THE COST OF INACTION

Quantifying the Impact of **Climate Change** on **Health** in Low- and Middle-Income Countries

CIF CLIMATE INVESTMENT FUNDS
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Foreword

Climate change has profound and extensive adverse impacts on health, and these are expected to intensify in the coming decades. As casualties and fatalities increase, the climate-related health crisis risks overwhelming health care facilities and systems, particularly in low- and middle-income countries. As a result, the health impacts of a warming planet could push millions of people into extreme poverty.

A vital first step toward addressing the health emergency arising from climate change involves identifying the multiple health impacts and estimating the cost of inaction. Building on an earlier effort by the World Health Organization, this World Bank report quantifies the impacts and costs of projected climate change on health in low- and middle-income countries.

The study reveals that climate change-related health impacts will be severe, even in the short term, and certain regions like Sub-Saharan Africa and South Asia will bear a disproportionate share of the global burden. The cost of inaction is expected to be far higher than projected in the report, which did not cover all of the health risks linked to climate change.

These projections should galvanize decision-makers and spur urgent, transformative action. Countries must adopt bold measures to limit the impacts of climate change and significantly boost the resilience of their health care systems. This cannot be about addressing the impact on specific diseases alone. Instead, we must focus on strengthening health systems so they can adapt and mitigate the broader impacts of climate change on health conditions.

The World Bank aims to reach 1.5 billion people with quality health services by 2030. This goal will not be reached, without expanding our investments in climate and health to help countries build high-quality, climate-resilient, and low-carbon health systems. These are not just words. In fact, last year climate investments in health projects amounted to a third of the Bank’s total financing for health.

Further we are focusing on assessing country-specific climate-health vulnerabilities to inform the design of tailored solutions to guide our investments to build resilient, low-carbon health systems; as well as deepening partnerships at the global, regional, and country levels to support these efforts. Looking ahead, the World Bank is developing a full range of financing instruments for both adaptation and mitigation activities, which will enable us to increase our support to help low- and middle-income countries tackle climate-health challenges.

Climate change is a global crisis – we must join forces now to address its direct and indirect impacts on health and limit the high human and economic costs. This is a wake-up call for all of us to act decisively and urgently to safeguard our future.

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ABBREVIATIONS

AR6	Sixth Assessment Report (of the IPCC)
CCKP	Climate Change Knowledge Portal
CMIP6	Sixth Phase of the Coupled Model Intercomparison Project
CO_2	Carbon Dioxide
COI	Cost of Illness
COP	Conference of the Parties (to the UNFCCC)
COP26	26th Conference of the Parties
EAP	East Asia and Pacific
ECA	Europe and Central Asia
GDP	Gross Domestic Product
IAM	Integrated Assessment Model
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
LAC	Latin America and the Caribbean
LMICs	Low- and Middle-Income Countries
MENA	Middle East and North Africa
OECD	Organisation for Economic Co-operation and Development
RCP	Representative Concentration Pathway
SA	South Asia
SIDS	Small Island Developing States
SRES	Special Report on Emissions Scenarios
SSA	Sub-Saharan Africa
SSP	Shared Socioeconomic Pathway
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States Dollar
VSL	Value of Statistical Life
WEF	World Economic Forum
WHO	World Health Organization
YLL	Years of Life Lost

UNITS OF MEASUREMENT

°C	Degree Celsius
Gt/yr	Gigatons Per Year
W/m2	Watt Per Square Meter

Summary

Climate change is impacting human health in myriad ways, including by increasing the frequency of extreme weather events, the emergence and spread of infectious diseases, and disruptions to food systems. The impacts of climate change on health—already profound—are only expected to worsen over time. Not only will the number of diseases and deaths from climate-sensitive health risks increase, but so too will the geographical range of these diseases. Low- and middle-income countries (LMICs) are expected to face a disproportionate burden of these impacts due to their higher levels of poverty and income inequality, and weak healthcare systems. With growing recognition that the climate crisis is a health crisis, the international community has expressed urgent calls for action on climate and health.

The response of the health community and researchers has been largely focused on studying the link between climate change and health. A limited number of studies have established empirical links between climate conditions and the variability in the number of different diseases in specific national (or subnational) contexts, particularly focusing on vector-borne and waterborne diseases. In addition, few studies have aimed to assess the economic cost associated with the health impacts of projected climate change.

This report aims to address the existing knowledge gap and provide a deeper understanding of the interconnection between climate and health, in terms of the risks to human health and the economic burden of these risks. Specifically, it provides a quantitative assessment of the potential impacts of climate change based on the number of cases and the number of deaths resulting from selected vector- and water-borne diseases, stunting, and extreme heat. An assessment of the economic cost of climate change on health (in terms of both morbidity and mortality) is also provided.

The analysis covers 69 low-income and middle-income countries with national populations exceeding 10 million people in the base year 2020. These 69 countries comprise 96 percent of the total population of all LMICs.

Estimates of the impacts of climate change on health are provided for different time periods including 2026-2030, 2026-2050, and 2026-2100 in the context of two socioeconomic development scenarios featured in the *Sixth Assessment Report* (AR6) of the Intergovernmental Panel on Climate Change (IPCC)—namely, SSP3-7.0 and SSP2-4.5 (referred to hereafter as SSP3 and SSP2). These two scenarios represent middle-of-the-road development paths between the worst-case (RCP8.5) and the increasingly unlikely best-case scenarios (RCP2.6 and RCP1.9). SSP3 represents a challenging pathway, assuming high population growth, limited economic development, and reduced investments in health and education, whereas SSP2 presents moderate challenges, characterized by steady population and economic growth.

The main findings of this report are as follows:

1. **The impacts of climate change on health are significant and call for immediate action at the global and country levels.** Between 2026 and 2050, climate change is projected to cause between 4.1 billion (SSP2) and 5.2 billion (SSP3) cases across LMICs. The impact of climate change on mortality will be equally stark. By 2050, the number of deaths caused by climate change could reach between 14.5 million (SSP2) and 15.6 million (SSP3). Immediate, decisive action is needed to avert these devastating impacts on health across LMICs.

2. **Scaling climate-health action is needed to avert trillions of dollars in economic costs arising from these selected health impacts of climate change in the coming decades.** By 2050, the economic cost of the health impacts of climate change is projected to reach between USD 8.6-15.4 trillion under SSP3. These costs translate to between 0.7 percent and 1.2 percent of the gross domestic product (GDP) of LMICs. These estimates are higher under SSP2, reaching between USD 11.0-20.8 trillion translating to 0.7 percent and 1.3 percent of GDP in LMICs.

3. **Sub-Saharan Africa (SSA) and South Asia (SA) will bear the brunt of the health impacts of climate change.** These impacts will be particularly severe in SSA, which is projected to experience approximately 71 percent of all cases and nearly one-half of all deaths caused by climate change between 2026 and 2050 under both socioeconomic development scenarios. SA is projected to experience approximately 18 percent of all cases and one-quarter of all deaths under both scenarios. In these two regions combined, the number of deaths caused by climate change is projected to reach between 10.5 million (SSP2) and 11.7 million (SSP3) by 2050. The economic cost will be significantly higher for SSA than for any other region—by 2050, this cost will amount to between 2.7 percent and 3.6 percent of the region's GDP under both scenarios.

4. **The health impacts of climate change presented in this report are significant but likely to be just the tip of the iceberg.** The analysis presented in this report includes the potential impacts of climate change on a limited number of health risks. The potential impacts of climate change on other health risks, such as non-communicable diseases and mental health, are not included in this report. Moreover, the analysis of these health risks has not considered the change in their geographical trajectory because factors, such as migration and water stress, can only be captured through a dynamic model. As a result, the results presented here

should be understood as a notable underestimate of the scale of the real impacts of climate change on health in LMICs.

The findings of this report confirm the AR6's projection of a significant increase in cases and deaths due to climate change and the uneven geographical distribution of this future burden, with SSA and, to a lesser extent, SA bearing the brunt of the projected increase. Furthermore, by estimating the associated economic costs of these health impacts, this report argues for intensifying and accelerating efforts to reduce greenhouse gas emissions as well as for LMICs to prioritize investments in health systems. These investments are needed to build resilient and sustainable health systems that can weather the adverse impacts of climate change on health. It must be clearly stated that this report does not advocate for a vertical approach to the health risks included in the analysis. A health systems approach is needed to tackle the projected impacts of climate change on health effectively and efficiently.

1. Introduction

Climate change has been impacting human health at an accelerated pace over the past decade. This includes increases in heat-related illnesses, waterborne and vector-borne diseases (including outbreaks), and malnutrition from reduced crop productivity, among numerous others. These effects are expected to worsen over time, with changes not only in the number of diseases and deaths from climate-sensitive health risks but also in their geographical range (George et al. 2024). In addition to impacting health outcomes, climate change is projected to adversely impact health systems. As a result of poverty, income inequality, and weak healthcare systems, low- and middle-income countries (LMICs) are expected to face disproportionate increases in morbidity, as well as increasing losses and damages to health facilities. Urgent calls for action have been expressed by the global community (Fielding 2023; Intergovernmental Panel on Climate Change [IPCC] 2023; Romanello et al. 2023; United Nations Environment Programme [UNEP] 2023). Over 200 health journals have recently called on the United Nations (UN), political leaders, and health professionals to treat the ongoing climate and nature crises as one global health emergency (Abbasi et al. 2023).

Despite the scale of this crisis, evidence quantifying the impact of climate change on health remains limited. The underlying physiological factors linking climate change and the incidence of vector-borne and waterborne diseases have been discussed by numerous experts (George et al. 2024; Semenza et al. 2023; Thomson et al. 2022; Wong 2023). However, the extent of the risk of climate change on health remains poorly quantified (Mora et al. 2022). Only a limited number of papers have aimed to transform this knowledge into quantified assessments of the potential impacts of climate change on specific health risks.[1] Given the scarcity of public resources, future policy responses on their allocations require going beyond understanding the underlying nature of climate change and health links to quantify the extent of the linkages in terms of future incidences, mortality, and economic costs (Ebi 2022, 2024). This lack of comprehensive quantification may partially explain why health-specific climate actions represent only 6 percent of total adaptation funding (World Health Organization [WHO] 2023). It has been estimated that LMICs require at least USD11 billion in funding per year this decade to adapt to climate and health impacts and increase the resilience of their health systems (UNEP 2023).

To address the evidence gap, this report provides estimates of the economic cost of inaction on selected health risks linked to climate change. It provides a quantitative assessment of the

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[1] A limited number of studies have established and estimated empirical links between climate conditions, variability, and the incidence of diseases in specific national (or subnational) contexts. Examples include Brazil (Barcellos et al. 2014); China (Xiang et al. 2018; Zheng et al. 2017); Colombia (Quinterro-Herrera et al. 2015); Iran (Salahi-Moghaddam et al. 2017); Philippines (Su 2008); Sierra Leone (George et al. 2023); Singapore (Struchiner et al. 2015); Tanzania (Kulkarni et al. 2016); Uganda (Boyce et al. 2016); Vietnam (Xuan et al. 2014); and Zambia (Bennett et al. 2016).

potential impacts of climate change on (1) the number of cases and deaths resulting from selected health risks: extreme heat, waterborne diseases (diarrhea), stunting, and vector-borne diseases (dengue and malaria); (2) the number of years of life lost (YLL) from deaths arising from these health risks attributable to climate change; and (3) the economic cost of the incremental number of cases and deaths attributable to climate change. These impacts are estimated for 69 LMICs whose population exceeds 10 million people in the base year 2020. Estimates of the impacts are generated for the short term (2026–2030), medium term (2026–2050), and long term (2026–2100) based on two (of the five) climate scenarios forming the basis of the *Sixth Assessment Report* (AR6) of the Intergovernmental Panel on Climate Change (IPCC) — SSP2 and SSP3.

This report builds on previous work and leverages new analysis to further deepen the understanding of the health impacts of climate change. It expands on an assessment conducted by the World Health Organization (WHO 2014) on the impacts of climate change on morbidity and mortality resulting from dengue, diarrhea, extreme heat, malaria, and stunting for the years 2030 and 2050.[2] This report adopts the same methodological approach as a starting point but extends the analysis in numerous directions as explained in Section 2 below.

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[2] WHO (2014) also included an analysis of the impacts of climate change on deaths resulting from floods. Floods are not included in the current analysis: the nature of the modeling required differs significantly from the modeling of the impacts of climate change on diseases.

2. Methods

2.1 Selection of Countries

The analysis presented in this report focuses on the LMICs of the six regions based on the World Bank Group's classification.[3] A total of 69 countries with a national population exceeding 10 million in the baseline year 2020 are included. The list of countries included in the analysis is provided in **Annex 1**. These 69 countries represent 96.2 percent of the total population of all LMICs.[4] When grouped by region, East Asia and Pacific (EAP) constitute 32.5 percent of this total population of LMICs, followed by South Asia (SA — 29.6 percent) and Sub-Saharan Africa (SSA — 17.0 percent).

This analysis is conducted at the country (national) level. As such, it does not capture subnational variability pertaining to climate projections, socioeconomic characteristics, and levels of health risks. The consequences of this constraint of the analysis are discussed further below.

2.2 Selection of Climate Scenarios

Climate data of relevance were obtained from the latest projections made available by the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6). These projections also formed the foundation of IPCC's AR6.

Furthermore, this analysis also relied on IPCC's shared socioeconomic pathways (SSPs) in combination with representative concentration pathways (RCPs) to illustrate potential climate futures. As such and for ease of use in this report, we refer to each specific combination of SSPs and RCPs as *climate scenarios*. For its preparation of the AR6, IPCC developed five SSPs — extending from SSP1 to SSP5. They represent socioeconomic narratives for possible 21st-century global developments in the absence of new climate policies. Each SSP depicts a different development storyline in terms of assumed population projections, economic growth, technological breakthroughs, and land use, among numerous other variables (Table 1).

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[3] The six regions are East Asia and the Pacific (EAP), Europe and Central Asia (ECA), Latin America and the Caribbean (LAC), Middle East and North Africa (MENA), South Asia (SA), and Sub-Saharan Africa (SSA).

[4] The total population of all LMICs in 2020 reached 6.6 billion.

Table 1. Shared Socioeconomic Pathways

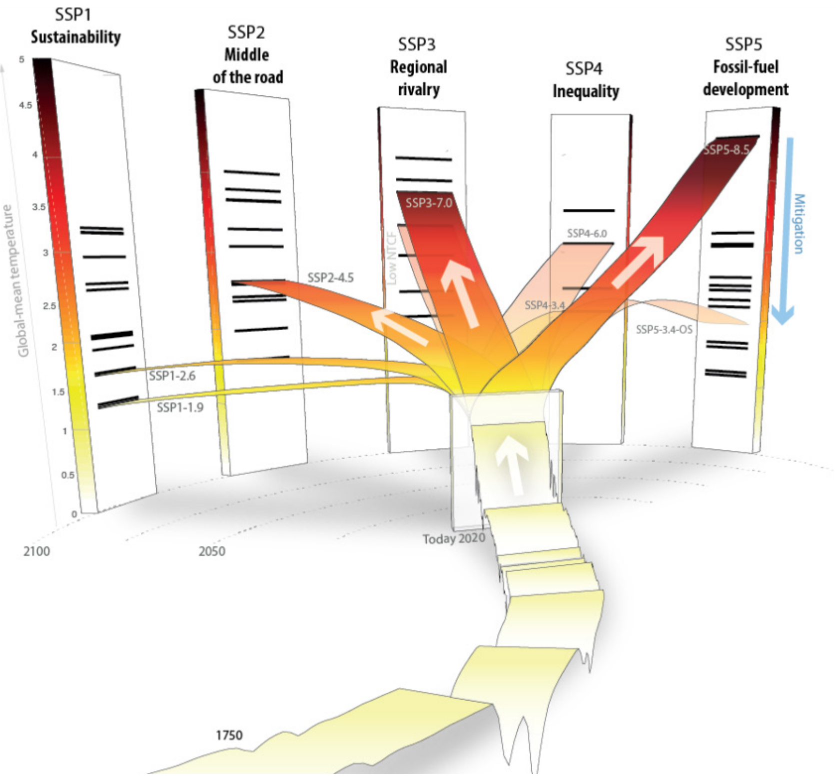
Pathway	Description	Development Storyline
SSP1	Sustainability	Population decline and significant economic growth with increased commitment to sustainable development
SSP2	Middle of the road	Moderate population and economic growth with slow progress toward the Sustainable Development Goals
SSP3	Regional rivalry	High population growth and limited economic growth with limited investments in human development
SSP4	Inequality	Moderate population growth and limited economic growth with unequal investments in human capital
SSP5	Fossil-fuel development	Population decline and significant economic growth with rapid technological progress, strong investments in human development, and exploitation of fossil fuel resources.

Projections of carbon dioxide (CO_2) are associated with each development pathway. For example, based on the development assumptions for SSP5, CO_2 emissions are expected to increase rapidly from the current 40 gigatons per year (Gt/yr) to approximately 130 Gt/yr by 2100. On the other hand, under both SSP1 and SSP2, emissions are projected to decline (starting almost immediately under SSP1 and around the mid-century under SSP2), reaching approximately 10 Gt/yr under SSP2 and negative values under SSP1. Under SSP3, emissions will double approximately in value from the existing level by 2100.

These emissions pathways are mapped onto RCPs, whose projected value of radiative forcing (measured in watts per square meter [W/m^2]) corresponds directly with CO_2 emissions levels. Higher levels of emissions lead to greater atmospheric concentration levels of greenhouse gases that, in turn, lead to higher levels of radiative forcing. The levels have a range of 1.9 to 8.5 W/m^2. The RCPs are numbered accordingly from RCP1.9 to RCP8.5 to reflect the projected value of radiative forcing.

Although five scenarios — SSP5-8.5, SSP3-7.0, SSP2-4.5, SSP1-2.6, and SSP1-1.9 — are explored in great detail in IPCC's AR6 (Figure 1), this assessment has selected SSP3–7.0 and SSP2-4.5 (henceforth, SSP3 and SSP2, for short) for analysis. These two scenarios represent middle-of-the-road development pathways between RCP8.5 (deemed to be a worst-case scenario) and the increasingly unlikely best-case scenarios (RCP2.6 and RCP1.9). The selected scenarios were used to project changes in socioeconomic conditions and climate conditions in each of the 69 countries included in the assessment. Additional details concerning SSPs and RCPs are provided in **Annex 2**.

Figure 1 SSPs and RCPs



Source: Meinshausen et al. (2020).

The assumptions about socioeconomic development contribute significantly to the estimates generated with and without climate change in order to clearly isolate the impact of climate change. Concomitantly, the selection of scenarios also has a substantial influence on the estimated health effects of climate change.

The choice of different scenarios also partially accounts for the differences between the results presented in this analysis and previous modeling efforts. For example, Carleton et al. (2022) used climate projections from the combination of RCP4.5 and 8.5 with SSP2, SSP3, and SSP4, while WEF (2024) used the sole combination of SSP2-6.0 for its study.

WHO (2014) — to which this analysis is most closely related — employed a single emissions scenario, known at the time as SRES A1b, from the Special Report on Emissions Scenarios (SRES). The A1 family of scenarios assumes a future world of very rapid economic growth (all other things being equal, rapid economic growth results in a smaller number of cases of health risks), a global population that increases until the mid-century and declines thereafter, and perhaps, more importantly, the rapid introduction of new and more efficient technologies. The subset, A1b, further assumes the balanced use of all fossil-intensive and non-fossil energy sources (IPCC 2000). At the time of the WHO assessment, only three general circulation models were used to provide climate projections.[5] As indicated in WHO (2014), "[n]ew post-SRES emissions scenarios (Representative Concentration Pathways) were developed for the IPCC fifth assessment report, but scenario data for these were not available at the time (…)" (p. 99). While WHO (2014) did use the best available information at the time, the A1b SRES scenario, in retrospect, may be overly optimistic, with pre-CMIP6 climate projections currently outdated.

2.3 Modeling and Analytical Approach

As mentioned previously, this assessment closely follows and builds on the methodology and modeling developed by WHO (2014) to estimate climate-related impacts on health. Key similarities and differences between the methodological approach described below and that of WHO (2014) are summarized in Table 2.

Table 2. Comparative Analysis of Approaches: WHO (2014) and This Report

Parameters	WHO (2014)	This Report
Health risks	Dengue, diarrhea, extreme heat, malaria, stunting, and coastal flooding	Dengue, diarrhea, extreme heat, malaria, and stunting
Climate scenarios	SRES A1b (from the Special Report on Emissions Scenarios published in 2000)	SSP3-RCP7.0 and SSP2-RCP4.5 (from IPCC's AR6 of 2021)
Baseline year	2000	2020
Time horizon	2030, 2050	2030, 2050, 2100
Countries	All countries of the WHO regions	69 LMICs with populations greater than 10 million in all six regions of the World Bank
Malaria	Statistical modeling: Strictly monotonic increase with temperature	Statistical modeling: Inverted U-shape as a function of temperature
Malaria fatality rate	No modeling of malaria fatality rate	Malaria fatality modeled as a function of GDP per capita and female education
Dengue	Spline function: Monotonic increase with temperature-precipitation	Spline function: Inverted U-shape as a function of temperature-precipitation
Stunting estimates	Stepwise approach based on establishing a correlation between climate change and undernutrition	2030 and 2050 using the WHO estimates; 2100 using income elasticity due to lack of data

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[5] These models were BCM (from the Bjerknes Centre for Climate Research, University of Bergen, Norway), EGMAM (from the Freie Universitaet Berlin, Institute for Meteorology, Berlin, Germany), and CM4v1 (from the Institut Pierre Simon Laplace, Paris, France).

Parameters	WHO (2014)	This Report
Extreme heat	Statistical modeling	Same as WHO
Diarrhea	Statistical modeling	Same as WHO
Economic assessment	No	Yes

Estimating the Impacts of Climate Change on Morbidity and Mortality

Modeling

The analysis presented in this report utilized individual models to estimate the impacts of climate change on morbidity and mortality for each health risk. Except for stunting, statistical models were used to estimate the future number of cases for each health risk in each country and the year of interest. For stunting, the assessment used regional stunting data for cases and deaths due to climate change from WHO (2014) to derive country-level data. The individual statistical models used for dengue, malaria, diarrhea, and extreme heat, as well as the model used to derive data for stunting, are described in detail in **Annex 3**.

Calculating the Number of Cases and Deaths

Except for stunting, estimates of the future likelihood (probability) of diseases were obtained using socioeconomic and climate projections from the datasets described later in this section. The estimated future likelihood levels were then applied to the national country populations projected under the relevant SSP scenario to estimate morbidity levels in each country in the years 2030, 2050, and 2100.

For dengue and malaria, fatality rates (number of deaths per case of each disease) were calculated for the base year 2020. In the first version of this analysis, it was assumed that the fatality rates of dengue and malaria would remain constant over 2020–2100, in line with the WHO (2014) approach. In this updated analysis, a model was developed to estimate malaria fatality rates for 2030, 2050, and 2100 based on GDP per capita; a proxy for socioeconomic development that is assumed to be negatively correlated with fatality rates; and female education, which has been shown to be negatively associated with the likelihood of mortality from extreme weather events

(Blankespoor et al. 2010). Although a similar model was tested for dengue, the results were inconclusive;[6] thus, a constant fatality rate was assumed for 2020, 2050, and 2100. Details are presented in **Annex 4**. For stunting, the analysis used estimates from WHO (2014) for 2030 and 2050 and followed the WHO (2014) approach to derive estimates for the year 2100.

The estimates provide a measure of the health impacts attributable to climate change. It is important to note that the modeling assumes no adaptation and does not include any assumptions about specific breakthroughs in vaccines, medicine, or increased coverage in protection measures. These were assumed to remain at the same level as the baseline year 2020.

Estimating the Number of Years of Life Lost from Climate Change

To estimate the number of years of life lost (YLL), the analysis first derived estimates of life expectancy for each of the 69 countries in the baseline year 2020 and then for 2030, 2050, and 2100. The life expectancy for any given country for 2020 was obtained from the World Bank's World Development Indicators database. To estimate the life expectancies for future years, the analysis relied on published literature from Kc and Lutz (2017).

Kc and Lutz (2017) outlined assumptions concerning the demographic and human capital components (specifically fertility, mortality, migration, and education) corresponding to each SSP to project national populations over time. In the case of mortality, SSP2 was characterized as a "medium" mortality scenario: life expectancy was assumed to increase by two years per decade. SSP3 was considered a "high" mortality scenario: life expectancy was assumed to increase by one year per decade. These assumptions for mortality were used to estimate life expectancies for all countries for the years 2030, 2050, and 2100.

Further assumptions were made for the different health risks. As mortality typically affects young children for stunting and diarrhea, the analysis assumed that the number of YLL is equal to the estimated life expectancy of every death associated with stunting and diarrhea for the purpose of simplification. Concerning extreme heat, the analysis adopted methods developed by WHO (2014): it assumed that the number of deaths between the expected life expectancy in the year of interest and 65 years would be uniformly distributed. For malaria and dengue, the analysis first

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[6] Coefficients were not statistically significant and the R2 coefficients were very low in all specifications. The further testing of various specifications, for example, by including the three levels of female education and testing non-linear and logistic regressions, also led to inconclusive results. A study by Ali (2024) showed a significant and positive correlation between mortality rates in the most recent dengue outbreak in Bangladesh with population density and air quality index. This finding could account for the lack of relationships among dengue, GDP per capita, and female education.

derived the distribution of mortality across the age groups for each country, followed by estimates of the number of deaths by age group to derive the number of YLL associated with these health risks. **Annex 5** provides a detailed description of the methods and calculations.

Estimating the Economic Cost of the Health Impacts of Climate Change

The analysis applied two approaches to estimate the economic cost associated with the health impacts of climate change: the first is based on the value of a statistical life (VSL), while the second is based on YLL. Both approaches include the cost of illness (COI). It is readily understood that the approach based on YLL will yield a lower estimate of the economic cost of climate change than the approach based on VSL, as the VSL does not account for the fact that certain diseases impact different cohorts of individuals (for example, the statistical modeling of extreme heat assumes an impact only on those above 65 years old).

Approach Based on VSL

The first approach to estimate the economic cost of mortality was the VSL. VSL serves as a measure of a population's willingness to pay for risk reduction and the marginal cost of enhancing safety. The use of VSL is a common approach in cost-benefit analyses to measure the economic benefit individuals receive from enhancements to their health and safety, and to assess the economic cost of premature deaths. Banzhaf (2022) provides a thorough review of the concept and of its use.

This approach estimated the national VSL with a benefit-transfer approach, using an estimated VSL of USD6 million in the United States as a starting point. To estimate country-specific VSL, the VSL in the base year 2020 was adjusted across each of the 69 countries to account for differences in GDP per capita across the countries in 2020, assuming an income elasticity of one. Once a VSL was estimated for 2020 for any given country, the VSL for 2030, 2050, and 2100 was then calculated by multiplying the 2020 estimated VSL with the ratio of GDP per capita in 2030, 2050, and 2100 to GDP per capita in 2020. Annex 6 outlines the approach in detail, provides the equations used, and presents the estimated values of VSL for all 69 countries and both SSPs for 2020 (baseline), 2030, 2050, and 2100.

Approach Based on YLL

A noted drawback of the VSL approach is that it does not explicitly account for the fact that various diseases impact individuals in different age groups. For example, mortality from diarrhea is known to be more significant for young children and infants, while heat-related mortality impacts mostly older individuals. The use of YLL allows for such control. As a result, the economic cost of mortality is lower using YLL than VSL. This approach measured the economic cost of climate-associated health impacts solely on mortality by multiplying the estimated YLL in any given country in 2030, 2050, and 2100 by the average annual VSL in the same country for the same years. **Annex 6** provides further details and the equation used.

Estimating COI

The value of COI is specific to diseases, country, and time. Numerous studies provide COI estimates for malaria (mostly in the SSA countries) and for dengue (mostly in the countries of Asia and Latin America).

In the case of malaria, excellent reviews of studies are provided in Devine et al. (2019) and Andrade et al. (2022). Specific estimates of COI for malaria are available for Burkina Faso (Duval et al. 2022), Gambia (Duval et al. 2022), Ghana (Dalaba et al. 2018), India (Singh et al. 2019), Kenya (Ayieko et al. 2009; Chuma et al. 2010), Malawi (Hennessee et al. 2017), Mozambique (Alonso et al. 2019), Myanmar (Cho and Gatton 2004), Nigeria (Ezenduka et al. 2017; Onwujekwe et al. 2013; Salawu et al. 2016), and Sri Lanka (Attayanake et al. 2000), among others. For this analysis, we used the aforementioned estimates when country-specific COIs were available. However, as all these studies were conducted prior to 2020—the base year used in this analysis, the COI values provided in the various papers were adjusted for 2020 using the national consumer price index.

For both stunting and extreme heat, the estimated economic costs include only the economic cost of mortality, not the economic cost of morbidity, as estimates of COI for stunting and extreme heat were not available. Information from the literature to derive COI for developing countries on stunting and extreme heat was very limited. For the purpose of estimating the morbidity cost arising from diarrhea, it was determined that only 0.5 percent of all cases of diarrhea require treatment (Lamberti et al. 2012).

When original COI estimates are not available for any given country, national COI values were estimated by using the benefit-transfer approach, which was adjusted for differences in the GDP per capita (similar to the approach for estimating the country-specific VSL). The COI values of 2020 for any given country were estimated for the years 2050 and 2100.

The COI estimates are included in both the VSL and YLL approaches to estimating the cumulative economic cost. The cumulative economic cost of cases and deaths was estimated for 2030, 2050, and 2100 in relation to its value as a percentage of GDP. Estimated economic costs are presented in dollars for the year of interest in real terms, not in present-value terms.

Estimated values of COI for all 69 countries and both SSPs for 2020 (baseline), 2030, 2050 and 2100 are presented in **Annex 6** for dengue, malaria, and diarrhea.

2.4 Data

Socioeconomic, climate, and health data were used to assess the impacts of climate change on the number of cases and deaths related to the health risks included in this analysis.

Socioeconomic data for the year 2020 (demographic and economic) were obtained from the World Development Indicators. Socioeconomic data for the years 2030, 2050, and 2100 for both SSP scenarios were obtained from the SSP website.[7]

Mortality rates for SSP2 and SSP3 were derived from the World Population Prospects 2022 web page of the UN Department of Economic and Social Affairs Population Division.[8]

Climate data (namely precipitation levels and temperatures) were obtained through the World Bank's (2021) Climate Change Knowledge Portal (CCKP).[9] For each climate variable, under each time period and each development scenario, projections were made available from the multi-model ensemble developed under CMIP6, resulting in a probability distribution of projections. CCKP makes available values for the 10th percentile, median, and 90th percentile of the probability distribution. This study used the national median value.

Finally, health data on the global burden of disease were obtained from the Institute for Health Metrics and Evaluation's (2024) Global Health Data Exchange website for the years 2019 and 2020.[10] On some occasions, the year 2019 was selected as the baseline due to insufficient data as a consequence of the COVID-19 pandemic during the year 2020. The cyclical nature of some risk factors (for example, dengue) demands that a 10-year average be used to estimate values for the baseline year 2020, instead of a single year.[11]

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[7] IIASA (International Institute for Applied Systems Analysis), 2018, SSP Database (Shared Socioeconomic Pathways) — Version 2.0, December 2018, https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10.

[8] Department of Economic and Social Affairs Population Division, 2024, Mortality, https://population.un.org/wpp/Download/Standard/Mortality/.

[9] The World Bank Group, 2021, Climate Change Knowledge Portal, https://climateknowledgeportal.worldbank.org.

[10] IHME (Institute for Health Metrics and Evaluation), 2024, Global Health Data Exchange, https://ghdx.healthdata.org/.

[11] For example, Bangladesh experienced a high peak in the number of cases of dengue in 2019 (Ali 2024).

3. Impacts of Climate Change on Health and the Economic Cost of Inaction

3.1 Impacts of Climate Change on Health

This section presents the cumulative estimates of the impacts of climate change on morbidity and mortality for the selected health risks analyzed for the medium term (2026–2050). Supplementary estimates for the short term (2026–2030) and long term (2026–2100) are available in **Annex 7**.

Without decisive action, climate change will have a devastating impact on human health across LMICs, with SSA and SA bearing the brunt of these impacts. By 2050, climate change is projected to cause between 4.1 billion (SSP2) and 5.2 billion (SSP3) cases across LMICs (Table 3). SSA and SA will experience a disproportionate burden of these impacts. Under both scenarios, SSA will experience the majority (approximately 71 percent) of all cases, while SA will experience approximately 18 percent of all cases. The impact of climate change on mortality is equally stark (Table 4). By 2050, the number of deaths caused by climate change could reach between 14.5 million (SSP2) and 15.6 million (SSP3). The se impacts will be the greatest in SSA and, to a lesser extent, SA and EAP. SSA is projected to experience between 6.8 million (SSP2) and 7.8 million deaths (SSP3), accounting for roughly one-half of all deaths under both scenarios. SA will experience roughly one-quarter of all deaths under both scenarios, while EAP will experience between 21 percent (SSP3) and 24 percent (SSP2) of all deaths.

Table 3. Cumulative Number of Cases Attributable to Climate Change: 2026–2050

	SSP3 (million)	SSP2 (million)
EAP	240.6	186.1
ECA	60.0	29.6
LAC	151.1	95.1
MENA	147.0	72.3
SA	944.4	733.8
SSA	3,640.1	2,991.2
Total	**5,183.1**	**4,108.1**

Table 4. Cumulative Number of Deaths Attributable to Climate Change: 2026–2050

	SSP3 (thousands)	SSP2 (thousands)
EAP	3,234.7	3,413.3
ECA	149.2	136.2
LAC	271.2	273.5
MENA	226.2	159.7
SA	3,982.9	3,677.0
SSA	7,753.8	6,813.3
Total	**15,618.0**	**14,473.0**

3.2 Economic Cost of Inaction

The projected impacts of climate change on health shown above will impose significant costs on LMICs. As discussed earlier, this assessment applied two approaches to estimate the economic costs arising from selected climate-related health risks. The first is the VSL approach, which assesses the economic cost of mortality. The second is the YLL approach, which is based on monetizing the number of YLL by multiplying the estimated number of YYL in any given country by the average VSL in the same country. Both approaches include the estimated COI.[12] The application of these two approaches provides a range of estimated economic costs. This section presents estimates of the economic costs arising from the impacts of climate change on health for the medium term (2026–2050). Supplementary estimates for the short term (2026–2030) and long term (2026–2100) are available in **Annex 8**.

By 2050, the economic cost of the health impacts of climate change may well reach and surpass USD20.8 trillion across LMICs, with SSA and SA suffering significantly higher costs as a share of GDP. Under SSP3, the economic cost of health impacts attributable to climate change is estimated to reach between USD8.6 trillion (YLL approach) and USD15.4 trillion (VSL approach) by 2050 (Table 5). These costs amount to approximately 0.7 percent and 1.2 percent of the GDP of LMICs under the YLL and VSL approaches, respectively. The estimates are moderately

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[12] Two types of results may be expected when these approaches are applied. First, all other things being equal. Second, all other things being equal, the economic cost of climate change will be higher in upper-middle-income countries relative to lower-middle-income countries and higher in lower-middle-income countries relative to low-income countries. This is simply because both VSL and COI are higher in upper-middle-income countries than in the countries under the other two income levels in this analysis.

higher under SSP2, reaching between USD11.0 trillion (YLL approach) and USD20.8 trillion (VSL approach) by 2050, equivalent to 0.7 percent and 1.3 percent of the GDP in LMICs, respectively.[13] A larger share of this economic cost will arise in EAP and, to a lesser extent, in SA and SSA (Figure 2). The higher VSL and COI in EAP reflect the higher cost in this region, despite the absolute number of cases and deaths from climate change being higher in SSA.

Nonetheless, SSA will bear a significantly heavier economic burden than any other region, amounting to between 2.7 percent (YLL approach) and 3.6 percent (VSL approach) of the regional GDP under both scenarios. The economic cost for SA — amounting to between 1.2 percent (YLL approach) and 2.6 percent (VSL approach) of regional GDP under both SSP2 and SSP3 — will also be significant.

Table 5. Cumulative Economic Cost of the Health Impacts of Climate Change: 2026–2050

	SSP3				**SSP2**			
	YLL		**VSL**		**YLL**		**VSL**	
	Cost (Billions USD)	**Share of GDP (%)**	**Cost (Billions USD)**	**Share of GDP (%)**	**Cost (Billions USD)**	**Share of GDP (%)**	**Cost (Billions USD)**	**Share of GDP (%)**
EAP	3,338.0	0.46	6,036.4	0.83	4,540.1	0.51	8,389.6	0.94
ECA	101.9	0.10	491.8	0.47	70.8	0.06	530.2	0.43
LAC	285.3	0.19	588.3	0.40	338.3	0.20	763.3	0.45
MENA	98.7	0.18	246.8	0.44	65.8	0.11	233.2	0.38
SA	2,278.8	1.27	4,601.7	2.56	2,749.8	1.19	6,355.9	2.76
SSA	2,546.7	2.73	3,398.4	3.64	3,192.6	2.61	4,482.8	3.66
Total	**8,649.5**	**0.66**	**15,363.4**	**1.17**	**10,957.4**	**0.68**	**20,755.1**	**1.30**

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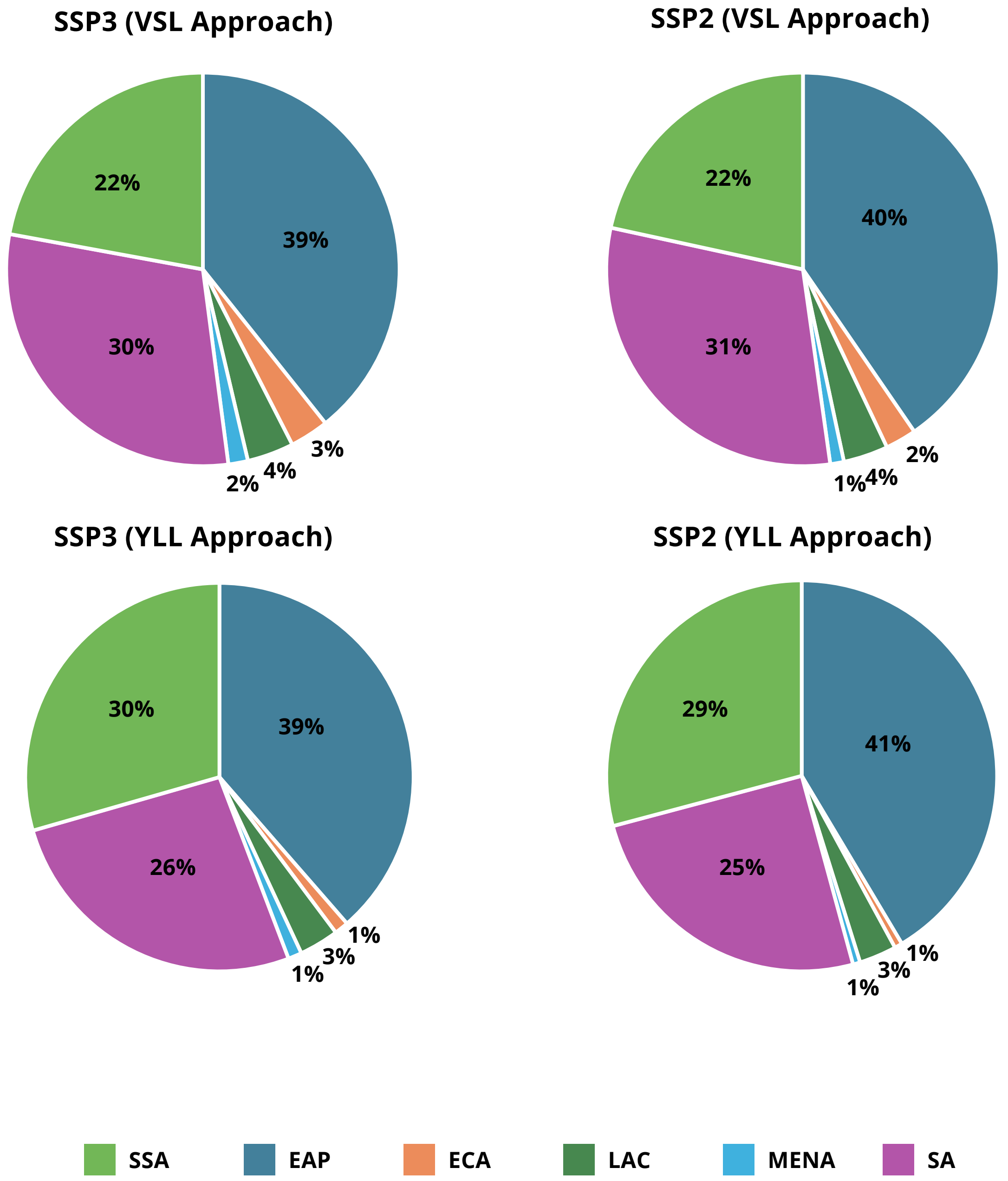
[13] Estimated costs are higher under SSP2 despite the higher number of cases and deaths under SSP3 than under SSP2. This is due to the assumption of significantly higher GDP under SSP2, which leads to higher VSL and COI figures under SSP2.

Figure 2. Distribution of the Economic Cost of the Health Impacts of Climate Change Across Regions: 2026–2050



4. Discussion

Using the latest available climate data (CMIP6) and socioeconomic data as modeled under SSP3 and SSP2, this report provides updated estimates of the impacts of climate change on the number of deaths and cases linked to selected health risks. It also presents estimates of the economic costs associated with these health impacts, illustrating the critical costs of inaction on climate change in LMICs. It is important to note that these estimates should not be interpreted as "predictions" or "best guesses" of what a future without climate action may look like. The estimates are conditional to the socioeconomic projections of specific SSPs, which are plausible (and not necessarily equally likely) storylines of global socioeconomic and technological development trajectories.

4.1 Summary of Key Findings

The main findings are as follows:

Without bold and decisive action, climate change will have a dire impact on health in LMICs. By 2050, climate change will cause between 4.1 billion (SSP2) and 5.2 billion (SSP3) cases and between 14.5 million (SSP2) and 15.6 million (SSP3) deaths across LMICs. SSA and SA will bear the brunt of these impacts, experiencing nearly one-half and one-quarter of all deaths caused by climate change, respectively, under both climate scenarios.

The health impacts of climate change presented in this report, though significant, are likely to be only the tip of the iceberg. This is because the assessment includes the potential impacts of climate change on only five selected health risks; other health risks, such as non-communicable diseases and mental health, are not included in this study. In addition, this assessment covers only a subset (69) of all developing countries. The analysis also does not consider the change in the geographical trajectory of these health risks because factors, such as migration and water stress, can only be captured through a dynamic model. Consequently, the results presented here should be understood as a notable underestimate of the scale of the real impacts of climate change on health.

In the absence of strong mitigation and adaptation measures, the economic cost arising from the health impacts of climate change in the LMICs could reach and likely surpass USD21 trillion by 2050. This report finds that the economic cost is projected to reach between USD8.6 trillion (YLL approach) and USD15.4 trillion (VSL approach) under SSP3. The estimated economic cost is higher under SSP2, reaching between USD10.9 trillion (YLL approach) and USD20.8 trillion (VSL approach). These figures would amount to approximately 0.7 percent and 1.3 percent of the GDP of the LMICs, respectively.

The findings of this report confirm the IPCC's AR6 reporting of a projected significant increase in disease burden and associated mortality due to climate change. This assessment also verifies the uneven geographical distribution of this future burden, with SSA and, to a lesser extent, SA bearing the brunt of the projected increases in illnesses and deaths. SSA will face a significantly higher cost than other regions, amounting to between 2.7 percent (YLL approach) and 3.6 percent (VSL approach) of regional GDP by 2050, regardless of the socioeconomic development scenarios. These results provide considerable empirical support for the urgent call for action to tackle the health impacts of climate change, particularly in these two regions.

4.2 Comparison of Findings with Key Literature

The findings presented in this report are assessed in comparison to other estimates of the health impacts of climate change, particularly the projections from the 2014 WHO analysis as well as other recent global studies utilizing alternative modeling approaches.

WHO (2014) — whose methodology serves as a basis for the current analysis — estimated that climate change would take the lives of an additional 250,000 per year due to infectious diseases, undernutrition, diarrhea, heat stress, and flooding over 2030–2050. However, we find this earlier result to be a significant underestimate of the potential impacts of climate change on mortality over this period. The estimates from this assessment suggest approximately 0.8 million deaths per year on average over the same period. Among the numerous factors contributing to this difference (as summarized in Table 2), a key factor is that WHO (2014) used datasets available in 2010 and 2011 for its projections of socioeconomic variables (population and GDP),[14] while the present study drew on the more recent SSP framework for this purpose.

Other models utilize different approaches to estimate the climate-driven health impacts. Integrated assessment models (IAMs) used to estimate the social cost of carbon[15] include modeling approaches to project future climate-driven health impacts. However, these approaches have been criticized for relying on outdated data and providing human mortality impacts that "do not reflect the latest scientific understanding" (Bressler et al., 2021). Based on a comparison of climate-driven mortality estimates from vector-borne diseases and diarrhea derived from WHO (2014) and those from one such IAM (the Climate Framework for Uncertainty, Negotiation and Decision – FUND) for

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[14] Population projections used the medium variant of the UN 2010 population projections (UN 2011). Projections of economic growth used 2010 and 2011 datasets made available by the World Bank, the International Monetary Fund, and the Organisation for Economic Co-operation and Development (OECD).

[15] The social cost of carbon quantifies the net cost of emitting one additional metric ton of carbon-dioxide-equivalent at a certain point in time.

2030 and 2050, Bressler et al. (2021) showed that FUND's estimates for vector-borne diseases were significantly lower in 2030 (more than 10-fold lower) and even more so by 2050 (more than 30-fold lower) than reported in WHO (2014). For diarrheal disease, FUND's estimates were similar to WHO's in 2030 but were half as large in 2050. Bressler et al. (2021) conclude that this disparity is likely due to larger income effects assumed in FUND, though lower sensitivity to temperature changes could not be ruled out. The results presented in the current assessment suggest that IAMs are significantly underestimating the climate-driven health impacts.

In recognizing the limitations of IAM models to estimate climate-driven mortality impacts, Bressler et al. (2021) produced country-level mortality damage functions for all countries globally by extrapolating mortality projections from temperature-related mortality (heat and cold) from a large epidemiological study.[16] The mortality estimates derived from this study for 2050 due to the direct impacts of cold and heat were nine times larger than WHO's estimates for deaths due to vector-borne diseases and diarrhea, further underscoring the point that the estimates provided by this study are likely only the tip of the iceberg given the focus on only selected climate and health impact pathways.

The World Economic Forum recently presented estimates of the impacts of "climate events" (floods, droughts, heat waves, tropical storms, wildfires, and sea-level rises) on morbidity and mortality (WEF 2024). These impacts of climate events were assessed under SSP2-6.0 scenario. The findings of the analysis showed that by 2050, climate change is likely to cause an additional 14.5 million deaths (WEF 2024). Given the nature of the "climate events" included in the WEF (2024) analysis, results cannot be immediately compared to those obtained in this analysis. However, barring significant overlaps, it may be more appropriate to think of climate events resulting in 14.5 million deaths in addition to climate change resulting in an additional 15.6 million deaths from the selected health risks included in this analysis.

WEF (2024) further reports that climate change is likely to cause an additional $12.5 trillion in economic losses. This economic impact is measured as the sum of the productivity loss caused by the increase in detrimental health outcomes, and the cost of treatment – a measure generally close to the COI approach. It is of interest to note that VSL is not used as a measure of mortality cost in the study. This alone would tend to provide lower estimates of the economic cost of the impacts of climate change on health.

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[16] Gasparrini et al. 2017.

Carleton et al. (2022) estimated the impact and economic cost of projected rising temperature on mortality under various combinations of SSPs and RCPs. The study used VSL to convert projected changes in mortality rates into dollars. This VSL was then transformed into a value per life-year lost to allow computing the total value of expected life-years lost due to climate change, accounting for different mortality-temperature relationships across age groups. The VSL is allowed to vary with income, using an income elasticity of one to adjust the U.S. estimates of the VSL to different income levels across the world and over time. The economic valuation approach used in in Carleton et al. (2022) and in this report are similar. Also, while limited to the sole impact of temperature rise on mortality, Carleton et al. (2022) estimates that the mean global increase in the mortality risk due to climate change could amount to 3.2 percent of global gross domestic product (GDP) in 2100.

The Lancet Commission on Investing in Health recently recognized that climate change will conceivably have large consequences for human mortality – albeit of an uncertain magnitude, especially in the long run (Jamison et al. 2024). The results presented in this report support this claim and calls for urgent action to address the climate-health crisis.

4.3 Study Caveats

There are several caveats to this assessment that are important to highlight.

First, this assessment modeled the relationship between temperature and precipitation and morbidity and mortality for only selected health risks. There are many additional causal pathways between climate change and health, both direct and indirect, that are not considered by this analysis. These include the health impacts arising from extreme weather events, other climate-sensitive diseases, and climate-induced migration and conflict, among others.

Second, the analysis does not explicitly account for the characteristics of different geographies that may impact infectious disease transmission (such as population density and altitude). Nor does it consider the projected change in the geographical trajectory of the modeled health risks as a result of either (or both) changes in climate conditions or the migration of populations, including urbanization, as a response to climate change.

Third, the modeling used to estimate morbidity and mortality from infectious diseases is also static in nature. As such, it does not account for the dynamic effects between the vector and human populations or the seasonal/year-to-year variability in transmission. While such modeling is challenging to do at a global scale, capturing such dynamics could be done at the national or subnational levels, with dynamic modeling that explicitly captures changes in vector and other pathogen populations and other dynamics.[17]

Fourth, the health impacts of climate change were derived from the use of estimated statistical models that are based on exposure-response functions (that is, by associating temperature and precipitation with health outcomes). These functions are primarily based on current and historical data associations between climate change and health impacts. Therefore, they do not account for potential future individual (including physiological) and systemic adaptations to climate change or specific national and subnational climate and socioeconomic conditions. While the assessment infers future societal adaptative capacity using plausible SSP scenarios by accounting for socioeconomic factors such as demographic change, economic growth, human development, and technological progress, there remain significant uncertainties concerning what a future without climate action would look like.

Fifth, the analysis utilizes modeled data for the baseline morbidity and mortality estimates, which inherently include uncertainties. Furthermore, there is a lack of data from the literature to allow us to derive COI estimates for stunting and extreme heat. Therefore, the estimated economic costs derived from this study are likely to be an underestimate even beyond the likely underestimates of the burden of disease.

Lastly, the methodology based on which this analysis is conducted relies on VSL estimates extrapolated from the United States, adjusted for GDP per capita, due to a lack of data from LMICs. While common in the literature, a noted limitation is that this approach does not account for the potential impacts of variables other than differences in GDP per capita in the measurement of country-specific estimates of VSL Furthermore, VSL is often critiqued for its reliance on assumptions that may not fully reflect individual preferences or behaviors. Despite these challenges, VSL remains a practical tool for policymakers, offering a way to quantify trade-offs between mortality risk reductions and regulatory costs, though it requires careful consideration of ethical and context-specific factors to enhance its applicability and acceptance. Recognizing these limitations, this study also employed the use of the YLL methodology in its analysis to provide a range of economic impacts.

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[17] For example, Servadio et al. (2018) found that warming at lower temperatures in South and Southeast Asia may increase vector and pathogen proliferation while warming at higher temperatures may decrease vector-borne disease outbreaks. Such effects cannot be captured when modeling is taking place at national levels.

4.4 Policy Implications and Future Directions

Despite the above limitations, this report provides significant findings that underscore the need for urgent action to address the climate-health crisis. It has demonstrated the urgency of the issue by showing that a substantial number of people will suffer and die due to climate-sensitive diseases in the near future. Urgent and scaled-up action is needed to transition to low-carbon care pathways and strengthen the capacity of health systems and communities to prevent, detect, and respond to climate-related health threats. Such action will require significant financing and investment in health systems. However, the cost of inaction is far higher. Therefore, it is crucial that policymakers and development partners — both in LMICs and globally — work to increase health financing to address the climate and health crisis. A key step toward this objective is ensuring that health adaptation is prioritized in national adaptation agendas.

It must be clearly stated that this report does not advocate for a vertical disease approach to the selected health risks included in the analysis. Instead, it calls for a health systems approach to effectively and efficiently tackle the projected impacts of climate change on health.

As this report is limited to identifying and assessing the impacts and economic costs of climate change on health, it does not, as such, provide an assessment of the costs and benefits of alternative actions aimed at mitigating these impacts. An immediate next step should thus be aimed at providing guidance on how the climate resilience of the health sector can be enabled.

Annexes

Annex 1. Countries Included in the Analysis

Table A.1 LMICs Included in the Analysis

Region[a]	Countries	Population (in 2020)[b]	Income classification[c]
East Asia and Pacific (EAP) **8 countries**	China	1,411,100,000	UM
	Indonesia	271,857,970	LM
	Philippines	112,190,977	LM
	Viet Nam	96,648,685	LM
	Thailand	71,475,664	UM
	Myanmar	53,423,198	LM
	Malaysia	33,199,993	UM
	Cambodia	16,396,860	LM
	Total — EAP	**2,066,293,347**	
Europe and Central Asia (ECA) **7 countries**	Russian Federation	144,073,139	UM
	Turkey	83,384,680	UM
	Ukraine	44,132,049	LM
	Uzbekistan	34,232,050	LM
	Romania	19,265,250	UM
	Kazakhstan	18,755,666	UM
	Azerbaijan	10,093,121	UM
	Total — ECA	**353,935,955**	

Region[a]	Countries	Population (in 2020)[b]	Income classification[c]
Latin America and Caribbean (LAC) **12 countries**	Brazil	213,196,304	UM
	Mexico	125,998,302	UM
	Colombia	50,930,662	UM
	Argentina	45,376,763	UM
	Peru	33,304,756	UM
	Venezuela	28,490,453	UM
	Ecuador	17,588,595	UM
	Guatemala	16,858,333	UM
	Bolivia	11,936,162	LM
	Haiti	11,306,801	LM
	Dominican Republic	10,999,664	UM
	Honduras	10,121,763	LM
	Total — LAC	**576,108,558**	
Middle East and North Africa (MENA) **9 countries**	Egypt	107,465,134	LM
	Iran	87,290,193	LM
	Algeria	43,451,666	LM
	Iraq	42,556,984	UM
	Morocco	36,688,772	LM
	Yemen	32,284,046	L
	Syria	20,772,595	L
	Tunisia	12,161,723	LM
	Jordan	10,928,721	UM
	Total — MENA	**393,599,834**	
South Asia (SA) **6 countries**	India	1,396,387,127	LM
	Pakistan	227,196,741	LM
	Bangladesh	167,420,951	LM
	Nepal	29,348,627	LM
	Afghanistan	38,972,230	L
	Sri Lanka	21,919,000	LM
	Total — SA	**1,881,244,676**	

Region[a]	Countries	Population (in 2020)[b]	Income classification[c]
Sub-Saharan Africa (SSA) **27 countries**	Nigeria	208,327,405	LM
	Ethiopia	117,190,911	L
	Congo	92,853,164	L
	Tanzania	61,704,518	LM
	South Africa	58,801,927	UM
	Kenya	51,985,780	LM
	Sudan	44,440,486	L
	Uganda	44,404,611	L
	Angola	33,428,486	LM
	Ghana	32,180,401	LM
	Mozambique	31,178,239	L
	Madagascar	28,225,177	L
	Cote d'Ivoire	26,811,790	LM
	Cameroon	26,491,087	LM
	Niger	24,333,639	L
	Burkina Faso	21,522,626	L
	Mali	21,224,040	L
	Malawi	19,377,061	L
	Zambia	18,927,715	LM
	Chad	16,644,701	L
	Somalia	16,537,016	L
	Senegal	16,436,120	LM
	Zimbabwe	15,669,666	LM
	Guinea	13,205,153	L
	Rwanda	13,146,362	L
	Benin	12,643,123	LM
	Burundi	12,220,227	L
	Total — SSA	**1,079,911,431**	
69 countries	**Total all regions**	**6,351,093,801**	
18 countries	**Total L countries**	**608,532,284**	
31 countries	**Total LM countries**	**3,296,182,540**	
20 countries	**Total HM countries**	**2,446,378,977**	

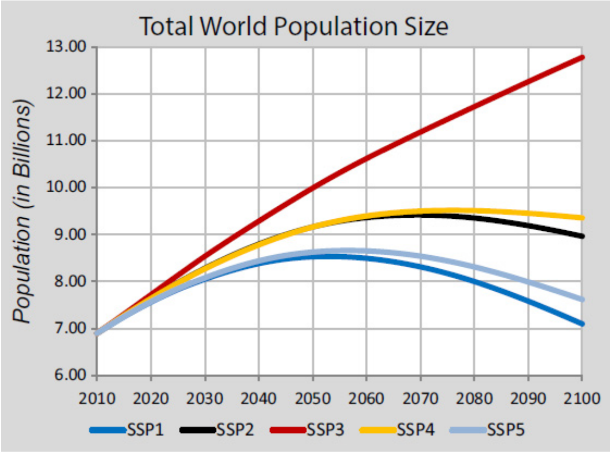
a Regional grouping of countries according to the World Bank. **b** Source: World Bank Development Indicators. **c** Income classification according to the World Bank: L = Low-income countries; LM = Lower-middle-income countries; UM = Upper-middle-income countries.

Annex 2. SSPs and RCPs

The five core SSPs developed by the IPCC represent socioeconomic narratives for possible 21st-century global developments in the absence of new climate policies. Each SSP depicts a different development storyline—in terms of assumed population projections, economic growth, technological breakthroughs, and land use among numerous other variables.

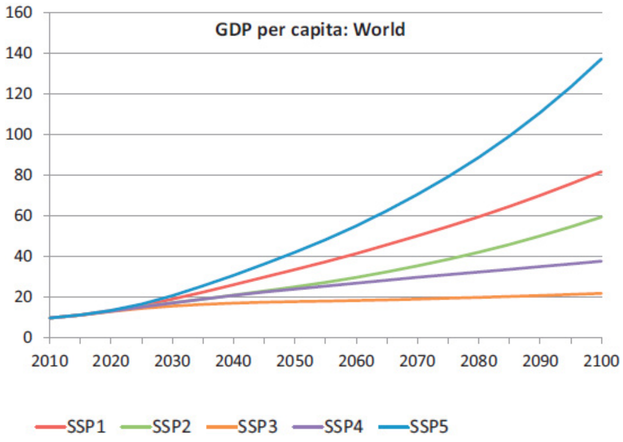
For example, SSP3 assumes high population growth (Figure A.1) and limited economic growth (Figure A.2). From the point of view of both mitigation and adaptation, SSP3 represents a challenging development scenario (a large population with relatively low income on average). Investments in education and health are low, with countries finding it difficult to sustain living standards and provide access to safe water, improved sanitation, and healthcare for marginalized populations. SSP2, occasionally referred to as the "middle-of-the-road" scenario (Riahi et al. 2017), is characterized by moderate population and economic growth. Progress toward achieving sustainable development goals—including improved living conditions and access to education, safe water, and health care—is slow under SSP2. SSP1 represents a sustainable development path, whereby populations decline rapidly and economies grow significantly over 2050-2100. Population decline, combined with relatively high income per capita, would facilitate the mitigation of greenhouse gases and adaptation.

Figure A.1 Population Growth under SSPs



Source: Kc and Lutz (2017)

Figure A.2 Economic Growth under SSPs



Source: Dellink et al. (2017)

The projected total regional populations under both SSP2 and SSP3 are reported in Table A.2. Observe that population estimates are significantly higher under the SSP3 pathway. Also note that while the population of SA is approximately twice the population of SSA in the baseline year 2020, the populations of these two regions are almost identical by 2100.

Table A.2 Total Projected Regional Population

	2020	2030	2050	2100
Regions	**SSP3**			
EAP	2,066,293,347	2,107,858,206	2,099,259,189	1,910,123,444
ECA	354,686,703	356,292,237	373,265,466	436,905,985
LAC	576,108,558	652,030,921	766,679,648	975,957,701
MENA	393,599,834	441,079,207	567,696,140	847,697,265
SA	1,881,244,676	2,175,760,563	2,718,675,735	3,731,808,658
SSA	1,079,911,431	1,319,304,138	1,967,870,576	3,450,632,176
Regions	**SSP2**			
EAP	2,066,293,347	2,165,263,367	1,987,146,447	1,385,022,963
ECA	354,686,703	359,816,074	363,879,772	313,251,233
LAC	576,108,558	627,901,155	667,314,762	606,546,778
MENA	393,599,834	415,875,700	489,855,010	520,993,748
SA	1,881,244,676	2,065,822,726	2,371,640,671	2,284,337,526
SSA	1,079,911,431	1,244,738,245	1,686,342,599	2,296,139,696

The projected total regional GDPs under both socioeconomic development pathways are reported in Table A.3. Note that the regional GDPs are significantly higher under SSP2 than under SSP3 for all regions.

Table A.3 Total Projected Regional GDP (Trillion USD)

	2020	2030	2050	2100
Regions	**SSP3**			
EAP	17.397	26.201	33.846	39.113
ECA	2.879	3.768	4.917	7.761
LAC	3.861	5.162	7.169	12.851
MENA	1.185	1.716	3.035	7.417

	2020	2030	2050	2100
Regions		**SSP3**		
SA	3.483	5.617	9.579	21.344
SSA	1.596	2.527	5.486	26.497
Regions		**SSP2**		
EAP	17.397	29.948	44.989	64.840
ECA	2.879	4.087	6.128	10.822
LAC	3.861	5.412	8.741	21.047
MENA	1.185	1.736	3.550	11.259
SA	3.483	6.046	13.847	47.055
SSA	1.596	2.721	8.016	65.292

Projections of carbon dioxide (CO_2) are associated with each development pathway. For example, based on the development assumptions for SSP5, CO_2 emissions are expected to increase rapidly from the existing 40 gigatons per year (Gt/yr) to reach approximately 130 Gt/yr by 2100. On the other hand, under both SSP1 and SSP2, emissions are projected to decline (starting almost immediately under SSP1 and around the mid-century under SSP2), reaching approximately 10 Gt/yr under SSP2 and negative values under SSP1. Under SSP3, emissions will double approximately in value from the existing level by 2100.

These pathways are mapped onto RCPs, whose projected value of radiative forcing (measured in watts per square meter [W/m2]) corresponds directly with CO_2 emissions levels. Higher levels of emissions lead to greater levels of atmospheric concentration of greenhouse gases which in turn leads to higher levels of radiative forcing. The levels have a range of 1.9 to 8.5 W/m2. The RCPs are numbered accordingly from RCP1.9 to RCP8.5 to reflect the projected value of radiative forcing.

At first glance, it may seem as though there are a large number of possible combinations of SSPs and RCPs, leaving analysts with the freedom to combine any SSP with any RCP for modeling purposes. However, the following two issues should be noted:

First, as indicated earlier, any given SSP assumes a specific development pattern that, in turn, leads to a specific path of emissions, radiative forcing, and global warming. Simultaneously, while different SSPs can result in a different range of radiative forcing, some SSPs exclude the realization of some degrees of radiative forcing. As such, SSP1-7.0, SSP1-8.5, SSP3-1.9, SSP3-2.6, and SSP5-1.9 cannot exist, just as SSP5 is the only development narrative found to be consistent with the radiative forcing level of 8.5 W/m2 (Kriegler et al. 2017). Hence, the selection of climate projections (arising from the different degrees of radiative forcing) must be consistent with the selection of a socioeconomic development scenario that generates the quantity of CO_2 underlying the selected RCP.

Second and just as importantly, differences in the model outputs between RCPs with higher radiative forcing (for example, 8.5 or 7.0), when compared to model outputs arising from RCPs with lower radiative forcing (for example, 2.6 or 1.9), should not be interpreted as the benefits of greenhouse gas mitigation policies. As noted in Pielke (2021), although such comparisons are common in the literature, this is invalid because socioeconomic, technological, and biophysical assumptions differ considerably across RCPs (since RCPs emerge from SSPs).

In AR6, IPCC emphasizes five scenarios in its climate experiments: SSP5-8.5, SSP3-7.0, SSP2-4.5, SSP1-2.6, and SSP1-1.9. Two of those scenarios—SSP3 and SSP2—were retained for this assessment of the health impacts of climate change. These two scenarios represent middle-of-the-road development pathways between the worst-case (RCP8.5) and the increasingly unlikely best-case scenarios (RCP2.6 and RCP1.9).

Annex 3. Estimating the Impacts of Climate Change on Morbidity and Mortality

The individual models used to estimate the future number of cases for each health risk are presented below. In the case of dengue, malaria, diarrhea, and extreme heat, the values for the climate and socioeconomic exogenous variables in the statistical models projected to prevail in 2030, 2050, and 2100 in each of the SSPs, which are specific to each of the 69 countries for climate and socioeconomic conditions, are provided.

Dengue

The statistical model used a splined interaction among the annual mean temperature and the annual mean precipitation and a standalone variable of GDP per capita:

(1)

$$\mathrm{Ln}\left[\frac{\mathrm{P}_{\mathrm{Dengue}}}{(1-\mathrm{P}_{\mathrm{Dengue}})}\right] = \mathrm{Constant} + \mathrm{F}_{(\mathrm{Temperature,Precipitation})} + 0.059\mathrm{Ln}(\mathrm{GDP}_{\mathrm{pc}})$$

where

$\mathrm{P}_{\mathrm{Dengue}}$:	Probability of dengue transmission;
F:	Spline function;[18]
Temperature:	Annual average temperature;
Precipitation:	Annual total precipitation; and
$\mathrm{GDP}_{\mathrm{pc}}$:	Real GDP per capita measured in purchasing power parity terms.

Malaria

WHO (2014) used a statistical model in which the likelihood (probability) of malaria is a monotonically increasing function of both temperature and precipitation:[19]

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[18] The spline function is used to draw a risk function curve: it allows for a flexible relationship and interaction between climate factors (temperature and precipitation) and the probability of dengue transmission areas.

[19] In the context of specific national or subnational modeling efforts, statistical modeling can capture behavioral variables, such as the extent of the use of bed nets. Beloconi et al. (2023) provided an example of such modeling with data extracted from Siaya County, which is located on the shores of Lake Victoria, Kenya.

(2) $$\text{Logit(Malaria)} = \beta_0 + \beta_1 T_{\text{min}} + \beta_2 PR_{max} + \beta_3 \left(\text{GDP}_{\text{pc}}\right)^{0.5}$$

where

Logit(Malaria):	Probability of malaria;
T_{min}:	Mean temperature of the coldest month; and
PR_{max}:	Mean precipitation of the wettest month.

Previous malaria models have considered 30°C to be the maximum temperature suitable for malaria transmission (Mordecai 2013). However, recent research suggests that an ideal range of malaria transmission occurs between 25°C and 27°C. It also notes that malaria transmission drops off sharply at temperatures below 16°C and above 34°C, with rates of malaria transmission decreasing symmetrically outside the ideal range (Suh 2024; Yamba 2023). This is in line with the methodology of other studies that indicate an increase in temperatures, eventually resulting in a decrease in malaria transmission (Murdock 2016).

In light of these findings, the model presented in Equation (2) was modified to increase monotonically (at the rate at temperatures from 16°C to 25°C, plateau between 25°C and 27°C, and then decrease monotonically (at the same rate) at temperatures beyond 27°C. The likelihood (probability) of malaria was assumed to be nil for any temperature values lower than 16°C or above 34°C. In mathematical terms, the statistical model used in this paper is as follows:

(3)

$$\begin{aligned}
&\text{For } 16 \le T_{\text{min}} \le T_{\text{ideal}_{\text{lower}}}\text{:}\\
&\qquad \text{Logit(Malaria)} = \beta_0 + \beta_1 T_{\text{min}} + \beta_2 PR_{\text{max}} + \beta_3 \left(\text{GDP}_{\text{pc}}\right)^{0.5}\\
&\text{For } T_{\text{ideal}_{\text{lower}}} \le T_{\text{min}} \le T_{\text{ideal}_{\text{upper}}}\text{:}\\
&\qquad \text{Logit(Malaria)} = \beta_0 + \beta_1 T_{\text{ideal}_{\text{lower}}} + \beta_2 PR_{\text{max}} + \beta_3 \left(\text{GDP}_{\text{pc}}\right)^{0.5}\\
&\text{For } T_{\text{ideal}_{\text{upper}}} \le T_{\text{min}} \le 34\text{:}\\
&\qquad \text{Logit(Malaria)} = \beta_0 + \beta_1 \left(T_{\text{ideal}_{\text{lower}}} - \left|T_{\text{ideal}_{\text{upper}}} - T_{\text{min}}\right|\right) + \beta_2 PR_{max} + \beta_3 \left(\text{GDP}_{\text{pc}}\right)^{0.5}\\
&\text{Logit(Malaria)} = 0\text{, otherwise}
\end{aligned}$$

where

T_{ideal_lower}:	Lower bound of ideal temperature range for malaria transmission; and
T_{ideal_upper}:	Upper bound of ideal temperature range for malaria transmission.

The above functional relationship suggests that some areas of the globe currently experiencing malaria may see a reduction in the number of cases of malaria as temperature becomes less than ideal for the carrying vector.

It should also be noted that the malaria burden is sensitive to factors beyond simply temperature and precipitation, including land disturbance and baseline water, sanitation, and hygiene infrastructure. Variations in GDP per capita may serve as a proxy for some of these other variables. Further modeling efforts may aim to explicitly capture the impacts of these other variables.

Diarrhea

The statistical model is as follows:

(4) $$n_{c,t} = N_{c,t} \frac{\exp(\beta \Delta T_{c,t}) - 1}{\exp(\beta \Delta T_{c,t})}$$

where

$n_{c,t}$	Number of diarrhea deaths attributable to climate change among children aged under 15 years in country c in year t;
$N_{c,t}$	Number of diarrhea deaths in children aged under 15 years in a future without climate change in country c in year t;
$\Delta T_{c,t}$	Temperature anomaly in country c in year t; and
$\beta = \log(1+\alpha)$	Mid-estimate of the log-linear increase in diarrheal deaths per degree of temperature increase, with α being the linear increase in diarrheal deaths per degree of temperature increase

Extreme heat

Based on Honda et al. (2014), the temperature-mortality function is assumed to be V-shaped, and the temperature value at which mortality is the lowest is defined as the optimum temperature. For temperatures above the optimum temperature, the mortality difference was defined as the heat-related mortality:

(5) $$\text{Heat} - \text{related deaths} = D_{av} \text{x } 0.88 \text{ x } (RR_t - 1)$$

where:

D_{av}	Daily average number of deaths in people aged 65 years and over; and
RR_t	Ratio of mortality at temperature index t, compared to mortality at the optimum temperature (84th percentile).

The above approach focuses on older ages (65 and above). It may be noted that heat shocks can also affect people of younger ages. The existing focus on the population of 65 years and over thus leads to underestimating the impacts of extreme heat. On the other hand, it may also be noted that in some countries (or perhaps more precisely—in some areas of some countries), increases in temperature may lead to a reduction in mortality associated with exposure to extreme cold. When this effect is not captured, the impact of rising temperatures will be overestimated.

Stunting

This study used the regional stunting data for cases and deaths due to climate change from the WHO (2014) study to derive country-level data. The WHO (2014) study established the links between climate change and undernutrition. The model developed by WHO comprises the following steps:[20]

Step 1: Estimate future post-global food trade national calorie availability for the years selected for analysis, with and without climate change.

Step 2: Estimate the proportion of the population considered to be undernourished.

Step 3: Estimate regional-level child stunting using an undernutrition model that accounts for projections of GDP per capita.

Step 4: Estimate mortality attributable to child stunting.

The results of the analysis by WHO (2014) were reported as the percentage of children aged under five, who were moderately or severely stunted, in 2030 and 2050, as well as the number of deaths of children due to stunting—with and without climate change.

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[20] Note that WHO (2014) provides estimates for the years 2030 and 2050. This report extends the analysis to the year 2100.

These estimates were used in the current assessment, with estimates of mortality for the year 2100 calculated in the following way (for each of the 69 countries):

Step 1: Estimate the percentage change (decrease) in the proportion of children aged under five who are stunted, based on the percentage increase in the GDP per capita between the years 2030 and 2050 (akin to a measure of income elasticity).

Step 2: Use the estimates from Step 1 to estimate the proportion of stunted children in 2100 based on the projected percentage increase in the GDP per capita between 2050 and 2100. Given the different projections of the GDP per capita in SSP2 and SSP3, estimates for the year 2100 vary across SSPs.

Annex 4. Modeling Fatality Rates

Malaria and Dengue

For both dengue and malaria, the fatality rates (the number of deaths per case of each disease) were calculated for the base year 2020. In the first version of this analysis, it was assumed that the fatality rates for dengue and malaria remained constant over 2020-2100. This approach was also employed by WHO (2014) for the selected period of analysis up to 2050. However, if the probability of malaria and dengue were negatively correlated with GDP per capita as indicated in the statistical functions presented above (Equations [1] and [2]), it can be assumed that fatality rates may also be negatively correlated with socioeconomic development for which GDP per capita serves as a proxy.

Previous work has also indicated that the likelihood of mortality from extreme events—be it climatic or geological in nature—is negatively associated with female education. Blankespoor et al. (2010) have shown that in any given population, the more educated females are, the lower the probability of death. These impacts were used in assessing the economic cost of adaptation in the influential World Bank (2010) report, Economics of Adaptation to Climate Change: Synthesis Report, in which investing in female education was highlighted as a means for adapting to the projected impacts of climate change.

It was thus hypothesized in the current analysis that female education could have the same impact on malaria and dengue fatality rates.

The general model being tested is the following:

$$FR_{jit} = \alpha_i + \beta_1\ GDP_{it} + \beta_2\ FEM_{it} + \beta_3\ GDP_{it} * FEM_{it} + \varepsilon \tag{5}$$

where

FR_{jit}	is the fatality rate for disease j in country i at time t, with j standing for malaria or dengue;
GDP_{it}	is GDP per capita in country i at time t; and
FEM_{it}	is female education in country i at time t.

Annual GDP per capita figures over the 2000-2022 period were obtained for all countries from the World Bank database. Figures for female education were obtained from UN Statistics.

For the purpose of testing, female education was defined in various ways:

- Proportion of female population with primary education (Fempri);
- Proportion of female education with lower secondary education (Femsec); and
- Proportion of female education with upper secondary education (Femup)

Malaria

Given the overwhelming concentration of global cases of malaria in SSA (accounting for 95 percent of all cases of malaria), the above model was tested using the 27 Sub-Saharan African countries included in our analysis; all 27 countries had positive fatality rates for malaria in the base year 2020. It was tested by using fatality rates found in WHO (2023), with a balanced panel dataset constructed covering the 2000-2022 period.

Various specifications were tested, including a non-linear specification for GDP per capita and logistic regressions. Estimated coefficients were statistically significant only for the linear model that offered the best explanatory power. Results for the specifications of various variables of interest are presented in Table A.4.

Three models were generated. Note that GDP per capita is strongly significant in all model specifications: as GDP per capita increases, malaria fatality rates fall. Taken individually, Fempri, Femsec, and Femup had a similar effect on fatality rates. However, Femup (Model 3) was noted to offer a much better fit than the other two models. Therefore, the estimated coefficients from Model 3 were used to estimate fatality rates in 2030, 2050, and 2100, based on the values of the GDP per capita and female education as projected in SSP2 and SSP3 for the same years.

Table A.4 Modeling Malaria’s Fatality Rate

	Dependent variable: Malaria’s fatality rate		
Independent variable	**Model (1)**	**Model (2)**	**Model (3)**
GDP	-0.134^{**} (0.054)	-0.093^{***} (0.028)	-0.084^{***} (0.011)
Fempri	-3.874^{***} (0.969)		
GDP * Fempri	0.002^{***} (0.001)		
Femsec		-5.053^{***} (1.756)	
GDP * Femsec		0.002^{***} (0.0003)	
Femup			-14.499^{***} (1.925)
GDP * Femup			0.004^{***} (0.0003)
Observations	360	271	195
R^2	0.073	0.104	0.452
Adjusted R^2	-0.005	0.004	0.359
F statistics	8.703^{***} (df = 3; 331)	9.400^{***} (df = 3; 243)	45.626^{***} (df = 3; 166)

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Dengue

For dengue, the model was tested by using 55 countries (out of 69) with non-zero fatality rates in the base year 2020.[21] However, as dengue fatality rates are available only in the 2009 to 2019 period, a balanced panel dataset was constructed over that period.

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[21] Fourteen countries had a zero fatality rate from dengue in 2020.

Similar specifications were used to model dengue's fatality rate as for malaria's fatality rate. However, the overall results were not conclusive: many of the coefficients obtained were not statistically significant and the R2 coefficients were very low in all specifications. The further testing of various specifications, for example, by including the three levels of female education and testing non-linear and logistic regressions, also led to inconclusive results.

A study by Ali (2024) showed a significant and positive correlation between mortality rates in the most recent dengue outbreak in Bangladesh with population density and air quality index. This finding could account for the lack of relationships among dengue, GDP per capita, and female education.

Hence, a constant fatality rate (equal to the 2020 level) was assumed for dengue.

Annex 5. Estimating YLL from Climate Change

Life Expectancy

In order to estimate the number of years of life lost (YLL), estimates of life expectancy are needed for each of the 69 countries in the baseline year 2020, and then in the years 2030, 2050, and 2100. We used LEXPECi,t to represent the life expectancy of country, i, in year, t.

The life expectancy of any given country, i, among the 69 countries included in the analysis for the baseline year 2020 (noted as LEXPECi, 2020) can be found in the World Bank Indicators database. The life expectancies of the other years, that is, LEXPECi,2030, LEXPECi,2050, and LEXPECi,2100, have to be estimated. Unfortunately, although the SSP database covers numerous socioeconomic variables, it does not include the values of life expectancy.

In order to obtain values of life expectancy, the analysis relied on Kc and Lutz (2017). The authors provided details on the assumptions concerning the demographic and human capital components of the SSPs (fertility, mortality, migration, and education). Concerning the mortality component, SSP2 was characterized as "medium" mortality while SSP3 was characterized as "high" mortality. Kc and Lutz (2017) asserted that a "medium" mortality assumption implies that life expectancy increases by two years per decade while a "high" mortality assumption implies an increase in life expectancy of one year per decade. We retained these assumptions in projecting the life expectancies for the years 2030, 2050, and 2100. Furthermore, we assumed that these increases would apply equally to all countries included in the analysis. The calculation of life expectancies is shown in Table A.5.

Table A.5 Estimating Life Expectancies

SSP Scenario	$LEXPEC_{i,2030}$ =	$LEXPEC_{i,2050}$ =	$LEXPEC_{i,2050}$ =
SSP2	$LEXPEC_{i,2020} + 2$	$LEXPEC_{i,2020} + 6$	$LEXPEC_{i,2020} + 16$
SSP3	$LEXPEC_{i,2020} + 1$	$LEXPEC_{i,2020} + 3$	$LEXPEC_{i,2020} + 8$

Calculating Years of Life Lost

Mortality from stunting and diarrhea typically affects young children. For simplification purposes, it is thus assumed that the number of YYL is equal to the estimated life expectancy for every death associated with stunting and diarrhea.

Regarding extreme heat, it is noted that the statistical modeling used in WHO (2014) applies only to individuals above 65 years old. For the purpose of estimating the number of YYL resulting from extreme heat death, it is assumed that the number of deaths is uniformly distributed between LEXPECi,t and 65. Hence, the number of YYL for that age group is [(LEXPECi,t – 65) / 2], provided that LEXPECi,t is larger than 65. In circumstances where LEXPECi,t is less than 65, it is assumed that the number of YYL is 0.

In order to estimate the number of YYL associated with both malaria and dengue deaths, the distribution of mortality across age groups is required. The mortality numbers from malaria and dengue across the age groups is available for each country included in the analysis with a positive number of deaths for the baseline year 2020.[22] For the purpose of illustration, the age distribution of deaths from malaria in Nigeria and Cameroon in the year 2020 is shown in Tables A.6 and A.7, respectively. Similar tables were constructed for each country with malaria and dengue deaths in the baseline year 2020.

Table A.6 Age Distribution of Deaths from Malaria in Nigeria in 2020

Age Group	Number of Deaths	% Distribution of Deaths
Less than 5 years old	129,822	55.59
5-14 years old	13,756	5.89
15-49 years old	40,657	17.41
50-69 years old	33,521	14.35
70+ years old	15,794	6.76
Total	**233,551**	**100**

Source: https://ourworldindata.org.

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[22] For malaria, the information is available at: https://ourworldindata.org/grapher/malaria-deaths-by-age. For dengue, the information is available in World Bank Indicators.

Table A.7 Age Distribution of Deaths from Malaria in Cameroon in 2020

Age Group	Number of Deaths	% Distribution of Deaths
Less than 5 years old	15,213	48.06
5-14 years old	1,394	4.40
15-49 years old	6,858	21.67
50-69 years old	5,571	17.60
70+ years old	2,619	8.27
Total	**31,654**	**100**

Source: https://ourworldindata.org.

We estimate the number of deaths by age group. Within each age group, it is assumed that the number of deaths is uniformly distributed within the age group. As a result, the number of YLL in country, i, in year, t (with t = 2030, 2050, 2100):

For the age group less than 5 years old: $LEXPEC_{i,t} - 2.5$[23]
For the age group 5-14 years old: $LEXPEC_{i,t} - 9.5$
For the age group 15-49 years old: $LEXPEC_{i,t} - 32$
For the age group 50-69 years old: $LEXPEC_{i,t} - 59.5$
For the age group 70+ years old: $LEXPEC_{i,t} - 70$

For the purpose of estimating the number of YLL, it is finally assumed that the percentage distribution of deaths across the age groups in the years 2030, 2050, and 2100 is similar as observed in the year 2020.

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[23] "2.5", "9.5", "32", "59.5", and "70" are the mid-point values of the respective age groups.

Annex 6. Estimating the Economic Cost of Climate-Related Health Impacts

Value of Statistical Life

The national VSL were estimated with a benefit-transfer approach, using an estimated VSL of USD6 million in the United States (US) in 2020 as a starting point.[24] A country-specific VSL was then estimated in the base year 2020 for each of the 69 countries, using the ratio of GDP per capita in the country of interest to GDP per capita (in PPP terms) in the US (Equation [6]). This approach assumes that VSL has an income elasticity of 1.[25] This approach allows the VSL in 2020 for each country to be estimated.

$$\mathbf{VSL_{2020,i} = USD6\ million * \left(\frac{GDP_{2020,i}}{GDP_{2020,US}}\right)} \quad (6)$$

where:

$VSL_{2020,i}$	is the estimated VSL in 2020 in the country, i,
$GDP_{2020,i}$	is the GDP per capita in 2020 in the country, i, and
$GDP_{2020,US}$	is GDP per capita in 2020 in the US.

Once a VSL in 2020 was estimated for any given country, the VSL in 2030, 2050, and 2100 for that country were calculated by multiplying the 2020 estimated VSL with the ratio of GDP per capita in 2030, 2050, and then 2100 to GDP per capita in 2020 (Equation [7]—which similarly assumes a unitary income elasticity):

$$\mathbf{VSL_{t,i} = VSL_{2020,i} * \left(\frac{GDP_{t,i}}{GDP_{2020,i}}\right)} \quad (7)$$

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[24] A VSL of approximately USD6 million was estimated in OECD countries in the mid-2000s. More recently, Viscusi (2020) used a VSL of USD11 million. A similar value was recently used by Carleton et al. (2022). This analysis uses the lower value of USD6 million as a baseline value for VSL, based on the preference of underestimating the economic cost associated with mortality.

[25] Viscusi (2020) adopted an income elasticity figure of 1.0 to estimate the global economic cost of the COVID-19 pandemic. The use of the income elasticity of 1 is consistent with the meta-regression analyses of the revealed preference labor market data in Viscusi and Masterman (2017a, 2017b). Similarly, a meta-regression analysis of the stated preference data in Masterman and Viscusi (2018) estimated that the overall income elasticity of the VSL ranged from 0.94 to 1.05 across countries. An income elasticity of 1 across time and geographical regions was also used by Carleton et al. (2022).

where:

$VSL_{t,i}$	is VSL in country, i, at time, t, with t = 2030, 2050, or 2100 and
$GDP_{t,i}$	is GDP per capita in country, i, at time, t, with t = 2030, 2050, or 2100.

In Equation (7), $GDP_{t,i}$ not only varies across time and country but also the SSPs, with SSP2 showing a higher GDP per capita than SSP3 for all the countries and years. The estimated values of VSL for all 69 countries and both SSPs for 2020 (baseline), 2030, 2050, and 2100 are presented below in Table A.8 and Table A.9 for SSP3 and SSP2 respectively.

Table A.8 Estimated Country-Specific Values for VSL (USD) – SSP3

Country	2020	2030	2050	2100
Afghanistan	194,240	238,049	380,247	1,171,832
Algeria	1,228,880	1,522,371	1,562,756	2,804,399
Angola	884,574	858,679	656,431	1,442,703
Argentina	2,603,498	3,139,257	3,663,703	4,878,483
Azerbaijan	1,371,923	1,550,281	1,474,724	2,375,253
Bangladesh	333,877	489,091	733,680	1,613,220
Benin	217,964	271,570	408,496	1,167,993
Bolivia	798,317	1,040,672	1,473,159	3,224,734
Brazil	1,747,278	2,063,543	2,246,594	2,324,466
Burkina Faso	210,100	273,368	402,433	1,075,220
Burundi	95,844	135,893	244,634	889,794
Cambodia	456,812	654,763	990,005	2,100,646
Cameroon	363,480	491,863	779,353	1,960,239
Chad	196,752	246,646	412,664	1,222,609
China	1,928,327	2,925,640	3,867,701	4,734,957
Colombia	1,517,280	1,754,464	2,117,938	3,520,566
Congo, DR	67,491	123,168	268,148	1,051,658
Cote d’Ivoire	336,113	571,609	1,052,209	2,441,970
Dominican Republic	1,517,096	1,803,721	2,171,160	3,510,295

Country	2020	2030	2050	2100
Ecuador	1,205,379	1,420,718	1,776,433	3,378,722
Egypt	982,983	1,352,955	1,984,679	3,871,077
Ethiopia	189,611	253,319	400,815	1,209,471
Ghana	340,965	466,727	663,098	1,659,815
Guatemala	624,829	737,587	1,004,761	2,134,802
Guinea	272,764	465,920	820,239	1,967,130
Haiti	199,908	296,222	537,901	1,696,886
Honduras	556,063	690,168	991,728	2,213,202
India	654,287	925,698	1,260,823	1,862,056
Indonesia	874,605	1,311,913	1,942,977	2,985,028
Iran	1,554,603	1,911,783	2,653,906	3,799,189
Iraq	823,619	1,079,443	1,401,315	1,648,835
Jordan	845,529	1,174,546	1,900,289	4,380,105
Kazakhstan	2,373,738	3,583,606	4,627,499	4,524,302
Kenya	262,244	338,246	500,750	1,479,346
Madagascar	127,157	171,042	306,575	1,149,514
Malawi	136,981	184,020	296,660	1,150,393
Malaysia	2,376,407	2,952,202	3,868,254	6,315,435
Mali	143,004	189,208	305,523	873,635
Mexico	2,045,542	2,397,662	2,841,860	3,823,935
Morocco	845,476	1,189,128	1,819,029	3,186,494
Mozambique	181,733	256,900	403,603	1,153,203
Myanmar	321,712	440,088	541,623	671,604
Nepal	180,852	231,379	338,401	931,095
Niger	115,163	139,705	201,276	719,240
Nigeria	416,268	554,709	788,966	2,203,405
Pakistan	379,577	469,368	666,715	1,476,281
Peru	1,794,937	2,374,122	3,116,373	5,055,980
Philippines	628,446	773,713	1,052,499	2,449,547
Romania	1,887,783	2,414,692	2,955,523	4,495,724
Russian Federation	2,703,222	3,592,915	4,621,660	6,133,900

Country	2020	2030	2050	2100
Rwanda	208,574	286,385	425,224	1,133,511
Senegal	286,362	360,055	507,812	1,263,590
Somalia	5,050	6,976	12,112	58,913
South Africa	1,696,305	2,154,195	2,748,392	4,068,813
Sri Lanka	1,050,723	1,500,735	2,010,613	2,936,687
Sudan	338,440	434,982	627,354	1,487,141
Syrian Arab Republic	878,340	1,208,245	1,856,760	3,599,869
Tanzania	238,072	332,854	538,993	1,480,536
Thailand	1,493,017	2,056,981	2,907,128	4,847,994
Tunisia	1,536,704	2,234,471	3,499,106	5,564,913
Turkey	2,277,972	2,706,597	3,207,772	4,130,196
Uganda	208,522	279,257	440,834	1,399,146
Ukraine	1,196,370	1,641,949	2,351,631	4,615,154
Uzbekistan	634,705	928,517	1,415,610	3,081,060
Venezuela	1,744,845	2,107,415	3,370,897	5,342,364
Vietnam	637,914	932,552	1,466,767	3,014,518
Yemen, Republic of	291,307	369,645	562,888	1,354,987
Zambia	270,963	373,205	604,011	1,832,436
Zimbabwe	72,646	101,280	235,534	1,380,054

Table A.9 Estimated Country-Specific Values for VSL (USD) – SSP2

Country	2020	2030	2050	2100
Afghanistan	194,240	259,249	550,050	4,059,516
Algeria	1,228,880	1,611,346	2,213,968	6,782,743
Angola	884,574	901,829	971,368	5,048,862
Argentina	2,603,498	3,414,099	5,090,673	10,663,927
Azerbaijan	1,371,923	1,561,647	1,858,423	5,401,424
Bangladesh	333,877	545,008	1,178,305	5,477,045
Benin	217,964	306,355	683,729	4,933,748
Bolivia	798,317	1,189,515	2,421,618	9,576,759
Brazil	1,747,278	2,228,730	3,183,610	7,197,721

Country	2020	2030	2050	2100
Burkina Faso	210,100	319,327	752,902	5,240,042
Burundi	95,844	158,835	470,932	4,341,914
Cambodia	456,812	732,934	1,524,311	6,828,685
Cameroon	363,480	557,704	1,262,241	6,498,942
Chad	196,752	277,456	689,694	5,301,730
China	1,928,327	3,198,784	5,306,407	10,144,168
Colombia	1,517,280	1,903,498	3,051,011	8,570,414
Congo, DR	67,491	142,995	494,281	4,377,246
Cote d’Ivoire	336,113	691,256	1,984,771	9,336,611
Dominican Republic	1,517,096	1,982,931	3,094,945	7,651,320
Ecuador	1,205,379	1,574,554	2,666,848	8,585,770
Egypt	982,983	1,494,762	2,947,555	8,845,187
Ethiopia	189,611	292,422	741,611	5,577,314
Ghana	340,965	535,189	1,174,970	6,043,698
Guatemala	624,829	876,482	1,709,332	7,363,580
Guinea	272,764	622,820	1,837,279	9,823,379
Haiti	199,908	340,493	953,902	6,427,046
Honduras	556,063	779,346	1,587,580	7,460,221
India	654,287	1,050,264	2,088,816	6,726,670
Indonesia	874,605	1,443,754	2,897,550	8,662,902
Iran	1,554,603	2,015,755	3,163,407	7,763,142
Iraq	823,619	1,058,961	1,461,527	4,496,679
Jordan	845,529	1,288,382	2,676,684	8,800,514
Kazakhstan	2,373,738	3,624,235	4,896,518	7,510,826
Kenya	262,244	390,798	859,037	4,905,011
Madagascar	127,157	194,162	515,075	4,220,352
Malawi	136,981	207,438	507,899	4,582,694
Malaysia	2,376,407	3,196,581	5,116,961	11,713,070
Mali	143,004	215,626	542,548	4,176,500
Mexico	2,045,542	2,566,018	3,905,805	10,319,880
Morocco	845,476	1,362,010	2,931,536	9,891,526

Country	2020	2030	2050	2100
Mozambique	181,733	295,542	733,635	6,088,111
Myanmar	321,712	483,299	823,310	2,535,833
Nepal	180,852	271,766	623,102	4,120,834
Niger	115,163	162,160	377,006	4,022,578
Nigeria	416,268	620,659	1,309,779	7,298,900
Pakistan	379,577	531,053	1,114,511	5,372,717
Peru	1,794,937	2,601,899	4,386,154	11,115,107
Philippines	628,446	859,110	1,590,852	6,117,223
Romania	1,887,783	2,593,981	3,968,903	9,414,624
Russian Federation	2,703,222	3,754,874	5,440,287	9,991,107
Rwanda	208,574	333,241	762,405	4,506,278
Senegal	286,362	423,391	955,571	5,964,809
Somalia	5,050	10,035	34,956	539,225
South Africa	1,696,305	2,299,296	3,621,892	8,345,570
Sri Lanka	1,050,723	1,654,488	3,066,034	8,935,757
Sudan	338,440	494,529	1,043,700	5,774,801
Syrian Arab Republic	878,340	1,345,067	2,706,542	9,211,826
Tanzania	238,072	385,080	902,993	5,202,281
Thailand	1,493,017	2,277,028	4,272,421	11,635,272
Tunisia	1,536,704	2,387,862	4,422,568	9,735,056
Turkey	2,277,972	2,961,581	4,449,355	10,030,464
Uganda	208,522	326,293	782,997	5,623,225
Ukraine	1,196,370	1,788,906	3,227,552	8,810,788
Uzbekistan	634,705	1,037,523	2,066,913	5,982,778
Venezuela	1,744,845	2,167,103	3,282,841	8,318,452
Vietnam	637,914	1,015,399	2,019,008	6,800,314
Yemen, Republic of	291,307	413,989	863,535	3,344,140
Zambia	270,963	429,801	1,032,153	6,400,551
Zimbabwe	72,646	118,484	414,901	4,349,512

Cost of Illness

Table A.10 Estimated Country-Specific Values for COI Dengue t

Country	2020	2030	2050	2100
Afghanistan	120	148	236	726
Algeria	870	1,077	1,106	1,985
Angola	626	608	465	1,021
Argentina	1,069	1,288	1,504	2,002
Azerbaijan	971	1,097	1,044	1,681
Bangladesh	207	303	455	1,000
Benin	154	192	289	827
Bolivia	328	427	605	1,324
Brazil	691	816	888	919
Burkina Faso	149	193	285	761
Burundi	68	96	173	630
Cambodia	612	877	1,327	2,815
Cameroon	257	348	552	1,387
Chad	139	175	292	865
China	2,107	3,197	4,226	5,173
Colombia	974	1,126	1,360	2,260
Congo, DR	48	87	190	744
Cote d’Ivoire	238	405	745	1,728
Dominican Republic	623	740	891	1,441
Ecuador	495	583	729	1,387
Egypt	696	957	1,404	2,739
Ethiopia	134	179	284	856
Ghana	241	330	469	1,175
Guatemala	307	362	494	1,049
Guinea	193	330	580	1,392
Haiti	82	122	221	696
Honduras	228	283	407	908
India	246	348	475	701
Indonesia	867	1,300	1,926	2,959
Iran	1,100	1,353	1,878	2,689

Country	2020	2030	2050	2100
Iraq	583	764	992	1,167
Jordan	598	831	1,345	3,100
Kazakhstan	1,680	2,536	3,275	3,202
Kenya	186	239	354	1,047
Madagascar	90	121	217	813
Malawi	97	130	210	814
Malaysia	2,838	3,526	4,620	7,543
Mali	101	134	216	618
Mexico	840	984	1,166	1,569
Morocco	598	842	1,287	2,255
Mozambique	129	182	286	816
Myanmar	358	489	602	747
Nepal	112	143	210	577
Niger	82	99	142	509
Nigeria	295	393	558	1,559
Pakistan	235	291	413	915
Peru	737	974	1,279	2,075
Philippines	639	787	1,070	2,491
Romania	1,336	1,709	2,092	3,181
Russian Federation	1,913	2,543	3,271	4,341
Rwanda	148	203	301	802
Senegal	203	255	359	894
Somalia	4	5	9	42
South Africa	1,200	1,524	1,945	2,879
Sri Lanka	651	930	1,246	1,821
Sudan	240	308	444	1,052
Syrian Arab Republic	622	855	1,314	2,547
Tanzania	168	236	381	1,048
Thailand	1,858	2,559	3,617	6,032
Tunisia	1,087	1,581	2,476	3,938
Turkey	1,612	1,915	2,270	2,923
Uganda	148	198	312	990
Ukraine	847	1,162	1,664	3,266
Uzbekistan	449	657	1,002	2,180
Venezuela	482	582	931	1,476

Country	2020	2030	2050	2100
Vietnam	459	671	1,055	2,168
Yemen, Republic of	206	262	398	959
Zambia	192	264	427	1,297
Zimbabwe	51	72	167	977

Table A.11 Estimated Country-Specific Values for COI Dengue (USD) – SSP2

Country	2020	2030	2050	2100
Afghanistan	120	160	340	2,508
Algeria	870	1,135	1,560	4,780
Angola	626	627	675	3,510
Argentina	1,069	1,393	2,078	4,352
Azerbaijan	971	1,105	1,314	3,820
Bangladesh	207	336	725	3,372
Benin	154	214	478	3,449
Bolivia	328	483	984	3,893
Brazil	691	877	1,252	2,832
Burkina Faso	149	223	526	3,657
Burundi	68	111	330	3,045
Cambodia	612	974	2,025	9,071
Cameroon	257	391	885	4,559
Chad	139	195	483	3,717
China	2,107	3,469	5,754	11,000
Colombia	974	1,217	1,950	5,479
Congo, DR	48	100	346	3,061
Cote d'Ivoire	238	481	1,381	6,497
Dominican Republic	623	808	1,261	3,118
Ecuador	495	641	1,086	3,498
Egypt	696	1,050	2,071	6,214
Ethiopia	134	205	520	3,912
Ghana	241	375	824	4,238
Guatemala	307	419	817	3,519
Guinea	193	421	1,241	6,638
Haiti	82	139	388	2,615

Country	2020	2030	2050	2100
Honduras	228	317	645	3,033
India	246	392	779	2,508
Indonesia	867	1,422	2,854	8,532
Iran	1,100	1,413	2,217	5,441
Iraq	583	744	1,028	3,161
Jordan	598	905	1,880	6,182
Kazakhstan	1,680	2,556	3,453	5,296
Kenya	186	273	600	3,427
Madagascar	90	136	362	2,963
Malawi	97	146	357	3,224
Malaysia	2,838	3,793	6,072	13,898
Mali	101	151	381	2,930
Mexico	840	1,049	1,596	4,217
Morocco	598	950	2,045	6,900
Mozambique	129	207	514	4,268
Myanmar	358	534	910	2,802
Nepal	112	166	379	2,509
Niger	82	113	264	2,815
Nigeria	295	436	920	5,124
Pakistan	235	326	685	3,302
Peru	737	1,060	1,787	4,530
Philippines	639	867	1,606	6,175
Romania	1,336	1,826	2,793	6,626
Russian Federation	1,913	2,645	3,832	7,037
Rwanda	148	234	534	3,158
Senegal	203	296	668	4,169
Somalia	4	6	22	339
South Africa	1,204	1,627	2,563	5,906
Sri Lanka	651	1,018	1,887	5,500
Sudan	240	346	730	4,037
Syrian Arab Republic	622	939	1,889	6,430
Tanzania	168	269	632	3,641
Thailand	1,858	2,809	5,271	14,354
Tunisia	1,087	1,679	3,111	6,847
Turkey	1,612	2,080	3,126	7,046

Country	2020	2030	2050	2100
Uganda	148	228	546	3,921
Ukraine	847	1,255	2,265	6,183
Uzbekistan	449	726	1,446	4,186
Venezuela	482	596	902	2,287
Vietnam	459	725	1,441	4,853
Yemen, Republic of	206	290	604	2,339
Zambia	192	300	720	4,467
Zimbabwe	51	83	290	3,038

Table A.12 Estimated Country-Specific Values for COI Malaria (USD) – SSP3

Country	2020	2030	2050	2100
South Africa	1,204	1,627	2,563	5,906
Afghanistan	20	24	38	118
Algeria	114	142	145	261
Angola	124	121	92	203
Argentina	98	118	138	184
Azerbaijan	128	144	137	221
Bangladesh	34	49	74	163
Benin	31	38	57	164
Bolivia	30	39	56	122
Brazil	66	78	85	88
Burkina Faso	16	21	30	81
Burundi	13	19	34	125
Cambodia	42	61	92	195
Cameroon	57	78	123	310
Chad	28	35	58	172
China	179	272	360	440
Colombia	26	30	36	60
Congo, DR	9	17	38	148
Cote d'Ivoire	47	80	148	343
Dominican Republic	57	68	82	132
Ecuador	45	54	67	127
Egypt	91	126	185	360
Ethiopia	27	36	56	170

Country	2020	2030	2050	2100
Ghana	23	32	46	114
Guatemala	24	28	38	81
Guinea	38	65	115	276
Haiti	8	11	20	64
Honduras	21	26	37	84
India	77	109	148	218
Indonesia	81	122	181	278
Iran	145	178	247	353
Iraq	77	100	130	153
Jordan	79	109	177	407
Kazakhstan	221	333	430	421
Kenya	37	47	70	208
Madagascar	26	35	63	236
Malawi	19	26	42	162
Malaysia	221	274	360	587
Mali	20	27	43	123
Mexico	77	90	107	144
Morocco	79	111	169	296
Mozambique	46	65	102	291
Myanmar	30	41	50	62
Nepal	18	23	34	94
Niger	16	20	28	101
Nigeria	34	46	65	181
Pakistan	32	40	56	124
Peru	105	138	182	295
Philippines	58	72	98	228
Romania	176	225	275	418
Russian Federation	251	334	430	570
Rwanda	29	40	60	159
Senegal	40	51	71	177
Somalia	1	1	2	8
South Africa	232	295	376	557
Sri Lanka	106	151	203	296
Sudan	48	61	88	209
Syrian Arab Republic	82	112	173	335

Country	2020	2030	2050	2100
Tanzania	33	47	76	208
Thailand	139	191	270	451
Tunisia	143	208	325	517
Turkey	212	252	298	384
Uganda	29	39	62	196
Ukraine	111	153	219	429
Uzbekistan	59	86	132	286
Venezuela	66	80	127	202
Vietnam	59	87	136	280
Yemen, Republic of	27	34	52	126
Zambia	38	52	85	257
Zimbabwe	10	14	33	194

Table A.13 Estimated Country-Specific Values for COI Malaria (USD) – SSP2

Country	2020	2030	2050	2100
Afghanistan	20	26	55	408
Algeria	114	149	205	628
Angola	124	124	134	697
Argentina	98	128	191	400
Azerbaijan	128	145	173	502
Bangladesh	34	55	118	548
Benin	31	42	95	684
Bolivia	30	44	90	358
Brazil	66	84	119	270
Burkina Faso	16	24	56	389
Burundi	13	22	66	604
Cambodia	42	68	140	629
Cameroon	57	87	198	1,018
Chad	28	39	96	737
China	179	295	490	936
Colombia	26	32	52	146
Congo, DR	9	20	69	608
Cote d'Ivoire	47	95	274	1,289
Dominican Republic	57	74	116	287

Country	2020	2030	2050	2100
Ecuador	45	59	100	321
Egypt	91	138	272	816
Ethiopia	27	41	103	776
Ghana	23	36	80	412
Guatemala	24	32	63	270
Guinea	38	84	246	1,317
Haiti	8	13	36	240
Honduras	21	29	59	279
India	77	122	243	782
Indonesia	81	133	268	800
Iran	145	186	291	715
Iraq	77	98	135	415
Jordan	79	119	247	812
Kazakhstan	221	336	454	696
Kenya	37	54	119	680
Madagascar	26	40	105	861
Malawi	19	29	71	640
Malaysia	221	295	473	1,082
Mali	20	30	76	581
Mexico	77	96	147	388
Morocco	79	125	269	907
Mozambique	46	74	184	1,523
Myanmar	30	45	76	234
Nepal	18	27	62	408
Niger	16	23	52	558
Nigeria	34	51	107	594
Pakistan	32	44	93	449
Peru	105	151	254	644
Philippines	58	79	147	565
Romania	176	240	367	871
Russian Federation	251	347	503	925
Rwanda	29	46	106	627
Senegal	40	59	133	827
Somalia	1	1	4	67
South Africa	233	296	377	559

Country	2020	2030	2050	2100
Sri Lanka	106	166	307	894
Sudan	48	69	145	801
Syrian Arab Republic	82	123	248	845
Tanzania	33	53	125	722
Thailand	139	210	394	1,073
Tunisia	143	221	409	900
Turkey	212	273	411	926
Uganda	29	45	108	778
Ukraine	111	165	298	812
Uzbekistan	59	95	190	550
Venezuela	66	81	123	312
Vietnam	59	94	186	628
Yemen, Republic of	27	38	79	307
Zambia	38	60	143	886
Zimbabwe	10	16	58	603

Table A.14 Estimated Country-Specific Values for COI Diarrhea (USD) – SSP3

Country	2020	2030	2050	2100
Afghanistan	72	88	141	435
Algeria	438	542	556	999
Angola	208	202	154	339
Argentina	1,457	1,757	2,050	2,730
Azerbaijan	603	681	648	1,044
Bangladesh	61	89	134	294
Benin	63	79	119	339
Bolivia	288	376	532	1,164
Brazil	923	1,090	1,186	1,227
Burkina Faso	58	75	111	296
Burundi	38	54	98	356
Cambodia	344	494	746	1,584
Cameroon	101	136	216	543
Chad	76	96	160	474
China	455	690	912	1,116

Country	2020	2030	2050	2100
Colombia	969	1,120	1,352	2,248
Congo, DR	33	60	132	516
Cote d'Ivoire	123	209	385	893
Dominican Republic	553	657	791	1,280
Ecuador	706	832	1,040	1,978
Egypt	178	245	360	702
Ethiopia	97	129	204	617
Ghana	263	360	511	1,279
Guatemala	445	525	715	1,519
Guinea	46	79	139	334
Haiti	99	147	267	841
Honduras	334	415	596	1,331
India	107	151	206	304
Indonesia	460	690	1,022	1,569
Iran	772	949	1,318	1,886
Iraq	345	452	587	691
Jordan	287	399	645	1,486
Kazakhstan	450	679	877	858
Kenya	181	234	346	1,023
Madagascar	42	57	102	384
Malawi	70	94	152	589
Malaysia	1,512	1,878	2,461	4,018
Mali	97	128	207	592
Mexico	972	1,140	1,351	1,817
Morocco	505	711	1,087	1,905
Mozambique	67	94	148	424
Myanmar	322	441	543	673
Nepal	65	83	122	336
Niger	40	49	71	253
Nigeria	174	232	330	923
Pakistan	74	92	131	290
Peru	510	675	886	1,438
Philippines	664	818	1,112	2,588
Romania	351	449	550	836
Russian Federation	411	546	703	933

Country	2020	2030	2050	2100
Rwanda	187	257	382	1,018
Senegal	101	126	178	444
Somalia	71	98	171	829
South Africa	851	1,081	1,379	2,042
Sri Lanka	422	603	807	1,179
Sudan	261	336	485	1,149
Syrian Arab Republic	73	100	154	298
Tanzania	64	89	144	395
Thailand	728	1,003	1,417	2,364
Tunisia	446	648	1,015	1,615
Turkey	480	570	676	870
Uganda	99	133	209	665
Ukraine	101	139	199	390
Uzbekistan	142	208	316	689
Venezuela	796	962	1,539	2,438
Vietnam	386	564	888	1,824
Yemen, Republic of	168	213	324	779
Zambia	129	178	288	874
Zimbabwe	78	108	252	1,475

Table A.15 Estimated Country-Specific Values for COI Diarrhea (USD) – SSP2

Country	2020	2030	2050	2100
Afghanistan	72	96	203	1,501
Algeria	438	571	785	2,405
Angola	208	208	224	1,165
Argentina	1,457	1,900	2,833	5,934
Azerbaijan	603	686	816	2,372
Bangladesh	61	98	213	990
Benin	63	88	196	1,416
Bolivia	288	425	866	3,425
Brazil	923	1,171	1,672	3,781
Burkina Faso	58	87	204	1,423
Burundi	38	63	187	1,722

Country	2020	2030	2050	2100
Cambodia	344	548	1,139	5,103
Cameroon	101	153	347	1,786
Chad	76	107	265	2,038
China	455	748	1,242	2,374
Colombia	969	1,210	1,940	5,449
Congo, DR	33	69	240	2,122
Cote d’Ivoire	123	249	714	3,358
Dominican Republic	553	718	1,120	2,769
Ecuador	706	915	1,549	4,988
Egypt	178	269	531	1,593
Ethiopia	97	148	375	2,820
Ghana	263	409	897	4,614
Guatemala	445	607	1,183	5,096
Guinea	46	101	298	1,591
Haiti	99	167	469	3,157
Honduras	334	464	946	4,443
India	107	170	337	1,087
Indonesia	460	754	1,514	4,526
Iran	772	991	1,556	3,817
Iraq	345	441	609	1,872
Jordan	287	434	902	2,965
Kazakhstan	450	685	925	1,419
Kenya	181	267	587	3,351
Madagascar	42	64	171	1,398
Malawi	70	106	259	2,333
Malaysia	1,512	2,020	3,234	7,403
Mali	97	145	364	2,804
Mexico	972	1,214	1,848	4,884
Morocco	505	803	1,728	5,829
Mozambique	67	108	267	2,218
Myanmar	322	481	820	2,526
Nepal	65	96	221	1,459
Niger	40	56	131	1,397
Nigeria	174	258	544	3,032
Pakistan	74	103	217	1,045
Peru	510	735	1,238	3,138

Country	2020	2030	2050	2100
Philippines	664	901	1,669	6,417
Romania	351	480	734	1,742
Russian Federation	411	568	823	1,512
Rwanda	187	296	678	4,009
Senegal	101	147	332	2,070
Somalia	71	125	436	6,725
South Africa	854	1,154	1,818	4,188
Sri Lanka	422	660	1,222	3,562
Sudan	261	377	797	4,407
Syrian Arab Republic	73	110	221	752
Tanzania	64	102	238	1,373
Thailand	728	1,101	2,065	5,624
Tunisia	446	689	1,275	2,808
Turkey	480	619	930	2,098
Uganda	99	153	367	2,632
Ukraine	101	150	271	739
Uzbekistan	142	229	457	1,322
Venezuela	796	984	1,491	3,778
Vietnam	386	610	1,213	4,084
Yemen, Republic of	168	235	491	1,901
Zambia	129	202	486	3,011
Zimbabwe	78	125	438	4,587

It is important to note that the estimates of the economic cost are limited to the application of the estimated COI to the number of cases of morbidity. The true economic cost of morbidity is, in all likelihood, larger than the one used here. For example, it is well documented that both extreme heat and stunting are accompanied by important productivity losses (Galasso et al. [2018]; Heltberg [2008]; International Labour Organization [ILO] 2019). However, productivity losses (with the exception of days of illness) are typically not included in the estimates of COI.

The cumulative economic cost of cases and deaths is estimated for 2026-2030, 2031-2050, and 2051-2100 in relation to its value as a percentage of GDP. Results are presented for the 69 countries as a whole and each of the six regions (following the World Bank's regional groupings).

Years of life lost

This approach measures the economic cost of climate change solely on mortality by multiplying the estimated YLL in any given country in each of the years—2030, 2050, and 2100—by the average annual VSL in the same country for the same years. The average VSL in any country i at time t, noted as $AVSL_{i,t}$, is simply estimated as

(8) $AVSL_{i,t} = VSL_{i,t} / LEXPEC_{i,t}$, with t = 2030, 2050, 2100.

Note that $AVSL_{i,t}$ is specific to SSP2 and SSP3, as both $VSL_{i,t}$ and $LEXPEC_{i,t}$ vary across SSPs.

Annex 7. Cumulative Estimates of the Impacts of Climate Change on Morbidity and Mortality in the Short Term and Long Term

Short Term (2026-2030)

Table A.16 Cumulative Number of Cases Attributable to Climate Change: 2026-2030

	SSP3		SSP2	
	Number of cases (Millions)	**Share of Total (%)**	**Number of cases (Millions)**	**Share of Total (%)**
EAP	30.1	5.82	26.2	4.96
ECA	8.2	1.58	5.5	1.05
LAC	19.3	3.72	14.5	2.74
MENA	18.9	3.66	12.2	2.31
SA	99.1	19.14	95.2	18.01
SSA	342.4	66.09	374.9	70.93
Total	**518.0**		**528.5**	

Table A.17 Cumulative Number of Deaths Attributable to Climate Change: 2026-2030

	SSP3		SSP2	
	Number of deaths (Thousands)	**Share of Total (%)**	**Number of deaths (Thousands)**	**Share of Total (%)**
EAP	289.9	16.72	384.6	20.62
ECA	16.4	0.95	16.0	0.86
LAC	27.2	1.57	31.6	1.70
MENA	23.9	1.38	21.8	1.17
SA	388.5	22.41	413.7	22.18
SSA	988.0	56.98	997.6	53.48
Total	**1,734.0**		**1,865.2**	

Long Term (2026-2100)

Table A.18 Cumulative Number of Cases Attributable to Climate Change: 2026-2100

	SSP3		SSP2	
	Number of cases (Millions)	**Share of Total (%)**	**Number of cases (Millions)**	**Share of Total (%)**
EAP	1,266.0	3.21	694.8	4.38
ECA	232.7	0.59	67.4	0.42
LAC	725.9	1.84	313.8	1.98
MENA	804.9	2.04	206.9	1.30
SA	9,647.4	24.48	3,343.9	21.08
SSA	26,727.2	67.83	11,238.2	70.84
Total	**39,404.0**		**15,865.0**	

Table A.19 Cumulative Number of Deaths Attributable to Climate Change: 2026-2100

	SSP3		SSP2	
	Number of deaths (Thousands)	**Share of Total (%)**	**Number of deaths (Thousands)**	**Share of Total (%)**
EAP	24,009.0	18.30	16,600.4	25.98
ECA	988.8	0.75	699.8	1.10
LAC	2,225.1	1.70	1,431.9	2.24
MENA	2,674.3	2.04	938.3	1.47
SA	47,852.5	36.47	20,928.1	32.75
SSA	53,465.8	40.75	23,295.3	36.46
Total	**131,215.3**		**63,893.9**	

Annex 8. Economic Cost of the Health Impacts of Climate Change in the Short Term and Long Term

Short Term (2026-2030)

Table A.20 Economic Cost of the Health Impacts of Climate Change: 2026-2030

	SSP3				SSP2			
	YLL		VSL		YLL		VSL	
	Cost (Billions USD)	Share of GDP (%)	Cost (Billions USD)	Share of GDP (%)	Cost (Billions USD)	Share of GDP (%)	Cost (Billions USD)	Share of GDP (%)
EAP	231.0	0.19	411.9	0.34	339.1	0.25	603.7	0.44
ECA	13.9	0.08	46.1	0.26	11.4	0.06	47.8	0.25
LAC	27.5	0.11	51.4	0.21	31.2	0.12	64.4	0.25
MENA	11.6	0.14	20.5	0.25	9.5	0.12	19.5	0.24
SA	192.3	0.74	360.5	1.39	209.9	0.76	437.8	1.58
SSA	267.5	2.28	355.2	3.03	298.4	2.39	408.3	3.27
Total	**743.8**	**0.35**	**1,245.7**	**0.59**	**899.5**	**0.39**	**1,581.5**	**0.69**

Long Term (2026-2100)

Table A.21 Economic Cost of the Health Impacts of Climate Change: 2026-2100

	SSP3				SSP2			
	YLL		VSL		YLL		VSL	
	Cost (Billions USD)	Share of GDP (%)	Cost (Billions USD)	Share of GDP (%)	Cost (Billions USD)	Share of GDP (%)	Cost (Billions USD)	Share of GDP (%)
EAP	39,181.3	1.53	64,593.3	2.53	54,066.1	1.48	92,952.0	2.55
ECA	659.4	0.16	4,215.8	0.99	476.0	0.09	4,783.9	0.87
LAC	3,182.6	0.49	6,714.0	1.03	3,624.7	0.39	8,746.4	0.95
MENA	1,612.6	0.50	5,062.9	1.58	719.8	0.17	4,404.3	1.01
SA	43,465.6	4.53	85,040.9	8.87	42,414.9	2.40	100,371.7	5.67
SSA	35,401.8	3.92	46,980.7	5.20	41,278.4	2.08	60,334.4	3.04
Total	**123,503.3**	**2.13**	**212,607.6**	**3.66**	**142,579.9**	**1.53**	**271,592.6**	**2.92**

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