Short Communication

CO_2 emissions in Indonesia: Key contributing factors and determinants

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Abstract

Climate change is driven by increasing greenhouse gas emissions, particularly carbon dioxide (CO_2). Developing countries such as Indonesia face a dilemma between meeting energy demands for development and reducing CO_2 emissions. The aim of this study was to analyze trends of CO_2 emissions in Indonesia during the period 1970–2023, utilizing secondary data from Our World in Data to obtain a comprehensive overview of national emission dynamics and Indonesia's contribution at regional and global levels. A quantitative descriptive analysis method was applied using time-series data for the period 1970–2023, complemented by comparative analysis to evaluate temporal trends, dominant emission sources, and Indonesia's proportional contribution at the Southeast Asia and global scales. The results indicate that Indonesia contributes approximately 3% of total global CO_2 emissions and has the highest emission level in Southeast Asia, highlighting its strategic role in global climate change mitigation efforts. Historically, CO_2 emissions in Indonesia showed a significant increase over the study period, rising from 3.37×10^8 tons in 1980 to 1.18×10^9 tons in 1984, largely due to economic growth from industrialization and increased energy consumption. The highest increase in CO_2 occurred in 1997 due to forest fires and the El Niño phenomenon. Furthermore, the findings show that fossil fuel consumption, particularly coal, was the dominant contributor to national emissions in 2020. In conclusion, continued dependence on fossil energy remains a major challenge for Indonesia in achieving mitigation targets, underscoring the importance of energy transition and improved land-management strategies to curb future emission growth.

Keywords: CO_2 emissions, Indonesia, fossil fuels, climate change, energy consumption

Introduction

Climate change is one of the most crucial global issues currently under discussion, largely driven by increasing concentrations of greenhouse gases (GHGs) in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), and dinitrogen oxide (N_2O) [1]. These gases can absorb and reflect heat radiation from the Earth's surface, thereby enhancing the greenhouse effect and global temperature [1,2]. Among various types of GHGs, CO_2 plays a primary role in global warming and causes direct impacts on the national environment, such as rising average temperatures, changes in rainfall patterns, increased frequency and intensity of hydrometeorological disasters, ecosystem degradation, and declining air quality [3,4]. The increase in CO_2 emissions results from the energy, industry, and transport sectors, as well as land-use change, including deforestation and plantation expansion [4].

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Developing countries with high economic and population growth are facing the dilemma between economic development and carbon emission control, as is the case for Indonesia [5]. Indonesia, as an archipelagic country rich in natural resources with a large population, faces this challenge [6-8]. Indonesia's CO_2 emissions not only impact the national environment but also have significant implications for global climate change mitigation efforts [9-10]. Therefore, in-depth research on the dynamics of CO_2 emissions in Indonesia is a necessity to understand the main factors influencing emission trends and to formulate effective mitigation strategies.

In recent decades, the increased consumption of fossil fuel-based energy, deforestation, expansion of agricultural and plantation land, as well as industrial and transport growth, have been the dominant factors influencing the increase in national CO_2 emissions [11]. Although the government has committed to reducing emissions through various mitigation policies, such as implementing the Nationally Determined Contribution (NDC) and developing new renewable energy [12-14], Indonesia's CO_2 emissions continue to show an increasing trend year after year [15]. Previous research indicates a highly significant surge in annual CO_2 emissions, which increased nearly twentyfold from 1970 to 2022 [16]. This increase potentially worsens environmental quality, alters local climate patterns, increases the risk of natural disasters, and hinders the achievement of Sustainable Development Goals (SDGs) [17]. Therefore, the aim of this study was to analyze trends in CO_2 emissions in Indonesia during the period 1970–2023, identify the major contributing factors, and evaluate their implications for environmental sustainability and development. Understanding the main causes of increasing CO_2 emissions in Indonesia is crucial for informing more targeted mitigation strategies, particularly by emphasizing reductions in sectors that most strongly contribute to climate change. Using secondary data from Our World in Data, this study provides a comprehensive overview of national emission dynamics and Indonesia's contribution at regional and global levels, thereby supporting the transition towards low-carbon development and sustainable environmental management.

Methods

Study design and data sources

This study was conducted to analyze the trends and temporal dynamics of CO_2 emissions in Indonesia, identify the dominant factors influencing national CO_2 emissions, and assess Indonesia's proportional contribution to CO_2 emissions at the Southeast Asian and global levels. The analysis focused on the processing and interpretation of secondary data regarding CO_2 emissions sourced from Our World in Data (accessed on November 5, 2025), specifically annual CO_2 emission indicators measured in tons [18]. The extracted data includes total global annual CO_2 emissions, annual CO_2 emissions for the Southeast Asia region (Indonesia, Malaysia, Philippines, Thailand, Vietnam, Singapore, Myanmar, Cambodia, Laos, Brunei, and East Timor), as well as Indonesia's CO_2 emissions across various contributing factors such as coal, gas, oil, cement, and flaring.

Analytical approach and data processing

The study employed a quantitative descriptive research approach [19], based on time-series data covering the period 1970–2023. Temporal trend analysis was conducted to identify major emission patterns and peak periods. These trends were interpreted contextually with reference to supporting literature on environmental, economic, and climate-related phenomena. Data processing procedures involved tabulation and preliminary data processing using Microsoft Excel, culminating in the generation of graphical visualizations using OriginPro 2024.

Indonesia's positioning and proportional contribution were determined through global and regional comparative analyses. Global contribution was assessed by comparing Indonesia's average annual CO_2 emission with total global emissions from 1970 to 2023. Regional contribution was evaluated by comparing Indonesia's emissions to those of other Southeast Asian countries using data from the period of 2000 to 2023. The use of this specific range for region data (2000–2023) was necessitated by data gaps in several Southeast Asia regions prior to 1970, thereby focusing on the 2000s to provide a more accurate current profile of Indonesia's role in the region. In addition, because comprehensive data on all emission-influencing factors in

Indonesia were limited, covering only coal, gas, oil, cement, and flaring, the determination of dominant factors was categorized into two groups: fossil fuels (coal, gas, oil, and flaring) and other factors. This classification was based on the initial hypothesis that fossil fuel consumption significantly dominates over other factors, such as industrial activities or land-use change.

Results

The increase in atmospheric CO_2 concentrations has emerged as a major global issue contributing significantly to climate change. Based on the data analysis (**Figure 1**), total global CO_2 emissions reached approximately 18,072,177,361 tons, of which Indonesia contributed about 646,198,262 tons, equivalent to approximately 3% of total global emissions. Although this proportion appears relatively modest at the global scale, Indonesia's contribution is highly significant at the regional level, making it the largest CO_2 emitter in Southeast Asia (**Figure 2**).

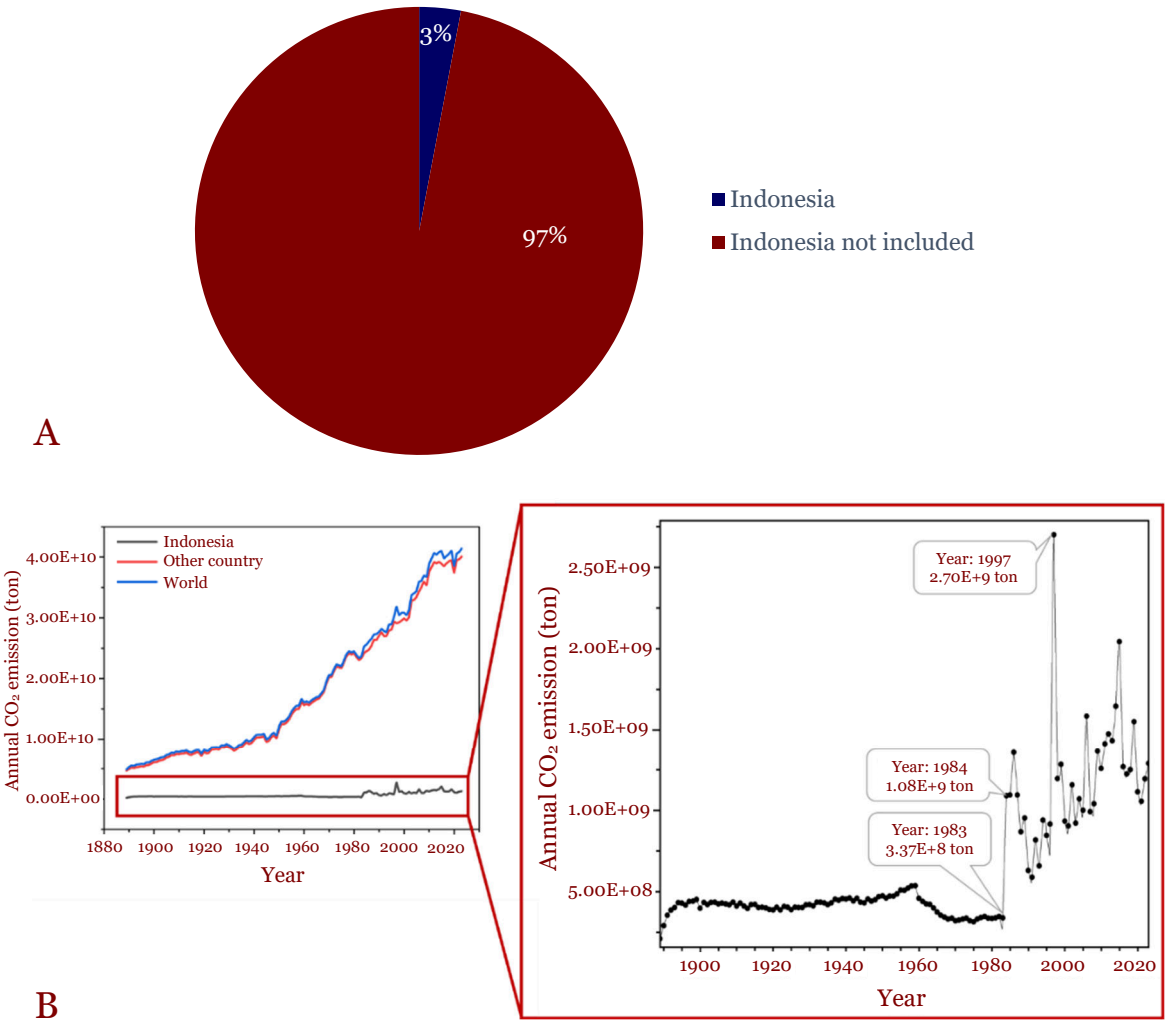

Figure 1. CO_2 emissions produced by Indonesia from 1970 to 2023. (A) Average CO_2 emission contribution to total world emissions and (B) CO_2 emission contribution trend in Indonesia.

Historically, the CO_2 emission trend in Indonesia showed an increasing pattern since the early 1980s. A significant spike occurred from 1983 (3.37×10^8 tons) to 1984 (1.08×10^9 tons). The highest emission peak was recorded in 1997 with a value reaching 2.70×10^9 tons. Based on data from 2000 to 2023, Indonesia is recorded as the largest contributor to CO_2 emissions in Southeast Asia with a cumulative total of 1.15×10^{10} tons, followed by Thailand (5.81×10^9 tons) and Malaysia (5.08×10^9 tons). Furthermore, Vietnam exhibited a significant year-on-year increase in CO_2 emissions over the study period. The Philippines also experienced an increasing trend, although at a comparatively lower rate than Vietnam. In contrast, other countries such as Singapore,

Myanmar, Cambodia, Laos, Brunei Darussalam, and Timor-Leste have shown relatively stable annual CO_2 emissions levels.

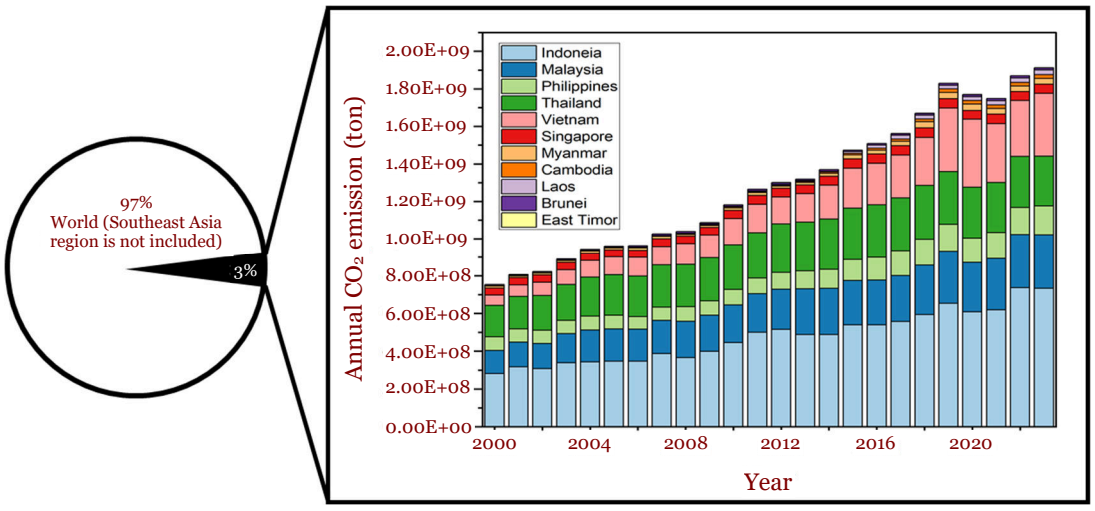

Figure 2. CO_2 emission contribution in the Southeast Asian region (including Indonesia) to total world emissions from 2000 to 2023.

The distribution of CO_2 emission sources in Indonesia from 1970 to 2023 was influenced by multiple factors, including coal, oil, gas, cement production, flaring, and other sources. Graphical analysis illustrates the proportional contribution of each factor to total annual emissions (**Figure 3**). The results clearly indicate that fossil fuel use represents the dominant source of carbon emissions over the study period (**Figure 4**).

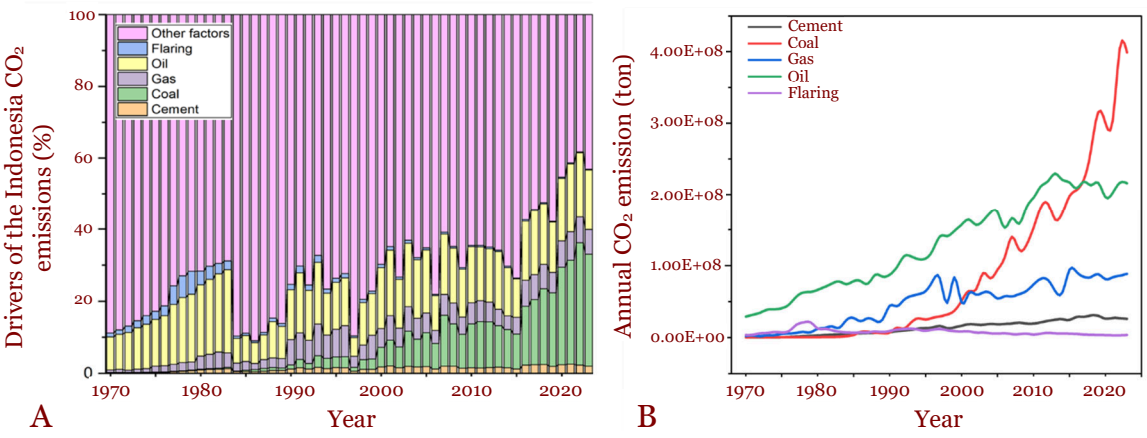

Figure 3. Annual CO_2 emissions. (A) Overall CO_2 emission percentage and (B) CO_2 emission values from several factors.

The data in this study represent total emissions along with contributions from primary sources. Indonesia's CO_2 emissions have exhibited significant changes, marked by a surge in emissions from coal since early 2020. Coal emissions have continued to rise, surpassing other sources and reaching nearly 4.00×10^8 tons by 2023. This phenomenon marks a shift in primary emission sources from previous periods that were dominated by oil and gas. In contrast, sources such as cement production and flaring tend to display much more stable and lower contributions compared to coal, which has now become the main driver of Indonesia's carbon footprint.

Emissions from the fossil fuel sector have demonstrated a stable, consistent, and continuous upward trend for over five decades (1970–2023). The contribution from the fossil fuel sector even surpassed other factors in 2020. At that time, total emissions reached 4.00×10^8, with approximately 55% (7.07×10^9 ton) contributed by fossil fuels. In subsequent years, the fossil fuel

sector has become the dominant contributor to national CO_2 emissions, and its contribution continues to increase relative to other sectors.

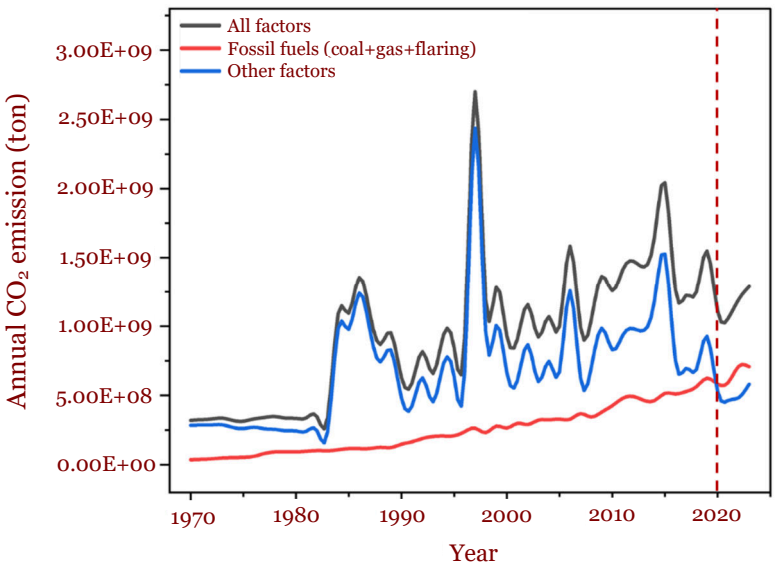

Figure 4. Evolution of fossil fuel sector contribution to total annual CO_2 emissions in Indonesia.

Discussion

This study reveals that Indonesia's CO_2 emissions trajectory reflects a complex temporal dynamic, shaped by economic growth and continued dependence on natural resources. The principal finding indicates a sharp rise in emissions from 1983 to 1984, closely correlated with the acceleration of national industrialization and a surge in energy consumption. A peak in emissions was recorded in 1997 as an anomaly driven by large-scale forest fires in Kalimantan and Sumatra associated with the El Niño phenomenon [20]. This event triggered massive carbon releases from peatlands into the atmosphere [20], rendering national emissions more volatile and heightening Indonesia's vulnerability to climate change through the combined effects of natural factors and human activities.

Indonesia's CO_2 emissions trend has continued to increase, consistent with its strategic position as one of the largest emitters in Southeast Asia, as validated by prior studies indicating that CO2 emissions grow year by year [16]. Sectorally, the main drivers of emissions can be grouped into fossil-fuel use and non-fossil factors, such as industrial activities (cement, steel, and petrochemical production) and land-use change (deforestation and land conversion). In 2020, fossil-fuel consumption was the primary contributor to rising CO_2 emissions; this dominance exceeded other categories due to the high demand for coal in electricity generation [21], followed by petroleum and its derivatives in the transportation sector and natural gas use in industrial operations [9]. Demand for fossil fuels has increased annually, with particularly significant growth in coal use. Meanwhile, the industrial sector contributes through process-related emissions—especially decarbonation reactions—and intensive fossil-energy combustion [22]. Interactions across sectors reinforce one another: growth in the construction sector drives direct emissions from material production while simultaneously increasing national energy demand. This phenomenon is further complicated by land-use dynamics, where deforestation and the conversion of forests into oil-palm plantations or intensive agriculture continue to reduce Indonesia's natural carbon sequestration capacity [23,24].

The implications of these findings underscore the need to strengthen land governance in an integrated manner alongside industrial decarbonization strategies and investments in low-carbon technologies. In the global context, although Indonesia's contribution to total global emissions is relatively small, its impacts can still influence broader climatic conditions. This aligns with a hypothesis suggesting that CO_2 emissions originating from Indonesia may contribute to prolonged global climate change [25]. Rising atmospheric CO_2 concentrations have become a global challenge that significantly contributes to climate change. Globally, CO_2

emissions have increased rapidly in tandem with industrial expansion and fossil-based energy consumption [26]. The future mitigation challenge lies in Indonesia's ability to decouple economic growth from emissions increases. Although initiatives to develop renewable energy—such as geothermal and bioenergy—have begun, their contributions have not yet been sufficient to offset the dominant role of fossil energy in meeting national demand. Therefore, accelerating the energy transition and strengthening regulation in the forestry sector are crucial steps to ensure long-term climate resilience. These insights provide a clearer picture of the policy direction needed to reduce Indonesia's CO_2 emissions in the future.

This study has several limitations. The analysis relied on secondary data from Our World in Data, which, although widely used, is subject to uncertainties inherent in aggregated national emission estimates. The descriptive time-series approach limits causal inference between emission trends and their underlying drivers. In addition, sectoral analysis was restricted to major emission sources (coal, oil, gas, cement, and flaring), while other contributors such as detailed land-use change, could not be fully examined due to data constraints. Regional comparisons were also limited to the post-2000 period because of data gaps in earlier years. These limitations suggest that future studies incorporating higher-resolution data and causal modeling approaches are needed to strengthen evidence for targeted mitigation strategies.

Conclusion

Indonesia accounted for approximately 3% of total global CO_2 emissions and was the largest contributor within the Southeast Asia region during the study period. National emission trends showed a sustained increase beginning in the mid-1980s, with a pronounced peak in 1997 associated with large-scale peatland and forest fires during the El Niño event. Sectoral analysis indicated that fossil fuel use has increasingly dominated Indonesia's emission profile, becoming the main source of CO_2 emissions by 2020, while land-use change continued to contribute substantially, particularly during episodic fire years.

Ethics approval

Not required.

Acknowledgments

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

We hereby confirm that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

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