

# Vietnam's Future Under A Warming World: The Growing Challenge of Heat Stress

February 2026 – No. 85 | AFD GEMMES Viet Nam 2 project

## INTRODUCTION

As global warming intensifies, Vietnam is expected to experience more frequent and intense extreme heat events in the coming decades. Designing efficient adaptation strategies in the face of these growing hazards requires assessments of future changes in hot extremes across the country.

In order to offer essential guidance for policymakers to develop effective heat stress adaptation and mitigation strategies, we have studied future changes of different hot extreme indicators across Vietnam for different climate change scenarios, using two different methodologies.

The results show that extreme heat conditions will intensify and could occur up to several months per year in some regions at high global warming levels. Hence, extreme heat exposure will be a significant threat to health and labor productivity in Vietnam and could have severe socio-economic consequences. We emphasize the urgent need for proactive planning and targeted adaptation measures.

## CONTEXT & MOTIVATION

**Rising hot extremes.** Anthropogenic global warming is driving an unprecedented rise in extreme weather and climate events that threaten human health, well-being, and livelihoods. In particular, hot extremes have become more frequent and intense worldwide. Vietnam, one of the countries most exposed to climate hazards, is no exception to this trend. The country has experienced a significant rise in both mean temperature and hot extremes over the past decades. The maximum daily temperature and the annual number of hot days above 35°C, for instance, have increased markedly since the 1980s. Heat stress has emerged as one of the most pervasive and dangerous challenges for the country.

**Heat stress is a major socio-economic issue.** Heat stress occurs when the human body cannot regulate its internal temperature effectively, caused by high air temperatures, humidity, strong solar radiation, and low wind speeds. Prolonged exposure can result in heat exhaustion, heat stroke, and premature death, while also

diminishing labor productivity, straining healthcare systems, and undermining economic growth. Rising temperatures further enhance ozone formation, worsening air quality and compounding health risks.

Vulnerable populations – including outdoor workers, older adults, children, and those with chronic illnesses – are most at risk due to higher exposure and/or limited adaptive capacity. In addition, more than 60% of Vietnam's workforce is employed in climate-sensitive sectors such as agriculture, construction, and manufacturing, amplifying exposure to extreme heat events.

**A growing threat for Vietnam.** Despite international pledges to limit global warming, global greenhouse gas emissions are still on the rise. The 1.5°C warming threshold of the Paris Agreement is expected to be crossed in the coming years, and if current policies continue, the planet could warm by more than 3°C by the end of the century. In this context, Vietnam is projected to face increasingly hazardous thermal conditions that could severely affect public health, infrastructure, and livelihoods across both rural and urban areas.

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**Geography** Vietnam

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**Key words** Climate change, heat stress, extreme temperature, global warming levels, CMIP6 projections

**Themes** Climate change, adaptation

## METHODS

Our analyses focus on four global warming levels (GWLs): 1.5°C, 2°C, 3°C, and 4°C above pre-industrial levels. These GWLs were defined using a 20-year moving window centered on the year each level was exceeded, allowing for a policy-relevant framing that compares impacts across warming scenarios. The timing when a GWL might be crossed depends on future global greenhouse gas emissions, and high GWLs are representative of high-emissions futures.

We integrate two complementary approaches, developed in two studies, to evaluate future heat hazards in Vietnam. The first one [1] focuses on extreme climate indices based on air temperature only, while the second [2] is based on the wet-bulb globe temperature (WBGT, see Box 1). Both methods rely on the projections of some CMIP6<sup>1</sup> global climate models, but with different downscaling approaches, to better represent Vietnam's diverse topography, coastal areas, and regional climate variations.

### Study 1

In this study, we used the projections from 33 CMIP6 models under different Shared Socioeconomic Pathways (SSPs), statistically downscaled for Vietnam at 10 km of spatial resolution and bias-corrected (CMIP6-VN database, see [3]). The use of a large number of climate models provides the ability to estimate the uncertainties of climate projections related to inter-model spread.

Extreme temperature analysis was conducted using seven extreme climate indices that describe the intensity, frequency, and duration of extreme temperature events, among which:

- the annual maximum value of **daily maximum temperature** (TXx);
- the annual **number of hot days** (SU35), when the daily maximum temperature is greater than 35°C;
- the **heat wave duration** (HWD), defined as the annual average

number of days with at least 3 consecutive days hotter than the 90<sup>th</sup> percentile of the reference period;

- the **heat wave intensity** (HWI), defined as the annual average of maximum daily temperature during the heatwave period (HWI).

### Study 2

In Vietnam, most existing heat stress studies have focused on simple temperature metrics or approximations of the WBGT index that neglect critical components such as wind and solar radiation. Simplified WBGT estimates, therefore, underestimate outdoor heat stress, particularly under intense sunlight, limiting their usefulness for public health and workplace safety planning.

To address this gap, we used the projections of two CMIP6 global climate models under 3 SSP scenarios. These projections are dynamically downscaled with a regional climate model<sup>2</sup> to a spatial resolution of ~25 km. Because WBGT is not a standard output variable of climate models, we used a physically-based model of this index to calculate it from available climate

model outputs. To enhance reliability, WBGT values derived from the model outputs were bias-corrected<sup>3</sup> in order to align modeled distributions with climate reanalysis while maintaining the projected changes in extremes that are crucial for heat-stress evaluation. Nevertheless, as with any modelling approach, the method involves biases relative to actual observed values. In the absence of available WBGT observation data, these biases could not be assessed.

Finally, heat stress was categorized into four levels based on occupational health standards (see Box 1). These thresholds link projected heat conditions to potential labor capacity loss, public health risks, and adaptation needs, providing policymakers with a practical framework for managing heat impacts under future warming scenarios.

### Projections calculations

In both Studies, the indices are first calculated for each year belonging to the 20-year period of a given GWL, for each model and SSP scenario,

#### Box 1. The wet-bulb globe temperature index and its use in occupational health standards.

The dissipation of the metabolic heat produced by a human body can be achieved through three mechanisms: evaporative cooling, heat conduction, and net infrared cooling. When air temperature rises above 34–37°C, only sweat evaporation remains effective. But high humidity can strongly reduce heat loss through sweating, which may lead to a dangerous rise of the core body temperature. Therefore, air humidity is a key factor to assess heat stress in a humid climate such as Vietnam.

The WBGT index is widely used and recognized to assess heat stress conditions, especially for working people. **It includes all relevant factors: air temperature, relative humidity, air movement and radiant heat** (from the Sun or from another source). To better assess the societal implications of heat stress, impact-relevant thresholds are utilized. In our study, we considered four impact-relevant levels based on occupational health standards, that indicates the ratio of work and rest per hour to safely perform medium work, depending on the WBGT value.

Table 1. Overview of the WBGT thresholds used in this study.

Levels	Thresholds	Recommendations
Level 1	29 °C	25% rest/hour
Level 2	30.5 °C	50% rest/hour
Level 3	32 °C	75% rest/hour
Level 4	37 °C	No work at all

Source: modified from [2].

<sup>1</sup> The climate models participating in the Coupled Climate Model Intercomparison Project, Phase 6.

<sup>2</sup> Simulations from the Coordinated Regional Climate Downscaling Experiment for the Southeast Asia domain (CORDEX-SEA).

<sup>3</sup> Using the Quantile Delta Mapping (QDM) method with ERA5 reanalysis data (1995–2014) as the reference.

and then averaged over the period. Future changes are calculated as averages across all climate models and SSP scenarios that reach this GWL, and compared to the 1995–2014 baseline.

In Study 1, uncertainties in the projections are evaluated using the signal-to-noise ratio (SNR<sup>4</sup>). SNR>1 indicates higher model agreement and greater confidence in the projections, whereas SNR<1 corresponds to low model agreement and high uncertainty

## RESULTS

### Intensifying hot extremes.

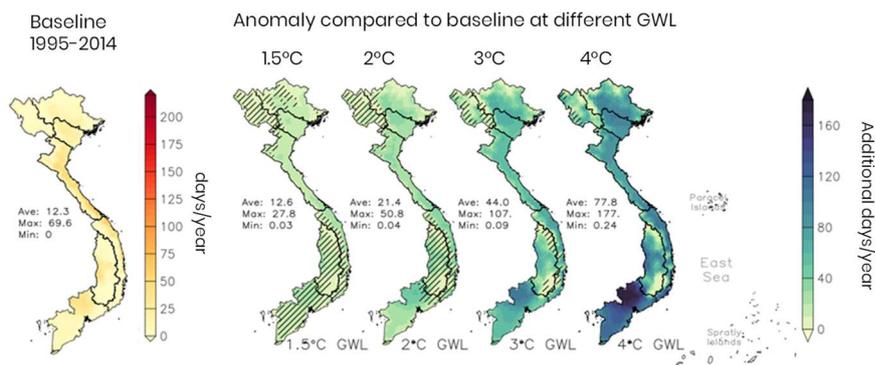
Projections indicate a robust and consistent rise in extreme temperatures across Vietnam at all GWLs. Relative to the 1995–2014 baseline, the hottest day of the year increases by 1.5°C at +2°C GWL, 2.2°C at +3°C GWL, and up to 3.6°C under +4°C GWL.

The annual maximum of daily maximum WBGT increases by 1–2°C at +2°C GWL and by up to 3°C at +4°C GWL. This indicates that currently rare extreme heat events may become common, heightening risks to health, labor productivity, infrastructure, and emergency response systems.

By contrast, heatwave intensity (HWI) only shows a modest rise, with stronger model agreement at higher warming levels.

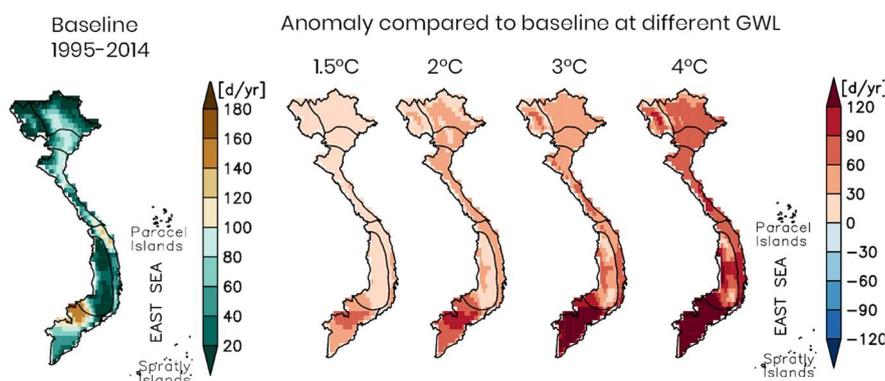
**Night-time heat stress.** Worryingly, increases are not confined to daytime conditions. The annual maximum and number of days exceeding Level 1 (>29°C) for daily minimum WBGT also increase significantly under higher emissions scenarios and hotter GWLs. This means nights are becoming hotter and less conducive to physiological recovery. Without cooler nights, heat accumulates in the human body, compounding daily exposure and elevating risks of chronic heat stress, especially for the elderly, people with pre-existing conditions, and outdoor workers.

**Figure 1. Projected changes of the annual number of hot days (T>35°C) under different GWLs (Study 1).**



Displayed values correspond to the multi-scenario, multi-model ensemble means. Hatched areas highlight regions where SNR<1, i.e. with low model agreement and high uncertainty in the projections. Source: Modified from [1]

**Figure 2. Projected changes in the annual number of days with a daily maximum WBGT above level 3 (>32°C) under different GWLs (Study 2).**



Only significant differences ( $p$ -value<0.05) are plotted. Source: modified from [2]

**Longer hot periods.** Not only do the heat extremes intensify, but they also occur far more often at higher GWLs.

Heatwave duration (HWD) is projected to increase substantially, from about 5 days per year during the baseline period at the national scale to roughly 15 days at +2°C GWL, 26 days at +3°C GWL, and over 40 days per year at +4°C GWL.

The number of hot days above 35°C rises from a national average of 12 days per year to 34, 57, and more than 90 days per year at +2°C, +3°C, and +4°C GWLs, respectively (Figure 1). The southern and coastal regions, particularly the Mekong Delta, are most affected, with up to 140–200 days above 35°C annually in some local areas in a worst-case scenario

of +4°C GWL – equivalent to nearly two-thirds of the year.

Over 1995–2014, most areas of Vietnam experienced fewer than 100 days per year with a daily maximum WBGT above the Level 3 threshold (severe heat stress). Under +4°C GWL, most regions could experience an additional 60–120 days per year of severe heat stress (Figure 2). The Mekong River Delta faces the most dramatic change, with exceedances increasing by over 90 extra days per year at +2°C GWL and up to 150 extra days per year at +4°C GWL, totaling 240–270 days annually in some areas. This would expose millions of people to hazardous conditions for much of the year, dramatically increasing risks to outdoor workers, rural livelihoods, and urban populations alike.

<sup>4</sup> Calculated as the multi-model and multi-scenario ensemble mean divided by inter-model variability.

**Regional hotspots.** The Red River Delta and Mekong River Delta emerge as **priority hotspots** for future heat stress. These regions combine high population density, major agricultural production, and rapid economic development with limited adaptive capacity. The projected escalation of heat stress means these deltas will be at the forefront of public health challenges, labor productivity losses, and migration pressures linked to climate change. Targeted interventions and region-specific adaptation strategies will be essential.

## IMPLICATIONS

Together, these findings imply that extreme hot conditions will not only become fiercer but will also evolve into prolonged seasonal phenomena. This represents a major and growing threat to Vietnam's public health, economy, and infrastructure. **Without decisive adaptation and mitigation**

**measures, the country could face significant human and financial costs.** Key areas of concern include:

- **Reduced Labor Productivity:** Outdoor sectors such as agriculture, construction, and fisheries will be heavily affected by more frequent days exceeding occupational heat thresholds. Workers will require longer rest periods or complete work stoppages during peak hours, reducing daily productivity, disrupting supply chains, and threatening household incomes and national economic output. This effect will be especially pronounced in rural areas and informal labor markets where protective measures are limited.
- **Increased Health Risks:** Elevation of the incidence of heat exhaustion, heat stroke, and aggravation of chronic diseases such as cardiovascular and respiratory conditions. Rising night-time heat further limits recovery, increasing the

likelihood of long-term health consequences.

- **Strain on Infrastructure:** The demand for cooling and air conditioning will surge, placing unprecedented stress on power grids and increasing the risk of blackouts. Healthcare systems will face higher patient loads from heat-related illnesses and may struggle to maintain capacity during extreme heat events, particularly in underserved areas.
- **Urban Vulnerability:** The urban heat island (UHI) effect in cities will amplify the impacts of global warming, making urban environments even hotter and more hazardous. Although urban greening and reflective infrastructure can provide partial relief, these measures alone are unlikely to offset the combined effects of rising background temperatures and urbanisation.

## RECOMMENDATIONS

To protect lives and livelihoods, **urgent and comprehensive strategies are needed**, including:

- ▶ **Developing robust heat-health warning systems and action plans to inform communities**, coordinate emergency responses, and prevent heat-related illnesses and deaths.
- ▶ **Strengthening healthcare preparedness** by increasing capacity in emergency services, expanding surveillance of heat-related illnesses, and training health professionals to manage extreme-heat events.
- ▶ **Implementing workplace safety regulations for heat exposure**, particularly in outdoor sectors such as agriculture, construction, and fisheries, with clear thresholds for rest, hydration, and protective measures.
- ▶ **Promoting heat-resilient urban planning and building designs**, including green spaces, reflective surfaces, improved ventilation, and heat-sensitive zoning to reduce urban heat island effects.
- ▶ **Investing in climate-resilient energy and water infrastructure** to meet surging demand for cooling, ensure a reliable power supply, and protect water resources during prolonged heat events.

**Equally critical is a strong global commitment to reduce greenhouse gas emissions**, which will ultimately determine the severity and duration of future heat extremes faced by Vietnam. Continued research, monitoring, and investment in context-specific solutions are essential to guide evidence-based policies, support vulnerable populations, and build a resilient, heat-adapted future.

## REFERENCES

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