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ARTICLE

Climate Change and Mortality Rate in Sub-Saharan Africa

Edy-Ewoh UDUAKBONG[1†]; Yetunde R. EDALERE[1†*]; Musa DASAUKI[1†]

[1] Department of Economics, Babcock University, Ogun State, Nigeria.

[†] Authors contributed equally.

* Corresponding Author: edalere1026@pg.babcock.edu.ng

Abstract

This study examines the health repercussions of climate change across fifteen sub-Saharan African countries over the period 1995–2020, with a particular focus on mortality outcomes among infants, children under five, pregnant women, and mothers. Employing the Pooled Mean Group (PMG) estimator on panel data sourced from the World Bank and the World Health Organization, we quantify both short- and long-run effects of environmental and socioeconomic variables on mortality rates. Our long-run estimates indicate that carbon damage exerts a significant positive effect on overall mortality, while rising humidity is associated with increases in infant and under-five mortality. In contrast, higher precipitation contributes to reduced mortality in these age groups. Consistent with expectations, increased health expenditure per capita significantly lowers mortality rates, whereas the crop production index exhibits only a marginal, statistically insignificant impact. These findings underscore the grave threat that climate change poses to public health in sub-Saharan Africa—exacerbating food insecurity, facilitating disease outbreaks, and intensifying extreme weather events. To mitigate these adverse outcomes, we advocate for substantial investments in climate-resilient health infrastructure, expanded health financing, and the adoption of sustainable agricultural practices tailored to the region's diverse agro-ecological zones.

Keywords: Carbon damage, Climate change, Hausman test, Mortality rate, Pooled mean group

JEL Classification: H51; C23; Q54; N37

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1. Introduction

frica is especially susceptible to climate change because of a confluence of social, economic, and geographic factors. The continent's varied topography includes coastal regions vulnerable to sea-level rise, tropical zones exposed to increased rainfall and flooding, and dry and semi-arid areas prone to droughts. Moreover, millions of livelihoods depend on climate-sensitive industries such as pastoralism, fisheries, and rain-fed agriculture, making them highly vulnerable to climate variability. This vulnerability is exacerbated by limited adaptive capacity, which hampers the ability of many African nations to respond effectively to climatic shocks. Widespread poverty, inadequate infrastructure, and weak institutional frameworks further compound this susceptibility. As climate change renders food and water scarcer, increases the incidence of vector-borne diseases such as malaria, and intensifies heat-related illnesses, the negative impacts on health outcomes are disproportionately severe. Consequently, mortality rates in Africa serve as a crucial metric for assessing the severity of climate change consequences, offering a clear illustration of the intersection between socioeconomic and environmental vulnerabilities across the continent.

Mortality rates in several sub-Saharan African countries are strongly influenced by extreme weather events and shifting climate patterns. Research indicates that heat waves, droughts, and heavy rains contribute to differing mortality outcomes in countries such as Kenya, Mali, and Malawi. In Kenya—where HIV/AIDS prevalence is high—droughts and cold snaps have been associated with elevated death rates (**Bakshi et al., 2019**). Conversely, Mali and

Malawi have experienced lower mortality during cold spells, underscoring regional variations in the effects of climate change (**Bakshi et al., 2019**). Although the link between climate change and mortality is increasingly acknowledged, significant gaps persist in the literature, especially regarding country-specific analyses in Africa. Much existing research focuses on global or regional trends, often neglecting the complex interactions among geographic exposure, socioeconomic disparities, and health-system constraints that shape national health outcomes. Additionally, studies rarely consider the compounded impacts of environmental stress, poverty, and conflict in the most affected nations.

By examining mortality rates in sub-Saharan Africa's most climate-impacted countries, this study aims to address these gaps and enhance understanding of the underlying mechanisms. It seeks to identify the primary drivers of climate-related deaths—such as food insecurity, extreme weather, and disease transmission—and to draw policy implications for reducing health risks and strengthening resilience among vulnerable populations. Specifically, the analysis focuses on a select group of countries chosen for their high mortality burden and pronounced susceptibility to climate change over the period 1995–2020. Through this targeted approach, the study endeavors to support the design of effective interventions that mitigate climate-related health hazards and promote adaptive capacity.

The remainder of the paper is organized as follows. Section 2 reviews the relevant theoretical frameworks and empirical literature. Section 3 outlines the methodology. Section 4 presents the empirical results and discussion. Finally, Section 5 concludes the paper.

2. Literature Review

2.1 Theoretical Framework

Climate change, which has largely been attributed to human activities, has been identified as one of the major causes of mortality in various regions and subregions, including sub-Saharan Africa (SSA) today (**IPCC, 2013**). The Anthropogenic Global Warming (AGW) theory posits that activities such as the burning of fossil fuels, hunting, deforestation, and industrialization have increased greenhouse gas concentrations in the atmosphere, causing global temperatures to rise. The resulting climate change has serious detrimental effects on human health, especially among vulnerable populations with very low adaptive capacity, such as those living in SSA (**Johnson et al., 2021**). Sub-Saharan Africa is particularly susceptible to these effects, as the region already experiences some of the highest levels of poverty, disease, and environmental degradation in the world. The impacts of climate change in this region are expected to exacerbate existing health challenges, ultimately leading to increased mortality rates. Mathematically, we can have that:

$$heout = f\left(cc\right) \tag{1}$$

Where HEOUT is health outcomes or health challenges (i.e. infant mortality, under-5 mortality, maternal mortality and lifetime risk of maternal death) and CC is climate change. Since measures of climate change are rising carbon damage (CD), shifting patterns of rainfall /precipitation (PREC), health expenditure per capita (HEXPC) and crop production index (CPI), then equation 1 can be re-written as:

$$heout = f\left(cc, humid, h\exp c, cpi\right) \tag{2}$$

2.2 Empirical Review

Recent empirical studies continue to demonstrate a strong and complex link between climate change and mortality outcomes in Sub-Saharan Africa (SSA), particularly through the transmission of climate-sensitive diseases and environmental stressors. **Diouf et al. (2020)** explored the connection between climate variability and malaria prevalence in West Africa, highlighting a significant correlation between rising temperatures, increased rainfall, and malaria incidence. Their findings suggest a non-linear relationship, with the strongest correlation occurring at moderate levels of temperature and precipitation. Notably, the study emphasized that malaria cases peak during the rainy season, pointing to the influence of additional variables—such as population density, urban overcrowding, and limited access to health care—that amplify climate-related mortality risks in malaria-endemic regions.

Complementing this, **Adzawla et al. (2019)** applied the Environmental Kuznets Curve hypothesis to examine the relationship between economic growth and greenhouse-gas (GHG) emissions in SSA, using data from 2009 to 2012. Although they found a short-run link between economic growth and environmental quality, the study did not identify a clear turning point for GHG emissions. Importantly, they reported that long-run exposure to global GHG emissions negatively impacts economic productivity, which indirectly exacerbates vulnerability to climate-related health outcomes and limits adaptive capacity.

Evidence from developed contexts also supports the critical role of temperature variations in influencing mortality. For instance, **Ishigami et al. (2017)** conducted a nationwide ecological study in Japan to assess how ambient temperature affects cardiovascular disease (CVD) mortality. Their time-series analysis across 47 prefectures revealed seasonal and regional disparities, with elderly women in northern areas disproportionately affected during colder months. This underscores the importance of context-specific climate-health dynamics and reinforces the call for tailored public health interventions, such as early-warning systems, improved housing, and climate-resilient healthcare infrastructure.

More recent studies in SSA have extended these findings. **Ayeb-Karlsson et al. (2021)** emphasized the psychosocial and health consequences of climate-induced displacement in regions like the Horn of Africa, where recurrent droughts and floods have intensified food insecurity and contributed to malnutrition-related mortality. Similarly, **Ngaruka et al. (2022)** utilized satellite-based climate data and mortality statistics from Eastern Africa to establish a robust association between prolonged heatwaves and spikes in all-cause mortality, especially among children under five and the elderly, suggesting that vulnerable populations bear the brunt of climate stress.

Recently, **Hanson et al. (2024)** examined the impact of heat exposure on perinatal mortality across 16 hospitals in SSA, finding that short-term heat exposure significantly increased the risk of intrapartum stillbirths, particularly during the hottest seasons. Similarly, **Traoré and Tetka (2025)** highlighted that climate change directly affects population health through climate-related diseases and indirectly through disruptions in food availability and agriculture.

3 Methodology

The panel Autoregressive Distributed Lag (PARDL) approach is employed to examine the impact of climate change variables on mortality rate in selected sub-Saharan Africa. Since the variables deployed are characterised by large cross-sectional units (N) and time series (T), the non-stationary heterogeneous panel is considered appropriate, as this enables us to capture the various characteristics of studied countries by estimating various short-run and long-run dynamics in the relationship between financial development and inclusive growth, such that the specifications regarding cross-sectional slope coefficients are easily accommodated. More so, the PMG estimator, which captures the inherent heterogeneity short-run dynamics and error variances but restricts the long-run coefficient to be homogenous across the sub-Saharan African countries' climate change variables and mortality rate is employed. This selection is further premised on its flexibility and capacity to account for more heterogeneous dynamics in the slope coefficients completely. Thus, we specify the generic representation of PARDL, enabling the capturing of the dynamic heterogeneity of financial development and inclusive growth of the examined 15 sub-Saharan African countries below.

$$mr_{it} = \sum_{j=1}^{p} \alpha_{1ij} mr_{i,t-j} + \sum_{j=0}^{q} \delta'_{1ij} X_{i,t-j} + \mu_{1i} + \varepsilon_{1it} \quad (3)$$

where ing_{it} denotes inclusive growth index, X_{it} is a $k \times 1$ vector of the independent variables, δ_{ij} is a $k \times 1$ vector of coefficients, α_{ij} are scalars while μ_i is the country-specific effect. Equation (1) is further reparametrised into the error correction equation to capture the short-run dynamics as well as the deviation from the equilibrium state, simultaneously.

$$\Delta mr_{it} = \sum_{j=1}^{p-1} \alpha^{*}_{ij} mr_{i,t-j} + \sum_{j=0}^{q-1} \delta'^{*}_{ij} \Delta X_{i,t-j} + \gamma_{1i} \left(mr_{i,t-1} - \lambda'_i X_{it} \right) + \mu_i + \varepsilon_{it} \quad (5)$$

The error correction term parameter is $\gamma_i = -\left(1 - \sum_{j=1}^{p} \alpha_{ij}\right)$ establishing any long-run equilibrium nexus, while $\lambda_i = \sum_{j=0}^{q} \delta_{ij} \Big/ \left(1 - \sum_{k} \alpha_{ik}\right)$ captures the long-run estimates; and $\alpha^{*}_{ij} = -\sum_{r=j+1}^{p} \alpha_{ir} \quad (j = 1, \ldots, p-1)$; and

$\delta_{ij}^{*} = -\sum_{r=j+1}^{q} \delta_{ir} \quad (j = 1, \ldots, q-1)$ are the short-run estimates. The vectors of explanatory variables in the study include annual change in temperature (TEMP), annual carbon damage (CD) and crop production index (CPI) in the sub-Saharan African countries.

4 Results and Discussion

Table 1 presents the summary statistics for key variables influencing mortality rates: carbon damage (CD), crop production index (CPI), GDP per capita (GDPPC), health expenditure per capita (HEPC), humidity (HUM), and mortality rate (MR). These statistics reveal notable disparities in socioeconomic and environmental conditions across countries, which have significant implications for health outcomes.

A clear pattern of inequality is evident in the GDP per capita and health expenditure figures. The mean GDP per capita is $2,815.97, while the median is substantially lower at $925.85. This suggests that a small number of wealthy countries with very high incomes are skewing the average, while most nations fall below the global mean. Similarly, the mean health expenditure per capita is $168.55, compared to a median of only $48.88. This disparity highlights the limited investment in health in many lower-income countries, which is often associated with poorer health outcomes and higher mortality rates.

Carbon damage also shows considerable variation, ranging from 0.00 to 2.88 percent of gross national income (GNI). This suggests that while some countries experience negligible environmental damage, others face severe economic losses due to pollution and climate change. Countries with heavy industrial activity and weak environmental regulations—such as some rapidly developing nations—are likely to fall at the upper end of this range, which may, in turn, contribute to health problems and increased mortality.

The mortality rate (MR) ranges from 13.90 to 225.90 deaths per 1,000, reflecting stark differences in public health performance across countries. This range captures both highly developed nations with advanced healthcare systems and under-resourced regions where access to basic medical services remains a challenge. The standard deviations of GDPPC (3,672.43), HEPC (196.90), and HUM (487.38) further confirm the high variability in economic and environmental conditions, which likely contribute to disparities in health outcomes.

Table 1: Descriptive Statistics

	CD	CPI	GDPPC	HEPC	HUM	MR
Mean	0.86	90.73	2815.97	168.55	190.49	103.96
Median	0.82	93.29	925.85	48.88	65.19	113.40
Maximum	2.88	178.33	16747.36	791.53	2020.00	225.90
Minimum	0.00	29.01	0.00	4.49	18.12	13.90
Std. Dev.	0.48	21.75	3672.43	196.90	487.38	50.83
Skewness	0.78	-0.21	1.92	1.22	3.47	-0.28
Kurtosis	4.42	3.59	6.11	3.40	13.04	2.32
Jarque-Bera	58.58	6.78	321.28	69.63	1953.35	10.20
Probability	0.00	0.03	0.00	0.00	0.00	0.01

Moreover, the skewness and kurtosis statistics shed further light on the underlying distributions. GDP per capita, health expenditure, and carbon damage all exhibit positive skewness, suggesting that while the majority of countries record low to moderate values, a small subset reports exceptionally high levels. Humidity, with a skewness of 3.47 and kurtosis of 13.04, reflects extreme outliers in regions characterized by persistent tropical rainfall. The significant

Jarque–Bera test results across most variables indicate departures from normality, implying that subsequent econometric analyses may necessitate appropriate data transformations to ensure robust inference.

These empirical patterns align with broader international evidence. Elevated carbon damage has been linked to increases in respiratory and infectious diseases, thereby contributing to higher mortality rates. Conversely, greater GDP per capita and health expenditure tend to correlate with lower mortality, although the effectiveness of resource allocation remains a critical moderating factor. Enhanced crop production supports food security and improves child survival rates, whereas excessive humidity creates favorable conditions for vector-borne disease transmission. Collectively, these descriptive statistics underscore the multifaceted determinants of mortality and highlight the imperative for context-specific policy interventions that address economic, environmental, and healthcare disparities.

Table 2: IPS Unit Root Test Result

IPS UNIT ROOT			
Variable	**Level**	**First difference**	
MR	-0.8804	-3.9800***	I(1)
HUM	-4.217***	-6.138***	I(0)
HEPC	-1.9390**	-4.0785***	I(0)
GDPPC	1.7139	-2.5641***	I(1)
CPI	-1.3980	-6.5556***	I(1)
CD	-2.764**	-5.175***	I(0)

Note: ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

Table 3: Estimation results for climate change and mortality rage nexus

	cd	***Hum***	***Hepc***	***Lcpi***
δ^{cd}	0.430 (0.017)			
δ^{hum}		-0.058 (0.021)		
δ^{hepc}			0.972 (1.652)	
δ^{lcpi}				2472 (1.691)
λ^{cd}	-11.403*** (2.258)			
λ^{hum}		0.912*** (0.230)		
λ^{hepc}			-16.098*** (1.824)	
λ^{lcpi}				-7.540* (4.163)
γ^{ECT}	-0.018 (0.284			

Note: The values in parentheses are the standard errors. The $\delta s'$ are for the short run while the $\lambda s'$ are for the long run. ***, ** & * imply significance at the 1%, 5% and 10% levels, respectively

4.2 Discussion of Findings

Table 4 presents the Pooled Mean Group (PMG) estimation results, which assess the long- and short-run impacts of climate and economic variables on mortality rates. In the long run, carbon damage (CD) exhibits a statistically significant negative effect on mortality (coefficient = –11.403, $p < 0.01$), suggesting that countries with higher measured carbon damage paradoxically report lower mortality rates. This counterintuitive finding departs from the prevailing literature, which generally associates environmental degradation with increased mortality—for example, **Zhou et al. (2021)** and **Amegavi et al. (2020)** document positive pollution–mortality linkages in vulnerable populations. A plausible explanation is that nations registering high carbon damage tend also to be more industrialized and to possess stronger healthcare systems capable of mitigating pollution's adverse health effects.

Humidity (HUM) exerts a positive and highly significant long-run effect on mortality (coefficient = 0.912, $p < 0.01$), consistent with studies by **Yoon et al. (2014)** and the **IPCC (2022)**, which highlight that elevated humidity fosters the transmission of vector-borne and infectious diseases—such as malaria and dengue—in tropical climates. Health expenditure per capita (HEPC) demonstrates a robust negative long-run impact on mortality (coefficient = –16.098, $p < 0.01$), reaffirming the widely held view that greater health financing improves population health and longevity. This finding mirrors those of **Bokhari, Gai, and Gottret (2007)** and **Farag et al. (2009)**, who report that increased health investment yields significant reductions in mortality in low- and middle-income contexts. The crop production index (LCPI) also has a negative long-run effect on mortality (coefficient = –7.540, $p < 0.10$), indicating that enhanced agricultural productivity—through improved nutrition and food security—contributes to lower mortality rates, as emphasized by **FAO (2020)** and **Smith and Haddad (2015)**.

In the short run, most variables—including CD, HEPC, and LCPI—do not register statistically significant effects on mortality, with the notable exception of humidity, which unexpectedly bears a negative short-run coefficient (–0.058, $p = 0.005$). This may reflect transient mitigating factors, such as seasonal rainfall reducing heat- or dust-related illnesses. The error-correction term (ECT) is negative, in line with theory, but statistically insignificant, indicating a weak and gradual reversion from short-run deviations to the long-run equilibrium. Finally, a Hausman test statistic of 0.41 supports the PMG estimator's assumptions, validating the homogeneity of long-run relationships across countries while allowing for heterogeneous short-run dynamics. These results reinforce the critical role of sustained investments in healthcare and agriculture, while also underscoring the complex and sometimes unexpected health implications of environmental stressors and regional climate variability.

5 Conclusion and Policy Recommendation

The aim of this study was to elucidate the multifaceted health impacts of climate change in Sub-Saharan Africa, with particular emphasis on the mortality burdens borne by infants, children, and pregnant women. To achieve this, we employed a mixed-methods approach that combined descriptive statistical analysis of key socioeconomic and environmental indicators—including carbon damage, humidity, health expenditure, and crop production—with advanced econometric modeling. Specifically, pooled mean group (PMG) estimations were used to distinguish long-run from short-run effects, while skewness, kurtosis, and unit-root tests informed the data's distributional and stationarity properties. We further contextualized our quantitative findings through a targeted review of recent empirical studies on vector-borne diseases, extreme weather events, and health-system capacities across high-burden SSA countries.

Our results confirm that rising humidity and extreme weather variability exert a significant positive effect on mortality, largely by amplifying vector-borne disease prevalence and undermining food and water security. Although the long-run coefficient for carbon damage appeared paradoxically negative—likely reflecting stronger healthcare infrastructures in more industrialized SSA economies—its interpretation underscores the importance of health-system resilience. Health expenditure per capita and crop production indices both demonstrated clear negative associations with mortality, reinforcing the critical role of public investment in healthcare and agricultural productivity. In the short run, only humidity exhibited a statistically significant effect, suggesting transient seasonal dynamics.

In conclusion, the study reveals that without substantial enhancements to climate-resilient health infrastructure, targeted agricultural support, and sustained increases in health financing, Sub-Saharan Africa's most vulnerable populations will continue to face escalating mortality risks. Policymakers must therefore integrate climate adaptation into health-sector planning, secure international climate finance, and expand social protection mechanisms to mitigate the region's growing vulnerability to climate-related health hazards.

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