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Analysis of GDP Per Capita, Population Density, and Number of Motor Vehicles on Environmental Quality in Indonesia

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A R T I C L E I N F O

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A B S T R A C T

Environmental quality is a critical issue faced by developing economies like Indonesia, which heavily rely on natural resource exploitation. This study analyzes the influence of GDP per capita, population density, and number of motor vehicles on environmental quality in Indonesia during 2012-2023. The research employs a descriptive quantitative approach using spatial panel data regression models. The Environmental Quality Index (ELI) serves as the dependent variable, while GDP per capita, population density, and number of motor vehicles constitute the independent variables. Secondary data were collected from the Central Statistics Agency (BPS) and the Ministry of Environment and Forestry. Results indicate that GDP per capita has a positive but insignificant effect on environmental quality (coefficient = 0.003737, p > 0.05). Population density exhibits a significant negative effect (coefficient = -0.073323, p < 0.05), and the number of motor vehicles shows a negative but insignificant effect (coefficient = -0.004381, p > 0.05). The Geographically Weighted Regression (GWR) analysis reveals spatial heterogeneity across provinces, with R-squared improving from 0.53 (global regression) to 0.81 (GWR model). These findings suggest that environmental quality determinants vary across regions, necessitating localized policy interventions for sustainable development.

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Introduction

Environmental quality degradation represents a significant challenge for developing economies, particularly Indonesia, which extensively relies on natural resource-based economic activities (Ghani & Sunarko, 2016; Kojima, 2007; Todaro & Smith, 2014; Warren & McCarthy, 2009). This issue constitutes a primary focus in implementing sustainable development concepts. Environmental degradation has become increasingly critical as numerous cases demonstrate how economic activities negatively impact environmental sustainability when ecological considerations are insufficiently addressed. Consequently, environmental degradation poses substantial challenges for economies striving to accelerate economic development without compromising environmental integrity.

Economic development fundamentally involves continuous human production and consumption activities to fulfill unlimited needs. Production processes combine economic resources, including human resources, natural resources, capital resources, and institutional resources. The availability and utilization of these resources directly influence environmental quality, potentially leading to either improvement or deterioration manifested through environmental pollution and damage.

The Environmental Quality Index (ELI) serves as a crucial indicator for assessing environmental degradation conditions (Idris, 2012; Karim et al., 2013; Ministry of Environment and Forestry, 2021; Pykh, Kennedy & Grant, 2000; Qodriyatun, 2016). In Indonesia, this indicator comprises three environmental quality components: Water Quality Index (WQI),

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Air Quality Index (AQI), and Land Cover Quality Index (LCQI). These indices provide comprehensive insights into environmental degradation across Indonesia, examining water quality deterioration, air quality decline, and forest cover reduction.

During 2018-2023, Indonesia's ELI exhibited fluctuating patterns, indicating unstable environmental conditions characterized by alternating deterioration and improvement. The average ELI during this period was 66.15, categorizing Indonesia's environmental quality as moderate according to the Ministry of Environment and Forestry classifications. This condition indicates relatively high environmental degradation and pollution cases. Therefore, intensified efforts to minimize environmental damage through conscious preservation initiatives remain essential.

Environmental degradation, reflected through water pollution, air pollution, and forest cover reduction, generates multiple negative impacts (Sutjipto, 2008). Water pollution from industrial waste causes health issues, including diarrhea, nausea, and fever, while also affecting agricultural productivity through pesticide contamination and marine catch quality from uncontrolled marine pollution. Land cover reduction leads to flooding during rainy seasons and droughts during dry seasons due to diminished water management functions. Additionally, air pollution triggers respiratory problems and cognitive decline. These environmental degradation impacts constitute negative externalities affecting output across economic sectors.

The relationship between economic growth and environmental quality presents considerable complexity. Economic growth enables societies to achieve higher living standards and prosperity. However, economic activities lacking sustainable development foundations impose severe environmental burdens on natural resource providers. As economic activities from the industrial sector increase, CO_2 emissions rise correspondingly. Enhanced CO_2 and sulfur emissions result from expanding production processes. Industries pursuing profit maximization through increased output require substantial production inputs. When industries utilize environmentally unfriendly technologies, they become major contributors to environmental quality deterioration.

Agricultural sector potential for enhancing regional economic scope depends significantly on regional characteristics, requiring government policies aligned with developmental opportunities, particularly for horticultural crops, plantation crops, fisheries, and livestock. Agricultural sector development toward agribusiness or agroindustry systems enhances agricultural added value, ultimately increasing agribusiness and agroindustry regional income. Contemporary agricultural practices emphasize organic farming and integrated systems, promoting farmer awareness regarding environmental conditions and environmental factor consideration in agricultural activities, thereby reducing chemical pesticide use and environmental impact while maintaining effectiveness, efficiency, and high environmental productivity.

Regional development depends critically on transportation infrastructure development, which itself depends on trade and commercial activities within communities. Transportation holds strategic value for regions, particularly economic value, contributing to community welfare enhancement. Increasing transportation importance may degrade air quality through pollution, with motor vehicles representing the primary urban pollution sources. Transportation advancement correlates with increasing motor vehicle numbers, facilitating community economic activities, but simultaneously producing exhaust emissions and dust, causing air pollution and environmental quality deterioration.

Previous research by Rahajeng (2021) identified positive significant relationships between economic growth and environmental quality in Indonesia. However, Damayanti and Chamid (2018) found negative relationships between GDP distribution and environmental quality, where lower environmental quality corresponds with higher GDP. Kuswantoro (2009) demonstrated that agricultural productivity negatively influences deforestation, while Prasurya (2018) found negative effects of the agricultural sector GDP on ELI in the Sumatra provinces. Conversely, Fachrudin (2018) identified positive relationships between economic growth and environmental degradation.

Gupito et al. (2013) established positive significant relationships between the transportation sector and CO_2 emissions, consistent with Rajagukguk's (2015) findings regarding motor vehicle impacts on CO_2 emissions. However, Prasurya (2016) reported negative effects of the transportation and warehousing sector GDP on ELI in the Sumatra provinces after bilateral testing.

This research analyzes the influence of GDP per capita, population density, and number of motor vehicles on environmental quality in Indonesia.

Method

This research employs descriptive quantitative methodology, presenting actual condition descriptions based on factual data obtained at specific times. Quantitative research utilizes broad research targets emphasizing numerical data analysis for theory testing using statistical methods (Sugiyono, 2012:5). The analysis implements spatial panel data incorporating time series data from 2012 to 2023 and cross-sectional data covering 33 Indonesian provinces.

Research Scope

This research focuses on analyzing GDP per capita, population density, and motor vehicle numbers' influence on environmental quality across 33 Indonesian provinces during 2012-2023.

Variables and Data Collection

The dependent variable is the Environmental Quality Index (ELI), while independent variables comprise GDP per capita (constant 2010 prices), population density (persons per km²), and total motor vehicles (units). Secondary data were obtained from the Central Statistics Agency (BPS) and the Ministry of Environment and Forestry publications.

Operational Definitions

GDP Per Capita: Regional Gross Domestic Product per capita at constant 2010 prices (Rupiah), calculated as GDP divided by total population. Population Density: Population per square kilometer, calculated as total population divided by land area. Number of Motor Vehicles: Total registered motor vehicle units, including passenger cars, motorcycles, trucks, and buses. Environmental Quality Index (ELI): Composite index measuring environmental quality based on water quality (30%), air quality (30%), and land cover (40%).

Analysis Method

The analysis utilizes spatial panel regression with the following model:

$$\log(ELI)it = \alpha_0 + \beta_1\log(GDPPCit) + \beta_2\log(PDit) + \beta_3\log(MVit) + \varepsilon it$$

Where:

ELIit = Environmental Quality Index for province i at time t

GDPPCit = GDP per capita for province i at time t

PDit = Population density for province i at time t

MVit = Number of motor vehicles for province i at time t

α_0 = Intercept

β_1, β_2, β_3 = Regression coefficients

εit = Error term

Model selection employs the Chow test, Hausman test, and Breusch-Pagan Lagrange Multiplier test to determine optimal estimation between the Common Effects Model (CEM), Fixed Effects Model (FEM), and Random Effects Model (REM). Subsequently, Geographically Weighted Regression (GWR) analysis examines spatial heterogeneity across provinces.

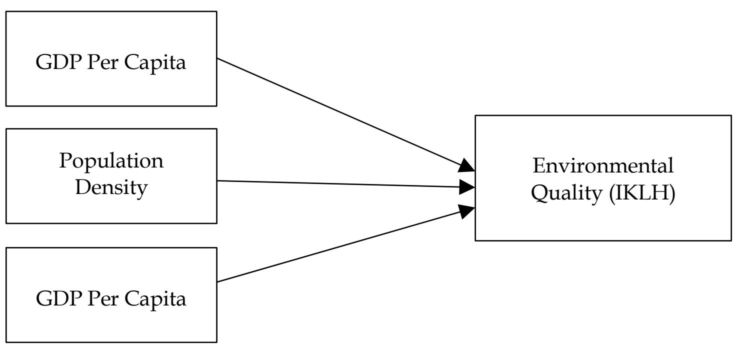

Figure 1. Conceptual Framework

Results and Discussion

This study analyzes the influence of GDP per capita, population density, and number of motor vehicles on environmental quality in Indonesia for the period 2012-2023. The analysis used spatial panel data from 33 provinces with a total of 396 observations. The selection of the best model is carried out through a series of statistical tests, including the Chow test, the Hausman test, and the Breusch-Pagan Lagrange Multiplier test.

Panel Regression Model Selection

The Chow test yielded a statistical F-value of 3.755490 with a probability of 0.0000 ($p < 0.05$), indicating that the Fixed Effects Model (FEM) was better than the Common Effects Model (CEM). Furthermore, the Hausman Test yielded a Chi-square value of 7.297575 with a probability of 0.0630 ($p > 0.05$), indicating that the Random Effects Model (REM) is more accurate than FEM. Therefore, the REM model was chosen as the best estimation model in this study.

Model Estimation and Hypothesis Testing Results

The results of the panel regression model estimation and Geographically Weighted Regression (GWR) analysis are presented in the following Table 1:

Table 1. Results of Panel Regression Estimation and GWR on Environmental Quality in Indonesia

Variable	Model REM		GWR Models	
	Coefficient	Prob.	Coefficients (Average)	Std. Deviation
Constant	4,567116	0,0000***	-	-
Log(PDRBK)	0,003737	0,6893	0,0030	0,0025
Log(KP)	-0,073323	0,0000***	-0,7077	0,3556
Log(JKB)	-0,004381	0,5782	-0,000003	0,000017
R-squared	0,2529		0,808	
Adjusted R²	0,2472		0,716	
F-statistic	44,29	0,0000***	-	
Bandwidth	-		10,25	

*Remarks: *** significant at α = 1%; ** significant at α = 5%; * significant at α = 10%*

Based on Table 1, the REM model yields an R-squared of 0.2529 or 25.29%, indicating that the variation in IKLH can be explained by all three independent variables of 25.29%, while the rest is explained by other factors outside the model. The F-statistical value of 44.29 with a probability of 0.0000 shows that simultaneously, GDP per capita, population density, and number of motor vehicles have a significant effect on the quality of the environment in Indonesia.

The Effect of Per Capita GDP on Environmental Quality

The results of the estimation showed that GDP per capita had a positive but insignificant effect on environmental quality ($\beta_1 = 0.003737$; $p = 0.6893 > 0.05$). This means that every 1% increase in GDP per capita will increase the IKLH by 0.0037%, assuming ceteris paribus. Although not statistically significant, the direction of the positive coefficient indicates that economic growth has the potential to improve the quality of the environment if managed properly. These findings are in line with the Environmental Kuznets Curve (EKC) hypothesis, which states that at a certain stage, economic growth can contribute positively to the quality of the environment (Panayotou, 2003). This comes as increased revenues allow for greater investment in green technologies and environmental management infrastructure. This result differs from the research of Damayanti and Chamid (2018), which found a negative influence of GDP on environmental quality, but it supports the research of Rahajeng (2021), which identified a positive relationship between economic growth and environmental quality in Indonesia.

The Effect of Population Density on Environmental Quality

Population density showed a significant negative influence on environmental quality ($\beta_2 = -0.073323$; $p = 0.0000 < 0.05$). Every 1% increase in population density will reduce the IKLH by 0.073%, ceteris paribus. These results confirm that population pressure is an important factor in environmental degradation in Indonesia. These findings are consistent with the research of Alam et al. (2013), which found a positive relationship between population density and water pollution in Pakistan, as well as the research of Hardini (2013), which identified the positive influence of population growth on CO emissions in Semarang City. High population density increases the consumption of natural resources, domestic waste production, and pressure on environmental infrastructure. In Indonesia, provinces with high population densities, such as DKI Jakarta, West Java, and East Java, show lower IKLH values than provinces with lower population density.

The Effect of the Number of Motor Vehicles on Environmental Quality

The number of motor vehicles has a negative but not statistically significant effect on environmental quality ($\beta_3 = -0.004381$; $p = 0.5782 > 0.05$). However, the direction of the negative coefficient indicates that the increase in the number of motor vehicles tends to reduce the quality of the environment through the exhaust emissions produced. These results are in line with the research of Sadullah et al. (2003), which showed a positive relationship between traffic volume and CO and SO_2 concentrations, as well as Zainordin et al.'s (2014) research on the effect of traffic on Ozone and NO_2 concentrations. Motor vehicles contribute to air pollution through emissions of carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), and particulates. Although the effect was not significant in the global model, the GWR analysis showed significant spatial variation, where the influence of the number of motor vehicles was greater in urban areas such as Jakarta, Surabaya, and Bandung.

Spatial Heterogeneity Analysis with GWR

The GWR model with the Adaptive Gaussian kernel and an optimal bandwidth of 10.25 produces an R-squared of 0.808, much higher than the REM model (0.2529). This shows that the GWR model is better able to explain the spatial variation of IKLH between provinces. GWR analysis revealed that the influence of the three independent variables varied spatially between provinces. For the population density variable, the strongest negative influence occurred in the provinces of Java (West Java, Central Java, East Java) and DKI Jakarta, where the coefficient reached the lowest value. On the other hand, in Eastern Indonesian provinces such as Papua and West Papua, the influence of population density is relatively small or even positive due to the low level of density.

The GDP per capita variable showed a stronger positive influence in regions with natural resource-based economies such as East Kalimantan, Papua, and the Riau Islands. In these regions, economic growth tends to go hand in hand with investment in environmental infrastructure. In contrast, in West Java and Banten, the influence of GDP per capita tends to be negative or insignificant, indicating that economic growth in this region still depends on sectors that exert great pressure on the environment. The number of motor vehicles shows a very varied influence between provinces. In urban areas such as DKI Jakarta, Surabaya, and Bandung, the negative influence is more significant. Meanwhile, in provinces with low motorization rates, such as East Nusa Tenggara and Maluku, this variable did not show a significant influence.

Conclusion

Based on a comprehensive analysis, this study concludes:

1. GDP per capita demonstrates positive but statistically insignificant effects on environmental quality in Indonesia, suggesting potential environmental benefits from well-managed economic development
2. Population density exhibits significant negative effects on environmental quality, indicating that increased population concentration substantially degrades environmental conditions
3. Number of motor vehicles shows negative but statistically insignificant effects on environmental quality, reflecting transportation sector contributions to environmental degradation
4. Factors influencing environmental quality vary substantially across provinces, demonstrating spatial heterogeneity requiring localized policy interventions. GWR analysis confirms three primary influential factors: GDP per capita, population density, and number of motor vehicles

Recommendations

1. Future research should employ pooled time-series data classifications for more homogeneous variance representations regarding environmental quality variables
2. Government authorities should implement and enforce environmental regulations through continuous monitoring, supervision, and legal enforcement against parties and business actors causing environmental degradation and pollution from irresponsible sectoral activities. Enhanced public environmental awareness through socialization programs emphasizing conservation remains essential
3. Policy interventions should prioritize population density and transportation management strategies, minimizing pollution from emission-producing transport activities while promoting sustainable economic development, balancing environmental preservation with welfare enhancement

References

Alam, M. M., Murad, M. W., Noman, A. H. M., & Ozturk, I. (2013). Relationships between carbon emissions, economic growth, energy consumption, and population growth: Testing the Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators, 70*, 466-479. doi:10.1016/j.ecolind.2016.06.043

Arifin, B. (2002). *Resource and environmental economics*. Jakarta: University of Indonesia Press.

Baltagi, B. H. (2008). *Econometric analysis of panel data* (4th ed.). West Sussex: John Wiley & Sons.

Damayanti, R., & Chamid, M. S. (2018). Environmental pollution in Indonesia uses the Geographically Weighted Regression (GWR) approach. *ITS Journal of Science and Arts, 7*(1), 23-28. doi:10.12962/j23373520.v7i1.28049

Daryanto, H. (2013). *Environmental management*. Yogyakarta: Gava Media.

Effendi, S. (2016). *Sustainable development*. Jakarta: Rajawali Press.

Ehrlich, P. R. (1968). *The population bomb*. New York: Ballantine Books.

Fachrudin, H. T. (2018). Analysis of the influence of economic growth on environmental degradation in Indonesia. *Indonesian Journal of Economics and Development, 18*(2), 151-168.

Ghani, E. K., & Sunarko, B. (2016). Natural resources and economic development in Indonesia. *Journal of Indonesian Economy and Business, 31*(2), 189-207.

Gupito, K., Aji, P. M., & Magaji, N. (2013). The relationship of GDP per capita from the industrial, transportation, agriculture and forestry sectors to environmental quality is measured from CO_2 emissions. *Economics Development Analysis Journal, 2*(4), 368-379.

Gujarati, D. N. (2004). *Basic econometrics* (4th ed.). New York: McGraw-Hill.

Hardini, S. (2013). Analysis of the relationship between population growth, poverty, and economic growth on environmental quality in Semarang City. *Journal of Economics, 2*(1), 45-58.

Harrington, W., McConnell, V., & Ando, A. (2003). *Are vehicle emission inspection programs living up to expectations?* Washington DC: Resources for the Future.

Hung, M. F., & Shaw, D. (2006). Economic growth and the environmental Kuznets curve in Taiwan: A simultaneity model analysis. *Inha Journal of Economic Theory & Econometrics, 37*(1), 1434-1455.

Idris, M. (2012). Environmental quality index as an indicator of sustainable development. *Journal of Environmental Technology, 13*(2), 152-160.

Inogouchi, T., Newman, E., & Keane, J. (2003). *The changing nature of democracy*. Tokyo: United Nations University Press.

Irawan, D. E., Puradimaja, D. J., & Notosiswoyo, S. (2016). Decreasing groundwater quality at Cisadane riverbanks: Groundwater-surface water approach. *Geological and Mining Research, 26*(1), 43-52. doi:10.14203/researchgeotam2016.v26.213

Ismawan, I. (1999). *Development economics*. Jakarta: Publishing Institution, Faculty of Economics, University of Indonesia.

Kadir, A. (2006). *Transportation: Its role and impact in national economic growth*. Jakarta: Bumi Aksara.

Karim, M., Saturi, S., & Novriansyah, A. (2013). Preparation of environmental quality index in Central Kalimantan. *Journal of Tropical Forests, 1*(2), 144-151.

Kartodihardjo, H. (2017). *Indonesia's Environmental Quality Index 2016*. Jakarta: Ministry of Environment and Forestry.

Ministry of Environment and Forestry of the Republic of Indonesia. (2021). *Indonesia's Environmental Quality Index 2020*. Jakarta: Ministry of Environment and Forestry.

Ministry of Environment and Forestry of the Republic of Indonesia. (2024). *Indonesia's environmental quality index 2023*. Jakarta: Ministry of Environment and Forestry.

Kojima, M. (2007). *Deforestation, forest degradation, and Indonesian economic crisis*. Washington DC: World Bank.

Kristanto, P. (2013). *Industrial ecology* (2nd ed.). Yogyakarta: Andi Offset.

Kusminingrum, N., & Gunawan, G. (2008). Air pollution due to motor vehicle activities on urban roads on the islands of Java and Bali. *Journal of Roads and Bridges, 25*(2), 127-140.

Kuswantoro, H. (2009). Analysis of the influence of agricultural productivity on environmental deforestation. *Journal of Development Economics, 10*(1), 89-104.

Lee, C. C. (1978). *Models in planning: An introduction to the use of quantitative models in planning*. Oxford: Pergamon Press.

Lubis, Z. (1992). *Forests in a socio-cultural perspective*. Jakarta: Yayasan Obor Indonesia.

Mankiw, N. G. (2007). *Macroeconomics* (6th ed.). Jakarta: Erlangga.

Mantra, I. B. (2007). *General Demography* (2nd ed.). Yogyakarta: Student Library.

Mantra, I. B. (2014). *Demographics and population*. Yogyakarta: Student Library.

Martono, D. N., Koestoer, R. A., & Rahardjo, N. (2004). The condition of nitrogen oxide gas pollution in the air in Jakarta is at zero meters and 120 meters from the highway. *Journal of Environmental Technology, 5*(2), 103-110.

Nafziger, E. W. (2012). *Economic development* (5th ed.). Cambridge: Cambridge University Press.

Nur, M. (2015). Analysis of factors affecting GDP per capita in Indonesia. *Journal of Economics and Development Studies, 16*(2), 183-192.

Panayotou, T. (2003). Economic growth and the environment. *Economic Survey of Europe, 2*, 45-72.

Paudel, K. P., Zapata, H., & Susanto, D. (2013). Environmental Kuznets Curve for water pollution: The case of border countries. *Applied Economics, 45*(3), 3397-3408. doi:10.1080/00036846.2012.714074

Pezzey, J. (1992). Sustainable development concepts: An economic analysis. *World Bank Environment Paper, 2*, 1-70.

Pykh, Y. A., Kennedy, E. T., & Grant, W. E. (2000). An overview of systems analysis methods in delineating environmental quality indices. *Ecological Modelling, 130*(1-3), 25-38. doi:10.1016/S0304-3800(00)00201-5

Qodriyatun, S. N. (2016). Indonesia's environmental quality index in 2013-2015. *Social Welfare Brief, 8*(19), 13-16.

Rahajeng, A. (2021). Analysis of economic growth and environmental quality in Indonesia. *Journal of Development Economics, 19*(1), 67-84.

Rajagukguk, E. (2015). Analysis of the influence of the number of vehicles on CO_2 emissions in Indonesia. *Journal of Economics and Public Policy, 6*(2), 149-163.

Ray, D. K., Ramankutty, N., Mueller, N. D., West, P. C., & Foley, J. A. (2011). Recent patterns of crop yield growth and stagnation. *Nature Communications, 3*, 1293. doi:10.1038/ncomms2296

Rodrigue, J. P. (2017). *The geography of transport systems* (4th ed.). New York: Routledge.

Rosyidi, S. (1995). *Introduction to economic theory*. Jakarta: Rajawali Press.

Rostow, W. W. (1960). *The stages of economic growth: A non-communist manifesto*. Cambridge: Cambridge University Press.

Sadullah, A. F., Huda, M. N., & Fuller. (2003). The effect of traffic flow on carbon monoxide and sulfur dioxide concentrations. *Journal of Civil Engineering, 10*(2), 89-98.

Sanusi, B. (2003). *Population and the environment*. Jakarta: Open University.

Sugiyono. (2012). *Quantitative, qualitative, and R&D research methods*. Bandung: Alfabeta.

Suhadi, A. (2005). The impact of the transportation sector on the environment. *Journal of Transportation, 5*(1), 23-34.

Sutjipto, H. (2008). *The impact of environmental pollution on health*. Jakarta: Rineka Cipta.

Sutomo, H. (2016). *Environmental economics: Theory and applications*. Yogyakarta: Student Library.

Syech, R., Purnama, H., & Rahman, A. (2014). Air quality analysis in the city of Pekanbaru. *Journal of Environmental Science, 8*(1), 56-68.

Thomas, V., Dailami, M., Dhareshwar, A., Kaufmann, D., Kishor, N., Lopez, R., & Wang, Y. (2001). *The quality of growth*. Washington DC: World Bank.

Todaro, M. P., & Smith, S. C. (2014). *Economic development* (12th ed.). Boston: Pearson.

Walpole, R. E. (2005). *Introduction to statistics* (3rd ed.). Jakarta: Gramedia Pustaka Utama.

Warren, C., & McCarthy, J. F. (2009). *Community, environment and local governance in Indonesia: Locating the commonweal*. London: Routledge.

Zainordin, N. S., Abdullah, S., & Ismail, M. (2014). The influence of traffic on ozone and nitrogen dioxide concentrations. *Asian Journal of Atmospheric Environment, 8*(2), 65-76. doi:10.5572/ajae.2014.8.2.065