

Heat Stress Impacts and Public Health Adaptation Strategies in Tropical Regions: A Narrative Review

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ABSTRACT

Global climate change is intensifying heat stress and environmental degradation, posing a growing threat to public health in tropical regions such as Indonesia. This narrative review synthesizes evidence on the clinical, occupational, and epidemiological impacts of heat stress, identifies vulnerable populations, and outlines environmental health adaptation strategies in tropical settings. A literature search of Google Scholar, PubMed/MEDLINE, and ScienceDirect (2020–2026) identified 379 records, of which 10 peer-reviewed studies met the predefined eligibility criteria following a two-stage screening process and were retained for narrative synthesis. The reviewed evidence suggests that heat stress is associated with elevated mortality risk among vulnerable groups, particularly older adults and young children, and with dehydration and subjective health complaints among outdoor workers. Climate-related environmental changes were also associated with shifts in the transmission of dengue fever and diarrheal disease. Effective adaptation appears to require integrated occupational health protection, environmental sanitation, disease surveillance, health education, and community-based interventions. Although Green Open Spaces (GOS) were not directly evaluated in the included studies, this measure is discussed with reference to the broader environmental health literature as a complementary strategy for reducing heat exposure. These findings underscore the need to embed climate-sensitive adaptation measures within environmental and public health policy to strengthen population resilience in tropical regions.

Keywords: climate change, community adaptation, environmental health, heat stress, tropical region

INTRODUCTION

Global climate change is no longer just a macro-scale environmental degradation issue, but has transformed into one of the most significant threats to public health in the 21st century. The main manifestation of this phenomenon is the increase in the Earth's average surface temperature and the increasingly erratic frequency of extreme weather events. Globally, The Lancet Countdown on Health and Climate Change report shows a dramatic spike in heat-related mortality, especially among vulnerable populations such as the elderly and toddlers (Romanello et al., 2022). This challenge is increasingly complex because thermal effects not only directly impact human physiology, but also trigger ecosystem instability that worsens overall environmental health quality. However, this risk burden is not evenly distributed across the globe; tropical regions and developing countries are identified as bearing far more severe

health impacts due to limited adaptation capacity (Ebi & Hess, 2020). This condition directly threatens the achievement of the global Sustainable Development Goals (SDGs), specifically Goal 3 regarding Good Health and Well-being, particularly Target 3.9 which mandates a significant reduction in the number of illnesses and deaths from environmental degradation and pollution by 2030 (United Nations, 2026).

As a tropical archipelago nation, Indonesia is highly vulnerable to the health impacts of this climate dynamics. Geographical characteristics and high population density accelerate the transmission of environment-based diseases across various regions. Emphasize that temperature and air humidity fluctuations in Indonesia directly correlate with the expansion of endemic areas for vector-borne diseases, particularly Dengue Hemorrhagic Fever (DHF), due to the accelerated replication cycle of the *Aedes aegypti* mosquito. On the other hand, prolonged droughts triggered by extreme temperature increases also threaten the availability of clean water. This condition worsens environmental hygiene and the role of sanitation at the household level, which in turn contributes significantly to the surge in gastrointestinal diseases such as diarrhea (Ambodale et al., 2024). According to the Indonesian Health Profile, environment-based infectious diseases, especially DHF and diarrhea, still account for a very high proportion of morbidity in various regions, requiring integrated cross-sectoral preventive interventions (Kementerian Kesehatan RI, 2024).

This threat experiences significant escalation in urban areas through the Urban Heat Island (UHI) phenomenon, where the massive accumulation of asphalt and concrete materials in city centers stores heat and raises micro-environmental ambient temperatures significantly above suburban areas. Exposure to extreme temperatures that exceed the body's adaptation threshold triggers a condition globally known as heat stress. In outdoor work environments, heat stress is reported to decrease physical productivity capacity due to acute fatigue symptoms and the risk of physical strain (heat strain) from dehydration, particularly in the field labor sector and open industries (Nadia et al., 2024). This condition indicates that the impact of temperature changes is multidimensional, affecting clinical, environmental, and socio-economic aspects of communities.

Although these health risks are real, the implementation of local adaptation strategies is often still reactive and not well-integrated into the public healthcare system. This condition indicates the need to strengthen the mandate of Law (UU) Number 17 of 2023 concerning Health, which emphasizes the importance of structured preventive-promotive efforts against environmental disease risk management (Republik Indonesia, 2023). Sustainable adaptation requires a

comprehensive approach, ranging from macro-scale built environment engineering to the institutionalization of adaptive behaviors and systemic protective measures at the individual (Romanello et al., 2022). Therefore, a deep analysis is required to map risks alongside applicable solutions relevant to the characteristics of tropical regions like Indonesia.

Consequently, this study employs a narrative review design which aims to analyze the clinical, occupational, and epidemiological impacts of heat stress, identify vulnerable populations, and formulate community-based and green open space (GOS) environmental health adaptation strategies. Through this comprehensive review, it is highly expected to provide a solid framework for environmental health practitioners, academics, and policymakers in designing effective interventions to manifest community resilience against climate change.

METHODS

Research Design

This study used a narrative review approach to summarize and interpret current evidence on the impacts of heat stress and public health adaptation strategies in tropical regions. A narrative review was chosen because it allows the integration of findings from different types of studies, including quantitative, qualitative, and experimental research, providing a broader understanding of environmental health issues in tropical settings.

Literature Search Strategy

The literature search was conducted between May and June 2026 using Google Scholar, PubMed/MEDLINE, and ScienceDirect. The search was restricted to peer-reviewed articles and official reports published between 2020 and 2026 to ensure consistency with the predefined eligibility criteria.

Search terms were built around three concept blocks: (1) exposure (heat stress, extreme heat, climate change), (2) outcome/response (public health adaptation, environmental health intervention), and (3) setting (tropical region, Indonesia). Because each database has distinct indexing structures and operator limitations, search strings were adapted individually as follows:

Google Scholar: "heat stress" AND "climate change" AND "public health adaptation" AND ("tropical region" OR "Indonesia") — filtered to 2020–2026, excluding patents and citations.

PubMed/MEDLINE: ("heat stress" OR "extreme heat") AND ("climate change" OR "global warming")

AND ("public health" OR adaptation OR "environmental health"). ScienceDirect: ("heat stress" OR "extreme heat") AND ("climate change" OR "global warming") AND ("public health" OR "health adaptation") AND ("tropical region" OR Indonesia) limited to Research and Review articles, 2020–2026.

Study Selection Process

Following the removal of duplicate records, titles and abstracts were screened against the pre-specified eligibility criteria described below. Full texts of potentially eligible articles were then independently assessed for final inclusion, and disagreements were resolved through discussion and consensus. This two-stage screening process resulted in the inclusion of ten studies published between 2020 and 2026 that met all predefined eligibility criteria and were retained for narrative synthesis. The complete screening trajectory is visually mapped in the PRISMA 2020 flow diagram (Figure 1)

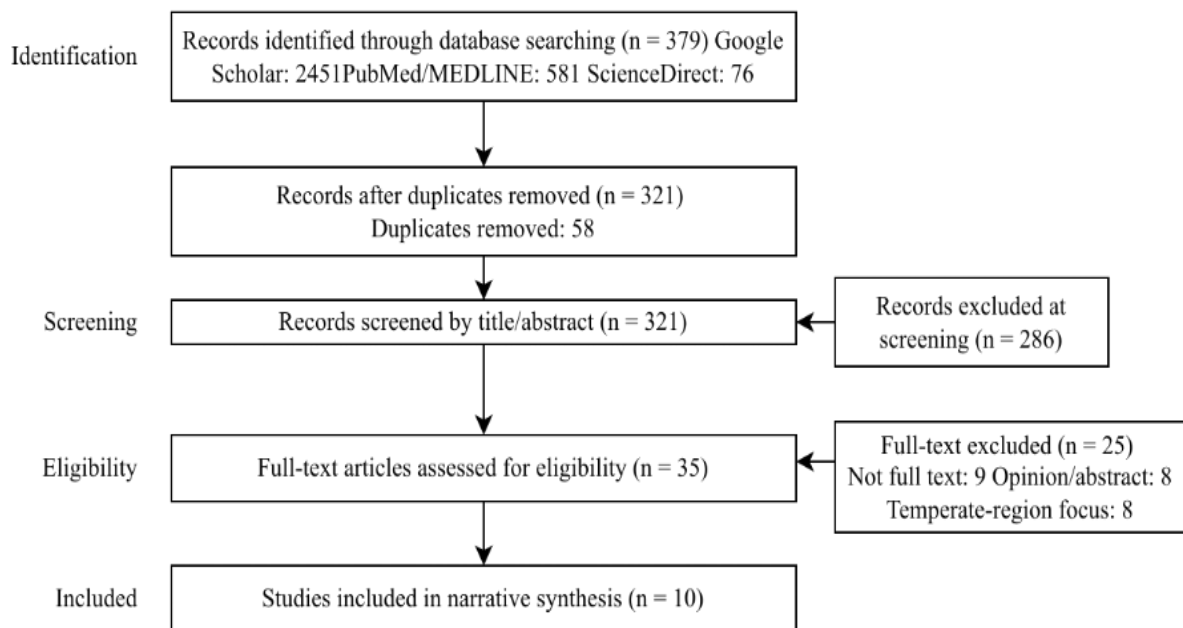


Figure 1. PRISMA-style flow diagram of study selection

Inclusion and Exclusion Criteria

Articles were eligible for inclusion if they were published in English or Indonesian between 2020 and 2026, available in full text, and addressed clinical, occupational, ecological, or environmental health evidence relevant to the impacts of heat stress or public health adaptation strategies in tropical regions directly reflecting the multidimensional objectives of this review.

Primary research articles and official reports meeting these domain criteria were included, whereas opinion papers, conference abstracts, studies lacking full-text access, or studies focused exclusively on temperate-climate settings without relevance to tropical conditions were excluded.

Data Extraction Procedure

Data extraction was performed independently by two reviewers using a standardized, pre-piloted extraction form capturing the author(s), publication year, study design, study population, environmental or occupational exposure variables, and reported adaptation strategies. Extracted data were cross-checked for accuracy and consistency between reviewers, and any discrepancies were resolved by referring back to the original source article.

Study Quality Assessment

As this study employed a narrative review approach, no formal critical appraisal tool was applied. Instead, the selected articles were assessed based on their relevance to the review objectives, publication in peer-reviewed journals, clarity of the research methods, and the credibility of the reported findings.

Data Synthesis Procedure

The extracted findings were synthesized narratively by identifying recurring patterns across the included studies and grouping similar findings into three main themes: (1) the health impacts of heat stress, (2) vulnerable population groups in tropical settings, and (3) public health adaptation strategies. These thematic categories were developed inductively through iterative reading and comparison of the extracted findings, rather than being predefined prior to data extraction, and this thematic approach facilitated the interpretation of evidence across the selected studies.

RESULTS

A literature search of three electronic databases identified 10 studies published between 2020 and 2026 that met the predefined inclusion criteria. The selected studies examined various aspects of heat stress and public health adaptation in tropical regions, including occupational heat exposure, vector-borne diseases, sanitation, and environmental risk factors.

Table 1 summarizes the characteristics of the included studies, including the authors, study designs, study populations, environmental health variables, and the main findings related to heat stress and public health adaptation.

Table 1. Characteristics and Key Findings of the Studies Included in the Narrative Review

No	Author (Year)	Study Design & Location	Population / Subjects	Health / Environmental Factors	Key Findings
1.	Ambodale et al. (2024)	Cross-sectional observational study (Indonesia)	Housewives and children under five attending primary healthcare centers	Basic sanitation facilities and diarrhea incidence	Poor sanitation and limited access to clean water were linked to higher diarrheal incidence; improved sanitation infrastructure and clean and healthy living behaviours (PHBS) were recommended.
2.	Hidayanto et al. (2025)	Cross-sectional study (Indonesia, Konawe Utara)	Industrial workers exposed to occupational heat	Occupational heat exposure, workload, fluid intake, and dehydration status.	Combined heat exposure, heavy workload, and inadequate fluid intake increased dehydration risk; workplace hydration programmes and scheduled rest periods were recommended.
3.	Clarke et al. (2022)	Global climate attribution study (Global multi-location).	Climate data and population health records from developing regions	Climate indicators and population health data.	Climate change disproportionately increases health risks in low- and middle-income countries, underscoring the need for climate surveillance and adaptation policy.
4.	Romanello et al. (2022)	Global longitudinal study (The Lancet Countdown).	Global vulnerable populations (Elderly over 65 and toddlers)	Extreme heat exposure and climate-related health risks	Climate change has increased the frequency and severity of extreme heat events, raising mortality and health risks among vulnerable groups; stronger adaptation policy, social protection, and heat-health preparedness were recommended.
5.	Ulya & Kesetyaningsih (2022)	Secondary data ecological correlation study (Indonesia)	Populations in tropical disease endemic areas.	Air temperature, humidity, rainfall, and dengue incidence.	Air temperature was negatively associated with dengue incidence, while humidity and rainfall were positively associated, supporting climate-informed surveillance and vector control.
6.	Ebi & Hess (2020)	Risk analysis and health equity study (Global)	Marginalized populations in developing countries and tropical regions.	Climate change, heat exposure, vulnerable populations, and adaptive capacity.	Climate change increases heat-related health risks, particularly among populations with limited adaptive capacity; stronger health systems, adaptation planning, and reduced social inequality are needed.

No	Author (Year)	Study Design & Location	Population / Subjects	Health / Environmental Factors	Key Findings
7.	Faried Karesya et al. (2023)	Analytical observational study (Indonesia).	Infrastructure construction project workers (outdoor workers).	Occupational heat exposure, workload, and subjective health complaints.	Occupational heat exposure was associated with more subjective health complaints among construction workers; heat exposure management, rest periods, and preventive measures were recommended.
8.	Setyani et al. (2024)	Analytical observational study with cross-sectional design (Boyolali, Indonesia)	Total population in endemic areas and DHF patients.	Host characteristics (age and sex), rainfall, temperature, humidity, land use, and population density	Dengue incidence was associated with host and environmental factors—age, rainfall, and population density positively, air temperature negatively—supporting targeted, climate-informed dengue prevention.
9.	Nadia, Syam et al. (2024)	Analytical observational study (Indonesia)	Industrial workers exposed to occupational heat.	Workload, water intake, work duration, health status, and heat strain	Workload, inadequate water intake, work duration, and health status were associated with heat strain; adequate hydration, workload management, and heat protection measures were recommended.
10.	Utami (2023)	Environmental spatial analysis (Indonesia).	Local community cohorts in diarrheal endemic clusters.	Bacteriological water quality, sanitation facilities, and diarrhoea distribution	Diarrhoea cases showed a clustered spatial distribution, associated with poor bacteriological water quality and inadequate sanitation; GIS-based mapping can support targeted interventions.

DISCUSSION

This narrative review synthesized evidence from ten studies published between 2020 and 2026 to examine the impacts of heat stress and public health adaptation in tropical regions. Overall, the reviewed evidence indicates that heat stress affects human health through interconnected occupational, environmental, and socio-ecological pathways. Three major themes emerged from the synthesis: (1) clinical and occupational pathways of heat stress, (2) climate and environmental drivers of climate-sensitive diseases, and (3) public health adaptation strategies. The following discussion integrates these findings while referring to additional supporting literature where appropriate to provide broader context for interpretation.

Clinical and Occupational Pathways of Heat Stress

Across the reviewed studies, occupational heat exposure consistently emerged as one of the primary pathways through which climate change adversely affects human health in tropical regions. Workers performing physically demanding outdoor activities are particularly

vulnerable because prolonged exposure to high ambient temperatures and humidity increases physiological strain, reduces work capacity, and elevates the risk of dehydration and heat-related illnesses (Faried Karesya et al., 2023; Hidayanto et al., 2025; Nadia et al., 2024). Collectively, these studies indicate that occupational heat stress should be recognized not only as an environmental hazard but also as an important occupational health issue requiring integrated preventive strategies.

Beyond occupational settings, the reviewed evidence also demonstrates that climate change has increased the frequency and intensity of extreme heat events, resulting in greater health risks for vulnerable populations. Global evidence indicates that older adults and young children experience disproportionately higher rates of heat-related morbidity and mortality because of their limited physiological capacity to cope with prolonged heat exposure (Clarke et al., 2022; Romanello et al., 2022). These findings highlight the importance of strengthening public health preparedness and protecting vulnerable groups in tropical regions facing increasing climate variability.

The occupational studies included in this review consistently showed that excessive heat exposure, heavy physical workloads, and inadequate hydration contribute to heat strain, dehydration, and declining work performance among outdoor and industrial workers (Hidayanto et al., 2025; Nadia et al., 2024). These findings suggest that existing workplace heat protection measures may become increasingly insufficient under warmer climatic conditions. Therefore, preventive strategies including adequate hydration, scheduled rest periods, workplace heat monitoring, and environmental modifications should be strengthened to reduce heat-related health risks and improve occupational safety. Similar observations have also been reported by Apriani et al. (2023), providing additional evidence that supports the interpretation of the findings synthesized in this review.

Indirect Ecological Pathways: Vector Borne and Waterborne Dissemination

Beyond direct thermal strain, fluctuations in tropical climate parameters act as critical environmental catalysts that alter the transmission dynamics of environment-based infectious diseases. The ecological patterns of vector-borne illnesses, particularly Dengue Hemorrhagic Fever (DHF), exhibit a highly sensitive relationship with local climate shifts (Ulya & Kesetyaningsih, 2022). These findings are consistent with previous evidence reported by Apriani et al. (2023), who also identified precipitation and temperature as important predictors of dengue incidence in Indonesian urban areas. Similar observations have also been reported

by Rojali et al., (2023), providing additional support for the interpretation that climate variability contributes to changes in dengue incidence. Moreover, recent epidemiological evidence emphasizes that the complex interplay between household micro-environments and shifting macro-climate parameters substantially amplifies the proliferation of breeding sites, thereby intensifying regional DHF endemicity during seasonal transitions (Setyani et al., 2024).

Elevated ambient temperatures within an optimal range accelerate the metabolic and replication rates of the *Aedes aegypti* mosquito. These environmental conditions may shorten the virus's extrinsic incubation period and increase vector biting frequency, thereby facilitating dengue transmission. Conversely, empirical correlations also indicate that seasonal drops in temperature paired with high rainfall and humidity expand stagnant breeding sites, demonstrating that tropical DHF endemicity is driven by a complex, multi-variable climate nexus (Ulya & Kesetyaningsih, 2022).

Simultaneously, extreme thermal strain and accompanying prolonged dry spells trigger a distinct waterborne pathway for gastrointestinal diseases. Severe droughts drastically deplete high-quality surface water sources, forcing vulnerable rural and dense urban communities to rely on substandard, unsanitary water alternatives (Utami, 2023). Limited access to safe water may also reduce household hygiene practices, thereby increasing the risk of waterborne diseases (Ambodale et al., 2024). When environmental moisture is altered and clean water availability is constrained, waterborne pathogens replicate efficiently and spread through the fecal-oral route. The risk of waterborne disease may increase where inadequate sanitation facilities, poor domestic wastewater management, and contaminated water sources coexist (Ambodale et al., 2024; Utami, 2023).

Integrated Environmental Health Adaptation Frameworks

Addressing the direct and indirect health impacts of heat stress requires a shift from fragmented interventions toward integrated socio-ecological adaptation frameworks (Ebi & Hess, 2020). The reviewed studies consistently indicate that effective adaptation requires the integration of occupational health measures and community-based public health interventions. Workplace adaptation strategies, including adequate hydration, scheduled rest periods, heat exposure monitoring, and occupational health education, are essential to reduce the risk of heat-related illnesses among outdoor workers (Hidayanto et al., 2025; Nadia et al., 2024), and create less favorable environmental conditions for mosquito proliferation (Ulya & Kesetyaningsih, 2022). Community-based adaptation also plays an important role in strengthening resilience to

climate-related health risks (Ebi & Hess, 2020). Empowering communities through environmental health education, workplace hydration practices, scheduled rest periods, and public awareness programs can improve individual preparedness and reduce the adverse health effects of prolonged heat exposure (Hidayanto et al., 2025; Nadia et al., 2024; Romanello et al., 2022).

For waterborne disease mitigation, community-led management of decentralized water systems and localized sanitation surveillance are vital to safeguard water quality during protracted droughts. Improving environmental health literacy among community health cadres and local communities can strengthen household sanitation practices and support climate-resilient public health interventions (Utami, 2023).

Although none of the reviewed primary studies specifically evaluated Green Open Spaces (GOS) as an adaptation intervention, broader environmental health literature recognizes urban green infrastructure as a complementary strategy to reduce heat exposure and improve thermal comfort in tropical urban environments (Ebi & Hess, 2020). Therefore, integrating environmental planning approaches with occupational health protection and community-based interventions may strengthen climate adaptation policies in the environmental health sector.

CONCLUSION

This narrative review demonstrates that climate change poses significant public health challenges in tropical regions through both direct and indirect pathways affecting human health. Direct impacts are primarily associated with occupational heat stress, which increases the risk of dehydration, heat-related illnesses, and reduced work capacity among outdoor workers. Indirect impacts occur through environmental changes that influence the transmission of climate-sensitive diseases, particularly dengue fever and diarrheal diseases.

The reviewed studies consistently indicate that effective adaptation requires integrated actions involving occupational health protection, environmental management, and community-based public health interventions across multiple sectors. Measures such as adequate hydration, workplace heat protection, environmental sanitation, disease surveillance, and health education are essential to strengthen resilience against the health impacts of climate change.

Overall, this review highlights the importance of integrating climate adaptation into environmental health policies to reduce population vulnerability, strengthen community resilience, and support sustainable public health systems in tropical regions.

LIMITATION

This narrative review has several limitations. First, the review was restricted to studies retrieved from Google Scholar, PubMed/MEDLINE, and ScienceDirect and included only English- and Indonesian-language publications published between 2020 and 2026. Consequently, relevant studies from other databases or languages may have been omitted. Second, no formal methodological quality appraisal or risk-of-bias assessment was conducted because this study adopted a narrative review approach. Finally, the included studies varied in study design, population, setting, and outcome measures, which may limit the generalizability of the findings.

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