



Impact of Climate Change on Increasing Land Surface Temperature in Indonesia: A literature review

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ABSTRACT

This research explores the impact of climate change on increasing land surface temperature (LST) in Indonesia, which has shown a significant upward trend in recent decades. Using a systematic literature review, the research analyzed 50 relevant studies, identifying factors such as deforestation, urbanization, and greenhouse gas emissions as the main causes of increased LST. The research also highlights the serious implications of temperature change on agriculture, public health and water resources, which could lead to food insecurity and increased health risks. In addition, the research emphasizes the importance of understanding public attitudes and beliefs towards climate change to formulate effective policies. With an interdisciplinary approach, the results of this research aim to provide insights for policymakers and stakeholders in developing sustainable mitigation strategies, as well as increasing community resilience to the impacts of climate change in Indonesia.

Keywords: *Climate Change, Land Surface, Relevant Studies*

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INTRODUCTION

Climate change has emerged as a critical global challenge, significantly impacting various environmental parameters, including land surface temperature (LST). In Indonesia, a country characterized by its diverse ecosystems and extensive archipelago, the effects of climate change are particularly pronounced, leading to an alarming increase in LST. Recent studies have highlighted that Indonesia is experiencing a notable rise in temperatures, which poses serious implications for its environment, agriculture, and public health (Sari et al., 2023; Rahman et al., 2022).

Climate change is one of the most pressing issues of our time, with far-reaching consequences for the environment, economy, and human societies (IPCC, 2023). In

Indonesia, the impact of climate change is particularly pronounced, with rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events (Hidayat et al., 2022). The terms "global warming" and "climate change" are often used interchangeably, but they have different meanings. Climate change describes long-term shifts in Earth's weather patterns that affect temperature, humidity, wind, cloud cover, and precipitation, while global warming refers explicitly to an increase in Earth's average surface temperatures caused by human activities (Global Warming Topic Overview, 2023).

Overwhelming scientific evidence supports the existence of both global warming and climate change. The Intergovernmental Panel on Climate Change (IPCC) has estimated that global surface temperatures increased by 1.1°C (1.98°F) between the latter half of the nineteenth century and the first two decades of the twenty-first century (IPCC, 2023). Climate change has been linked to severe, exceptional droughts across several regions, including Indonesia. Climate scientists refer to this phenomenon as a "megadrought," which has contributed to massive wildfires in the first decades of the twenty-first century (Rakuasa et al., 2024)

In Indonesia, the increasing land surface temperature is expected to have significant consequences for agriculture, water resources, and human settlements (Rakuasa., 2024). The production of rice, a key food staple in Indonesia, is sensitive to fluctuations in the start and duration of the wet season (Hansen et al., 2021). El Niño events have an impact on rice production by delaying rainfall and increasing chances of yearly rice shortages, and these events are predicted to become more frequent due to climate change (Rakuasa et al., 2024)

Indonesia's large tropical rainforests make it among the most biodiverse countries in the world (Margono et al., 2014). However, deforestation and forest loss (including peatlands), mainly due to the rise of agriculture development (e.g., palm oil plantations, illegal logging), threatens the growth of these carbon-rich forests and has implications for Indonesia's climate change mitigation efforts (Rakuasa et al., 2024). The country's vulnerability to climate change is exacerbated by its high population density in hazard-prone areas and strong dependence on natural resources (Rakuasa., 2023). Climate change could cost Indonesia between 2.5-7% of its GDP, with the poorest bearing the brunt of the burden (Global Warming Topic Overview, 2023).

Indonesia has significant solar photovoltaic and wind resources that can be used on a massive scale (Global Warming Topic Overview, 2023). However, an effective national strategy in Indonesia must consider the public's beliefs and attitudes about climate change, risk perceptions, and other responses to the environment (Santoso et al., 2022). Understanding how Indonesians respond to climate change and environmental problems – including what they know, believe, and support, as well as what they misunderstand, disbelieve, or oppose – has important implications for educating and communicating with the public to build more support and demand for climate policy (Zhou et al., 2019).

By examining the impact of climate change on land surface temperatures in Indonesia, this literature review aims to provide valuable insights for policymakers,

researchers, and stakeholders. Understanding the dynamics of temperature changes and their implications is vital for developing effective strategies to mitigate the adverse effects of climate change and promote sustainable development in Indonesia.

RESEARCH METHODOLOGY

This literature review employed a systematic search strategy to identify relevant studies published in English between 2021 and 2024. The search was conducted using multiple electronic databases, including Scopus, Web of Science, and Google Scholar, with keywords such as "climate change," "land surface temperature," "Indonesia," and "literature review." The search yielded a total of 50 studies, which were then screened for relevance and quality based on predetermined inclusion and exclusion criteria. The selected studies were then analyzed and synthesized to identify patterns, themes, and trends related to the impact of climate change on increasing land surface temperature in Indonesia. The methodological quality of the included studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools, and the results were presented in a narrative format to provide a comprehensive overview of the current state of knowledge on the topic.

RESULT AND DISCUSSION

Overview of Increasing Land Surface Temperature in Indonesia

Land surface temperature (LST) in Indonesia has been increasing over the past few decades, with significant implications for the country's ecosystems, biodiversity, and human settlements (Hidayat et al., 2022). Studies have shown that the increasing LST in Indonesia is attributed to various factors, including deforestation, urbanization, and greenhouse gas emissions (Maheng et al., 2024; Salmamza et al., 2022). The increasing LST has significant implications for the country's agriculture, water resources, and human health, with studies suggesting that it is affecting agricultural productivity, leading to food insecurity and economic losses (Zhou et al., 2019), and increasing the spread of diseases, heat stress, and other health-related problems (Yamamoto & Ishikawa, 2018). Remote sensing and GIS techniques have been used to analyze the increasing LST in Indonesia, highlighting the importance of these tools in understanding the phenomenon (Kittredge, 2024; Prata, 2019).

Drivers of Rising Land Surface Temperature

The drivers of rising land surface temperature (LST) in Indonesia are attributed to various factors, including elevation, cloud fraction, atmospheric water vapor, normalized difference vegetation index, and snow cover area (Rahman et al., 2022). Studies have shown that the increasing LST in Indonesia is also driven by deforestation, urbanization, and greenhouse gas emissions (Maheng et al., 2024; Salmamza et al., 2022). Additionally, the warming trend in Indonesia is influenced by elevation-dependent warming, particularly in high-altitude regions (Hidayat et al., 2022). Remote sensing data, such as MODIS, have been used to analyze the LST trends in Indonesia, highlighting the

importance of these tools in understanding the phenomenon (Kittredge, 2024; Prata, 2019).

Impacts on Agriculture

Climate change has significant impacts on agriculture in Indonesia, particularly on rice production, which is sensitive to fluctuations in the start and duration of the wet season. El Niño events, predicted to become more frequent due to climate change, delay rainfall and increase chances of yearly rice shortages (World Bank Group and Asian Development Bank, 2021). Deforestation and forest loss, mainly due to agriculture development, threaten the growth of carbon-rich forests and have implications for Indonesia's climate change mitigation efforts (Earth.Org, Shahreen, 2022). It is estimated that Indonesia lost over 28 million hectares of tree cover from 2001 to 2021 (Global Forest Watch, 2023). Moreover, degradation and deforestation of mangroves, responsible for 10% of the country's overall forestry-related greenhouse gas emissions, have significant implications for agriculture (Budi Arifanti et al., 2022).

Health Implications

Climate change has significant health implications in Indonesia, particularly in terms of heat-related illnesses, vector-borne diseases, and mental health. Rising temperatures and heatwaves are expected to increase the incidence of heatstroke, dehydration, and cardiovascular diseases, especially among vulnerable populations such as the elderly and children (Kusumawardani et al., 2022; Rakuasa., 2024). Climate change is also projected to alter the distribution and prevalence of vector-borne diseases like dengue fever, chikungunya, and Zika virus, which are already significant public health concerns in Indonesia (WHO, 2021; Rakuasa., 2023). Furthermore, the psychological impacts of climate change, including anxiety, depression, and post-traumatic stress disorder, are becoming increasingly evident, particularly among communities affected by climate-related disasters (Suardana et al., 2023). Additionally, air pollution, exacerbated by climate change, is a major environmental health risk in Indonesia, contributing to respiratory diseases and premature mortality (Apte et al., 2024).

Ecological Consequences

The ecological consequences of rising LST are alarming. Widyastuti et al. (2023) note that increased temperatures can lead to habitat loss and biodiversity decline, particularly in sensitive ecosystems such as coral reefs and tropical forests. The degradation of these ecosystems not only threatens wildlife but also diminishes the essential services they provide to human populations, such as clean water, carbon sequestration, and recreational opportunities. The review highlights the urgent need for conservation efforts to protect these vulnerable ecosystems. Climate change has significant ecological consequences in Indonesia, including impacts on the agricultural sector, where adaptation and mitigation strategies are crucial to reduce risks and build resilience. Ecological adaptation in crop farming involves technology adoption, intensive

farming management, environmentally friendly agriculture, cropping pattern and timing adjustments, water management, superior varieties, and crop diversification (Imelda & Hidayat, 2021). Furthermore, ecological adaptation in fisheries involves embracing new technology, modifying fishing schedules, and shifting fishing locations. The study highlights the importance of considering socioeconomic factors influencing adaptation and mitigation to climate change impacts, including individual characteristics, resource access, and institutional involvement.

Urbanization and Its Effects

Urbanization plays a crucial role in the increasing LST in Indonesia. The rapid growth of cities has led to significant land-use changes, which contribute to the urban heat island effect. Hadi et al. (2021) discuss how urban planning and infrastructure development often overlook the importance of green spaces, leading to increased surface temperatures. The lack of vegetation in urban areas reduces the natural cooling effect, exacerbating the impacts of climate change on LST. Urbanization in Indonesia has significant effects on the environment, economy, and society. The rapid growth of cities has led to increased air and water pollution, traffic congestion, and urban sprawl, resulting in the loss of natural habitats and biodiversity (Hidayat et al., 2021). Furthermore, urbanization has also led to social issues such as poverty, inequality, and social segregation, as well as increased pressure on urban infrastructure and services (Sulistyo et al., 2022). Additionally, urbanization has been linked to increased energy consumption, greenhouse gas emissions, and climate change vulnerability (Wijaya et al., 2023). Moreover, the COVID-19 pandemic has highlighted the need for sustainable and resilient urban planning, taking into account the health and well-being of urban residents (Rahman et al., 2024).

Mitigation Strategies

To address the challenges posed by increasing LST, effective mitigation strategies are essential. The literature suggests that transitioning to renewable energy sources, such as solar and wind power, can significantly reduce greenhouse gas emissions and help stabilize temperatures (Rahman et al., 2022; Rakuasa et al., 2024). Additionally, implementing sustainable land-use practices, including reforestation and urban greening initiatives, can enhance carbon sequestration and mitigate the urban heat island effect. Mitigation strategies for land surface temperature (LST) increase in Indonesia have been a topic of interest in recent years. A literature review by Saputra et al. (2023) highlights the importance of green infrastructure, such as green roofs and walls, in reducing urban heat island effects and mitigating LST increase. The study suggests that the implementation of green infrastructure in urban planning and design can significantly decrease LST and improve urban microclimate. Additionally, the use of cool materials, such as high-albedo surfaces and cool pavements, has been found to be effective in reducing LST (Pratiwi et al., 2024). Furthermore, the integration of urban forests and water bodies, such as parks and lakes, can contribute to the mitigation of LST increase (Wijaya et al., 2022).

Adaptation Strategies

Adaptation strategies are equally important in managing the impacts of rising temperatures. The review emphasizes the need for comprehensive climate adaptation plans that incorporate community engagement and stakeholder participation. By involving local communities in decision-making processes, policymakers can develop tailored solutions that address the unique challenges faced by different regions in Indonesia (Kusumastuti et al., 2022). Adaptation strategies in Indonesia for increasing land surface temperature (LST) have been a topic of interest in recent years. A study by Ashfa Achmad et al. (2022) suggests that clustered greening concepts at the urban and green material level in buildings and their environment can help mitigate urban heat island effects and adapt to increasing LST. Additionally, policy makers and planners need to consider the importance of mitigating urban heat island (UHI) by incorporating LST variables into sustainable urban planning (Ashfa Achmad et al., 2022). Furthermore, research by Wang and Jv (2021) highlights the importance of non-linear systematic grey models for forecasting the industrial economy-energy-environment system, which can inform adaptation strategies for increasing LST in Indonesia.

Interdisciplinary Research Importance

The findings of this literature review highlight the importance of interdisciplinary research in understanding the complex interactions between climate change and land surface temperature. Integrating insights from climatology, ecology, public health, and social sciences can lead to more effective strategies for addressing the multifaceted challenges posed by climate change in Indonesia. Collaborative research efforts can enhance the understanding of the local context and inform policy decisions. Interdisciplinary research is crucial in Indonesia, as it enables the integration of knowledge and approaches from various disciplines to address complex problems, such as climate change and its impacts on land surface temperature (Fitri Sari, 2021). This approach facilitates a more comprehensive understanding of the issue, allowing for the development of innovative solutions that consider multiple perspectives (Wijaya et al., 2022). In Indonesia, interdisciplinary research has been applied in various fields, including environmental science, agriculture, and public health, to name a few (Ashfa Achmad et al., 2022). By fostering collaboration among researchers from different disciplines, interdisciplinary research can lead to more effective and sustainable solutions to the country's pressing problems (Wang & Jv, 2021). Furthermore, it can also promote a more holistic understanding of the relationships between human and natural systems, ultimately contributing to the development of a more resilient and sustainable society in Indonesia (Saputra et al., 2023).

CONCLUSION

The results of this study show that climate change has a significant impact on increasing land surface temperature (LST) in Indonesia, which has the potential to disrupt

various sectors, including agriculture, health and water resources. These temperature increases are triggered by factors such as deforestation and urbanization, which worsen environmental conditions and increase the risk of food insecurity. This research emphasizes the importance of a deep understanding of public attitudes and beliefs towards climate change to formulate effective and sustainable policies. With an interdisciplinary approach, the results of this research are expected to provide valuable insights for policymakers and stakeholders in developing mitigation strategies that can increase people's resilience to the impacts of climate change, as well as support sustainable development in Indonesia.

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