan*, 26(01), 15–26. <https://doi.org/10.21009/plpb.v26i01.59043>
- Perrings, C., & Ansuategi, A. (2000). Sustainability, growth and development. *Journal of Economic Studies*, 27(1/2), 19–54. <https://doi.org/10.1108/EUM0000000005309>
- Pincheira, R., & Zuniga, F. (2021). Environmental Kuznets curve bibliographic map: a systematic literature review. *Accounting & Finance*, 61(S1), 1931–1956. <https://doi.org/10.1111/acfi.12648>

- Sahin, G., Naimoglu, M., Kavaz, I., & Sahin, A. (2025). Examining the Environmental Phillips Curve Hypothesis in the Ten Most Polluting Emerging Economies: Economic Dynamics and Sustainability. *Sustainability*, 17(3), 920. <https://doi.org/10.3390/su17030920>
- Sarwar, N., Bibi, F. N., Junaid, A., & Alvi, S. (2024). Impact of urbanization and human development on ecological footprints in OECD and non-OECD countries. *Heliyon*, 10(19), e38058. <https://doi.org/10.1016/j.heliyon.2024.e38058>
- Soeparno, W. S. I., Anggia, Y., Sari, R. L., & Purba, F. A. (2024). Economic Growth, Population Density, and Human Development: Key Drivers of Environmental Quality in Indonesia. *International Journal on Economics, Finance and Sustainable Development*, 6(8), 121–128. <https://doi.org/10.31149/ijefsd.v6i7.5310>
- Wang, Q., Zhang, Y., & Li, R. (2025). Achieving Sustainable Development: Bridging Economic Growth and Environmental Resilience Through <scp>EKC</scp> and <scp>LCC</scp>. *Sustainable Development*, 33(5), 7629–7656. <https://doi.org/10.1002/sd.3528>
- Zhang, F., Xiao, F., & Yu, P. (2024). A model of sustainable development in economic, social, and environmental aspects: the role of social capital in China. *Environmental Research Communications*, 6(4), 045001. <https://doi.org/10.1088/2515-7620/ad37a8>