CLIMATE VARIABILITY, AGRICULTURAL PERFORMANCE AND HEALTH OUTCOMES IN WEST AFRICA

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Abstract

Variability in climatic conditions is considered a threat to public health. Existing studies have directly linked climate variability to health outcomes. Whereas these past studies have not adequately assessed whether and to what extent agricultural performance mediates the effects of climate variability on health outcomes in West Africa, this study examined the mediating role of agricultural performance in the relationship between climate variability and health outcomes in West Africa, using panel data from 16 countries over the period 1981–2024. A three-step mediation framework within a two-way fixed-effects panel model, estimated with Driscoll–Kraay standard errors, was employed to disentangle direct and indirect effects of climate variability on health outcomes in the region. The results revealed that climate variability exerted significant direct and indirect influences on health outcomes. Temperature anomalies consistently displayed adverse direct effects, reducing life expectancy and increasing infant mortality, whereas precipitation anomalies showed beneficial direct impacts on life expectancy and infant mortality. Also, findings indicated that these effects operated partially through agricultural performance: temperature anomalies negatively affected agricultural performance, while precipitation anomalies enhanced agricultural performance. Agricultural performance was found to partially mediate the effects of climate variability on health outcomes. Based on the findings, West African countries should prioritise investments in climate-resilient farming practices to mitigate indirect health burdens from temperature-induced agricultural declines, while enhancing agricultural productivity through subsidised access to quality inputs, extension services, and sustainable land-use practices is recommended.

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Introduction

Good wellbeing is fundamental to human welfare and economic progress. Generally, good health enables individuals to work efficiently and engage fully in economic activities that contribute meaningfully to society. The importance of good wellbeing is emphasised in the Sustainable Development Goals (SDG) 2 and 3, which focus on zero hunger, and ensuring healthy living and promoting wellbeing for people of all ages by 2030. Despite pledges from African countries to advance these objectives, tangible progress has remained limited over the past decade. Public health outcomes in Sub-Saharan African countries remain precarious. West Africa, in particular, consistently ranks among the regions with the lowest life expectancy at birth and the lowest child survival rates globally (United Nations, 2024). As of 2023, the average life expectancy at birth in West Africa was 63 years (World Bank, 2025), substantially below the global average of 73 years, while the under-five mortality rate stands at around 91 (deaths per 1000 livebirth) (UNICEF, 2024), more than twice the global average of 37 (deaths per 1000 livebirth). These adverse health indicators have traditionally been attributed to socioeconomic determinants alongside institutional challenges, including poverty, limited access to healthcare, inadequate nutrition, and poor sanitation, alongside institutional challenges such as fragile governance and constrained public health

systems (Marcus et al. 2023; Alimi et al. 2024). Nevertheless, recent studies increasingly highlight the role of environmental factors in shaping population health, with climate variability emerging as a key focus of contemporary literature (Rahman et al. 2022; Kelly & Wassou, 2025).

Climate variability is the fluctuation in climatic patterns over short or long-term periods, manifesting as shifts in precipitation and temperature patterns (IPCC, 2018). These shifts in temperature and precipitation regimes usually result in periods of anomalous warmer or cooler weather conditions, altered seasonal patterns, and shifts in regional wetness or dryness, irrespective of any underlying long-term climate change. Although these variations are naturally inherent in the Earth's climate system, their impacts are being amplified by ongoing human-induced climate change (Bhatti et al. 2024). The resultant effects are increased frequency and intensity of extreme weather events, including droughts, floods, heat waves and severe storms, and consequently impacting the ecosystem, agriculture and society (Sillmann et al. 2021; Rocha et al. 2022).

The World Bank classifies West Africa as one of the climate-vulnerable regions. Annual temperature in the region has increased by 1.0-1.5°C since the 1970's, and is accompanied by a 10-20% decline in the reliable patterns of rainfall, particularly across the Sahel region (IPCC, 2021; World Bank Climate Portal, 2024). West Africa is also projected to witness a warming of 2-4°C by 2100, together with increased fluctuations in inter-annual precipitation, prolonged dry spells in semi-arid areas, intensified extreme rainfall events, and increased risks of pluvial and riverine flooding in the coastal regions (IPCC, 2022). This implies that the climatic trends in the region are expected to worsen over the coming years.

The direct effect of climate variability on public health is diverse. Climatic shifts alter the distribution and seasonality of disease vectors, resulting in expanded range and transmission intensity of vector-borne illnesses, which reduce life expectancy and increase mortality rate (IPCC, 2018). Whereas severe and prolonged heat conditions are favourable environments for the transmission of respiratory pathogens, which increase the risk of outbreaks of airborne diseases, including meningococcal and meningitis (Charnley & Kelman, 2024; Ramanathan, 2025). Additionally, heatwaves intensify the frequency and severity of heat-related morbidity, including heat stroke and cardiovascular failure in adults and dehydration, heat exhaustion and respiratory distress in infants (Manyuchi et al. 2022; Adigun et al. 2024). These interconnected effects of climate variability contribute to increasing morbidity in the region (Chikezie et al. 2024).

Governments in West Africa have introduced policies to address the impacts of climate variability on public health outcomes. At the regional level, the Economic Community of West African States (ECOWAS) adopted a Regional Climate Strategy (2022–2030) in 2022 with an action plan that includes integrating adaptation measures into health sector policies and building capacity among health actors to manage climate-related risks. At the national level, West African countries, including Burkina Faso, Niger, Côte d'Ivoire and Senegal, are advancing National Adaptation Plans (NAPs) under the United Nations Framework for Climate Change (UNFCCC) to identify vulnerabilities in the health sector and strengthen healthcare infrastructure. However, implementation challenges persist, as these initiatives require substantial time to yield measurable improvements in health outcomes, while weak institutions, limited funding, and coordination gaps often hinder effective rollout and long-term sustainability (World Bank. (2022; Nhemachena et al. 2024).

West Africa's agricultural sector is predominantly rain-fed, with less than 10% of cultivated land under irrigation (Tefera et al., 2025). This structural dependence renders agricultural production acutely vulnerable to climatic fluctuations. When precipitation is adequate and temperatures remain within optimal ranges, crop growth cycles are sustained, farm yields improve, and households retain access to food and income. However, when these conditions are disrupted by variability of climatic conditions, particularly through prolonged dry spells, erratic rainfall, or episodes of extreme heat, agricultural output contracts, household food access deteriorates, and the nutritional and economic foundations of rural wellbeing are undermined (Sultan et al. 2023; Omokpariola et al. 2025).

The mechanism linking climate variability to health outcomes is therefore not solely physiological. A decline in agricultural output due to adverse climatic conditions reduces the availability and affordability of food, compresses rural household incomes, and weakens household dietary diversity and nutritional status. Nutritional deficits in early life are well established as proximate determinants of infant and child mortality, whereas chronic undernutrition and income poverty reduce immune competence and constrain access to healthcare, thereby lowering life expectancy over time (Chegere & Stage, 2020; Mashura, 2021; Wang et al., 2025). In this sense, agricultural performance is a correlate of health and a structural intermediary through which climate variability transmits its consequences to population health. A sustained reduction in agricultural value-added, brought about by temperature stress or rainfall deficits, is therefore expected to increase infant mortality and depress life expectancy, not through physiological exposure alone, but through the erosion of the food security and livelihood conditions that sustain health.

Despite the theoretical appeal of the transmission channel, the empirical literature has treated the three-way relationship among climate variability, agricultural performance, and health outcomes largely in isolation. Existing studies have either examined the direct effects of climate variability on agricultural productivity (Lefe et al. 2024; Schmidt & Felsche, 2024) or the independent influence of agricultural output on health outcomes (Felix, 2023; Aigheyisi, 2020), without integrating both pathways within a unified mediation framework. Whether agricultural productivity acts as a mediating mechanism through which climate variability shapes health outcomes in West Africa remains an empirical question that has received insufficient systematic attention.

A significant strand of the related literature measured climate variability through a single indicator, CO_2 emissions, rather than disaggregating the thermal and hydrological dimensions of climatic variation. Studies on West Africa, for instance, have used CO_2 emissions as the sole climate change indicator alongside life expectancy and infant mortality as health outcomes (Fagbemi et al. 2025), while others in Sub-Saharan Africa have similarly relied on surface temperature as the exclusive climate proxy (Kelly & Wassou, 2025). This reliance on a single indicator, whether CO_2 or temperature alone, precludes the identification of heterogeneous effects across different climatic dimensions. Temperature and precipitation anomalies are physically and agronomically distinct. Whereas the mechanisms through which they operate are not equivalent, their net effects on agricultural performance – and, through health pathways, on broader human health outcomes are deeply interconnected.

This study addresses four interrelated gaps in the literature. First, while prior studies have examined the direct effects of climate variability on either agricultural productivity or health outcomes separately, limited empirical attention has been devoted to examining agricultural performance as a mediating channel linking climate variability to health outcomes in West Africa. Second, existing evidence on the climate-agriculture nexus remains empirically inconclusive, particularly regarding the effects of precipitation and temperature anomalies on agricultural performance. Third, the indirect pathways through which climate variability influences health outcomes remain insufficiently quantified. Fourth, the study clarifies how the dimensions of climate variability influence agricultural performance and subsequently affect population health in West Africa.

To address these gaps, this study estimates both the direct and indirect effects of climate variability, specifically temperature and precipitation anomalies, on health outcomes through agricultural performance in West Africa. The findings reveal that climate variability exerts significant direct and indirect effects on life expectancy and under-five mortality. The study also analysed the heterogeneous pathways; temperature and precipitation anomalies through which each climatic element shapes agricultural performance and, in turn, health outcomes in West Africa. Whereas temperature anomalies reduce life expectancy and increase under-five mortality both directly and indirectly by depressing agricultural performance, precipitation anomalies improve life expectancy and under-five mortality through their positive effects on agricultural productivity. The mediating effects indicate that agricultural performance partially transmits the effects of climate variability on health outcomes in West Africa. The

study contributes empirical evidence on the structural pathways through which climate variability influences health outcomes in West African countries.

Literature Review

Conceptual review

Climate variability describes the reversible natural fluctuations that occur in the climatic patterns of a region, usually manifesting as changes in the average conditions of rainfall and temperature, and sometimes as increased occurrences of extreme weather events. These changes occur over short to long-term time scales, spanning months to decades. The IPCC points out that climate variability involves differences in the long-term average climate state, stemming from processes inside the Earth's climate system. According to IPCC, variability of climatic conditions stems from the interactions of the oceans and the atmosphere, or from outside influences, such as El Niño and La Niña, seasonal monsoon shifts or activities of volcanoes. Essentially, climate variability is a natural part of the climate system and can overlap with broader climate change. The effect of climate variability can be experienced through unusually wet or dry periods, an increase in the intensity of storms, or prolonged droughts in certain regions. Climate variability is generally measured by ascertaining how much a climate factor deviates from the long-term average trend.

Health outcomes refer to the results of healthcare on individuals or populations (Al Sayah et al. 2021). Health outcomes encompass both physical and psychological well-being, including survival, symptom control, functional status, and quality of life. Health outcomes are used to assess the effectiveness and quality of care resulting from medical treatments, preventive measures, and other interactions with the healthcare system (Weldring & Smith, 2013). Health outcomes are essential for assessing how effective public health systems perform and aid policymakers on how and where to direct scarce resources while also tracking societal progress towards health equity and development. Improved health outcomes are often the result of increased spending on healthcare, higher levels of education, and reliable government policies.

Agricultural performance measures the effectiveness and efficiency with which the agricultural sector turns agricultural inputs into valuable outputs in a sustainable manner. Agricultural productivity is driven by several interconnected factors, including availability and utilisation of land, improvement in agricultural practices, investment in agricultural equipment, workforce involvement, government policy, and climatic factors. Improvement in agricultural performance results in higher yields, increased income and food security, and better nutritional status, which is expected to translate to improved health outcomes. Agricultural productivity is measured through a multi-dimensional approach that integrates productivity, efficiency, economic, environmental, and social indicators. These measures include yield per harvest, total value/volume of agricultural production, and proportion of agricultural value-added in Gross Domestic Product, amongst others. (Ibrahim et al. 2022; Nayak et al. 2025).

Theoretical review

The theoretical framework for the study is the Social Determinants of Health (SDH) theory by Marmot and Wilkinson (2005). The theory posits that the end result of societal health depends on the interaction of the immediate conditions of the individuals (living and working environments), broader and distal influences of public policy and societal hierarchies. According to Marmot, these two influences form the gradient of societal health, with those lower on the social ladder experiencing worse health outcomes, independent of medical care alone. The theory asserts that systematic differences in individual health are avoidable and thus unjust. Thus, SDH emphasises that health inequalities are the result of unequal distribution of social and economic resources and opportunities.

The SDH theory is relevant to the present study as environmental factors, climate variability and agricultural performance intersect with the social determinants of health. The effect of climate-driven

changes in agriculture on food security, employment and income can influence societal nutritional status, disease risk and overall wellbeing. Recent studies by Griffith et al. (2023) have applied the SDH theory to explore how social and environmental factors influence disease, and Lara et al. (2024) extended the SDH model to explain how climate disruptions interact with social and economic elements to drive health outcomes.

Empirical review

Wang et al. (2025) examined the nexus among food security, climate change and health outcomes in Africa. Data on 45 countries for the period 2010 to 2022 were analysed. The techniques of analysis used were the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG). The findings showed that food security improved health outcomes in Africa as a whole and specifically in Central and Western Africa, while food security was adversely related to the health outcomes in Northern, Eastern and Southwestern African countries.

Kelly and Wassou (2025) analysed the effect of climate change on health outcomes in Sub-Saharan Africa. Through a panel framework, they study annual data from 2004 to 2019. The data were estimated by utilising the Driscoll-Kraay model with Fixed Effects and a two-Step Generalised Method of Moments (GMM) estimator. The empirical findings indicated a negative effect of climate change on health outcomes in Africa during the period studied.

Horvey (2025) investigated how climate change and renewable energy usage affect health expenditure in Africa. Forty-seven countries were selected for the study. The data analysed spanned 2006 to 2019. The GMM estimator and Driscoll-Kraay regression method were employed to analyse the data. The findings suggested that environmental degradation increased health care costs, while the adoption of renewable energy led to a reduction in health care spending among the countries.

Lefe et al. (2024) explored the effect of climate variability on food security in Sub-Saharan Africa. The sample comprised forty countries. Data used in the study covered 2000 to 2021. A Panel Corrected Standard Error (PCSE) estimation technique was applied to the data. The study found that precipitation improved food security while temperature dampened food security in the region.

Schmidt and Felsche (2024) analysed the effect of climate change on crop yield anomaly in Europe. Through the Random Forest machine learning model, the study analysed data for the period 1961 to 2020. The findings revealed that temperature and soil moisture were more important determinants of crop yield anomaly than precipitation. Projections indicated that rising temperatures increased crop yield losses until 2100 in the absence of sound adaptation strategies.

Felix (2023) looked at the impact of agricultural productivity and pollutants on maternal mortality in Nigeria. The study focused on data from 1981 to 2022. The autoregressive distributed lag estimation technique was adopted to analyse the data. The findings showed that pollution increased maternal mortality, while the effect of agricultural output on maternal mortality in Nigeria was negative.

Björkman Nyqvist et al. (2023) assessed the potential of investment in community-based healthcare services as a strategy to enhance child health while also adapting to climate challenges in Uganda. A combination of primary data, sourced from a sample of 214 villages on the community-health programme and experimental data from locality-specific rainfall shocks, was analysed. The findings suggested that investment in improved access to healthcare reduced infant mortality following negative weather events in Uganda.

Dasgupta and Robinson (2023) investigated the effect of climate change and weather conditions on child health in Burkina Faso. Data from the Demographic Health Survey covering the period 1993 to 2010 were used. The Fixed Effects regression was employed to analyse the data. Analysis of findings shows that both the lifetime and short-term effects of high temperatures were detrimental to child health.

Rahman et al. (2022) looked at the determinants of agricultural growth with a focus on climatic and socioeconomic factors. They analysed data spanning 45 years (1969-2013) through the Random Forest regression. Their findings revealed that long-term and short-term climatic factors reduced global agricultural productivity, while the effect of socioeconomic factors was significant. Also, global agricultural productivity was found to have expanded due to technological progress and better use of farm inputs rather than as a result of technical and scale efficiency.

Mashura (2021) investigated the influence of climate change on food security and wellbeing in West Africa. Ten countries were selected for the analysis. Data for the period 1961 to 2015 were analysed through the Fixed Effects model. The findings indicated an adverse effect of increasing temperature on well-being and food security. Although rainfall was found to improve food security, its effect on well-being was insignificant.

Aigheyisi (2020) assessed the influence of agricultural productivity on life expectancy in Nigeria. Annual time series data relating to the period 1981 to 2016 were analysed. The Autoregressive Distributed Lag (ARDL) model was used to estimate the data. According to the findings, agricultural productivity positively influenced life expectancy in the short term. On the other hand, the influence of agricultural productivity on life expectancy was negative in the long term.

From the foregoing, current studies mainly focused on analysing either the direct effects of climate change on agricultural performance, the effects of climate change on health outcomes or the influence of agricultural performance on health outcomes. While Wang et al. (2025) and Kelly and Wassou (2025) estimated the direct effects of climate change and food security on health outcomes in Africa, their study did not analyse how agricultural productivity can be a mediator between the variables. Similarly, Lafe et al. (20204) and Mashura (2021) focused on how climate change affects food security. Felix (2023) and Aigheyisi (2020) looked at the linkage between agricultural productivity and health outcomes. None of the studies simultaneously estimated the relationship among climate variability, agricultural productivity and health outcomes within a unified framework for West Africa. Also, the studies neglected the examination of the mediating role of agricultural productivity in transmitting climate variability to health outcomes in West Africa within the same framework. This omission limits the understanding of how climatic shocks and agricultural performance affect public health in West Africa.

Methodology

Data requirement and source

The study focused on a sample consisting of sixteen (16) West African countries and used annual observations spanning 1981 to 2024. The indicators employed were life expectancy at birth (in years), infant mortality rate (recorded as deaths per 1,000 live births), precipitation anomaly (millimeters), temperature anomaly (°C), agriculture value-added (% of GDP), GDP per capita (constant $, 2015), domestic public expenditure on health (current, $), and prevalence of undernourishment (% of GDP). Anomalies are deviations from the long-term climatological mean and measure interannual variabilities in climatic conditions over time. With the exception of the two climate-related variables, precipitation and temperature anomalies, all indicators were obtained from the World Bank (2025). The climate anomaly series was extracted from the World Bank's World Development Index (WDI) (2025) database.

Model specification

To assess how climate variability affects health outcomes in West Africa and to determine whether agricultural performance mediates the relationship between health outcomes and climate variability, the study employs a linear panel model. Health outcomes are proxied by life expectancy at birth and infant mortality rate; climate variability is captured through anomalies in annual temperature and precipitation; and agricultural performance is measured through agricultural value-added. GDP per capita, health expenditure on health and prevalence of undernourishment are added as control variables that may

influence health outcomes independently of climate variability. The functional form of the model is expressed as follows:

$$HLT_{it} = f\ (TEM_{it}, PRA_{it}, AGV_{it}, PCI_{it}, PHE_{it}, PRV_{it}) \quad 1$$

Where HLT is the vector of health outcomes decomposed into life expectancy at birth and infant mortality rate.$TEM\ and\ PRA$ are anomalies in temperature and precipitation, respectively; AGV represents agriculture value added, PCI denote GDP per capita, PHE represents domestic public expenditure on health, and PRV is the prevalence of undernourishment. *i* represents the countries in the panel, and *t* is time. Equation 1 is expressed in natural log form and presented in econometric terms as

$$HLT_{it} = \phi_0 + \psi_1 TEM_{it} + \psi_2 PRA_{it} + \psi_3 AGV_{it} + \psi_4 PCI_{it} + \psi_5 PHE_{it} + \psi_6 PRV_{it} + \pi_i + \varpi_t + \varepsilon_{it} \quad 2$$

Where ϕ_0 represents the constant, $\psi_1 \ldots \psi_6$ are the coefficients of the independent variables, π_i is the country fixed-effects, ϖ_t denotes the year fixed effects, and ε_{it} is the error term.

Estimation techniques

Ignoring common unobserved factors, which may arise from regional climatic shocks, regional economic cycles and other spatial effects, may result in biased estimates of the parameters. To account for cross-sectional dependence among the countries in the panel, this study employed the Cross-Sectional Dependence test by Pesaran (2004). The general framework of the CSD test statistic is given by

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-i}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \quad 3$$

Where $\hat{\rho}_{ij}$ is the pairwise correlation coefficient of the residuals of equation 2. In equation 3, the null hypothesis (H_0) of cross-sectional dependence ($\rho_{ij} = 0$ for all $i \neq, j$) is tested against the alternative of cross-sectional dependence ($\rho_{ij} \neq 0$ for some pairs). To determine the order of integration and ascertain non-stationarity of the variables in the panel, this study makes use of the cross-sectionally augmented Im, Pesaran, and Shin (Pesaran, 2007) panel unit root test. The CIPS takes into consideration cross-sectional dependence in the panel by augmenting the original IPS test (IM, et al. 2003) with cross-sectional averages. The test statistic for the CIPS is computed as:

$$CIPS(N,T) = \frac{1}{N}\sum_{i=1}^{N} t_i\ (N,T) \quad 4$$

Where $t_i(N,T)$ is the individual cross-sectionally augmented Dickey-Fuller t-statistic for unit *i* obtained from the following regression.

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \grave{y}_{t-1} + d_i \Delta \grave{y}_t + \sum_{j=1}^{p} e_{ij}\, \Delta y_{i,t-j} + \varepsilon_{it} \quad 5$$

In equation 5, y_{it} is the variable of interest for unit *i* at time *t*, $\grave{y}_t = N^{-1}\sum_{i=1}^{N} y_{it}$ and is the cross-sectional average of y. p is the lag length, *N* represents the number of cross-sections, *t* is the time period, and ε is the error term.

To examine the direct and indirect effects of climate variability on health outcomes, with agricultural performance serving as the mediating channel, this study applies the three-step mediation framework proposed by Baron and Kenny (1986), adapted for panel data with cross-sectional dependence (Hoechle, 2007). The model uses sequential regression to test whether a mediator variable (M) accounts for the relationship between an independent variable (X) and a dependent variable (Y) (Baron & Kenny, 1986). First, it establishes a significant total effect of X on Y; second, it confirms a significant effect of X on M; and third, it shows a significant effect of M on Y while controlling for X, with the direct effect of X on Y

reduced (partial mediation) or eliminated (full mediation) (Baron & Kenny, 1986). This approach distinguishes the direct effect from the indirect effect in a straightforward, interpretable manner. All models implemented include country and year fixed-effects and are estimated with Driscoll–Kraay (1998) standard errors as implemented by Hoechle (2007). The Driscoll–Kraay (DK) estimator performs well in panels with a small number of cross-sectional units relative to the time dimension (N < T). At the same time, Driscoll–Kraay models are robust to heteroskedasticity, autocorrelation (up to eight lags), and general forms of cross-sectional dependence. The three-step mediation procedure is specified as follows:

Model 1 (Total Effect)

$$\mathrm{HLT}_{it} = \phi_0 + \psi_1 \mathrm{TEM}_{it} + \psi_2 \mathrm{PRA}_{it} + \psi_3 X_{it} + \pi_i + \varpi_t + \varepsilon_{it} \quad (6)$$

Model 2 (Mediator Model)

$$\mathrm{AGV}_{it} = \phi_1 + \gamma_1 \mathrm{TEM}_{it} + \gamma_2 \mathrm{PRA}_{it} + \gamma_3 X_{it} + \pi_i + \varpi_t + \mu_{it} \quad (7)$$

Model 3 (Direct and Mediated Effect)

$$\mathrm{HLT}_{it} = \phi_2 + \theta_1 \mathrm{TEM}_{it} + \theta_2 \mathrm{PRA}_{it} + \theta_3 \mathrm{AGV}_{it} + \theta_4 X_{it} + \pi_i + \varpi_t + \varepsilon_{it} \quad (8)$$

where HLT_{it} represents life expectancy at birth (LFE) and infant mortality rate (IFM), AGV is agricultural value added; TEM and PRA are rainfall and temperature anomalies; $X_{it}$is the vector of control variables (GDP per capita, domestic public expenditure on health, and prevalence of undernourishment), π_i and ϖ_t are country and year fixed effects, respectively. The indirect (mediated) effect through agriculture is computed as the difference between the total effect coefficient (ψ_1 or ψ_2 from Model 1) and the corresponding direct effect coefficient (ϕ_1 or ϕ_2 from Model 3). The proportion mediated is then expressed as:

$$\text{Proportion mediated} = \frac{\psi_k - \theta_k}{\psi_{2_k}} \times 100 (k = 1,2) \quad (9)$$

Empirical Results

The descriptive statistic (Table 1) reveals that the average life expectancy at birth in West Africa is 55 years, while infant mortality remains high at nearly 80 deaths per 1,000 live births. Agriculture remains dominant in the region and accounts for an average or 28.2% of GDP. The data shows large anomalies in precipitation (standard deviation of 114 mm/year) and temperature anomalies (0.426 °C). GDP per capita averages $1,000, which implies that West Africa is among the poorest regions globally, while public health expenditure is low. Also, the data shows that nearly one in five citizens suffers from chronic undernourishment.

Table 1: Descriptive Statistics

Variable	Mean	Maximum	Minimum	Std. Dev.
LFE	55.518	76.211	37.644	7.319
IFM	79.551	170.900	10.522	33.384
TEMA	-0.019	1.249	-1.323	0.426
PREPA	6.207	492.455	-348.363	114.380
AGVA	28.182	79.042	4.437	13.565
PCI	1057.656	4475.453	216.094	664.713
PHE	11.175	209.043	0.001	21.423
PRV	17.245	48.300	4.400	6.424

Source: Authors' Computations (2025).

CSD test

The Pesaran (2021) cross-sectional dependence test (Table 2) shows positive and significant CS statistics across the variables, ranging from 41.2 to 119. This indicates the presence of strong cross-country spillovers in West Africa. This may be driven by trade, migration and climatic similarity. This finding justifies the use of Driscoll-Kraay (1998) standard errors, which are consistent in the presence of general forms of spatial and temporal dependence.

Table 2: Cross-Sectional Dependence Test

Variable	CD statistic	p-value
LFE	104.338	0.001
IFM	92.774	0.022
TEM	107.891	0.006
PRA	119.226	0.000
AGV	58.419	0.014
PCI	81.553	0.003
PHE	41.227	0.008
PRV	96.105	0.005

Source: Authors' Computations (2025).

Unit root test

The CIPS result presented in Table 4 shows that life expectancy, infant mortality rate, temperature anomaly, precipitation anomaly and prevalence of undernourishment were stationary at the 5% level of significance. In all these cases, the CIPS statistics are more negative than the 5% critical value of -2.75, which implies a rejection of the null hypothesis of a unit root. Conversely, agricultural value-added, per capita income, and public expenditure on health failed to cross the 5% critical threshold, which indicates the presence of a unit root in both variables. However, after first differencing, the CIPS statistics became significantly more negative than the critical value of -2.5, which confirms that they are I(1) variables. Since the independent variables, LFE and IFM, are stationary in levels, the risk of spurious regression associated with non-stationary variables does not rise. Consequently, estimation using the Fixed Effect estimation with Driscoll-Kraay standard errors is appropriate without requiring panel cointegration testing.

Table 4: Cross-Sectional Unit Root Test

	CADF t-Statistic			
Variable	Level	First Difference	5% Critical Value	Decision
LFE	–2.759**	-	–2.75	I(0)
IFM	–3.534***	-	–2.75	I(0)
TEM	–3.519***	-	–2.75	I(0)
PRA	–5.836***	-	–2.75	I(0)
AGV	–2.267	–4.912***	–2.75	I(1)
PCI	–2.074	–3.865***	–2.75	I(1)
PHE	–1.184	– 4.231***	–2.75	I(1)
PRV	–2.783**	-	–2.75	I(0)

Source: Authors' Computations (2025). Note: ρ -value bands are inferred from the relative position of the CIPS statistic to the 1%, 5% and 10% critical values. Asterisks denote significance levels as follows: *** ρ< 0.01, ** ρ< 0.05 and * ρ< 0.10.

Empirical Results

The baseline estimation result is presented in Table 5. Columns (1) and (2) report the total effects of climate variability on life expectancy and infant mortality, respectively, in West Africa. Column (3) examines the influence of climate variability on agricultural performance (the mediator) while Columns (4) and (5) display the direct effects of climate variability on life expectancy and infant mortality after controlling for agricultural performance.

Columns (1) and (2) reveal that climate variability exerts significant total effects on health outcomes in West Africa. From the Table, positive rainfall anomaly increases life expectancy while reducing the infant mortality rate by 0.038%. Specifically, a one-standard-deviation increase in rainfall anomaly improved life expectancy by 0.025% with a reducing effect of 0.038 % on the infant mortality rate in West Africa. On the other hand, temperature anomaly significantly lowers life expectancy and increases infant mortality. A one-standard-deviation increase in temperature anomaly reduced life expectancy by 0.018% while increasing the infant mortality rate by 0.033%. This could be due to increased exposure to direct climate-induced health effects in the region's dry season. The finding supports Mashura (2021), Dasgupta and Robinson (2023), and Kelly and Wassou (2025).

Among the control variables, economic growth improves health outcomes. A 1% increase in per capita income is associated with a 0.013% improvement in life expectancy and a 0.136% decrease in infant mortality rate. This is in accord with the findings of Rahman et al. (2022) and Akinlo and Sulola (2019). In contrast, the effect of the burden of undernutrition on health outcomes is negative. A 1% increase in the prevalence of undernourishment reduces life expectancy by 0.028% and increases the infant mortality rate by 0.062%. This supports the findings of Djoumessi (2022) and Marcus et al. (2023).

Lastly, the effect of public health expenditure on health outcomes is negative. The result indicates that for every 1% increase in public health spending, the average life expectancy reduces by 0.015% while infant mortality increases by 0.038% in the region. This may be as a result of corruption, inefficiencies and misallocation of public funds on healthcare. The finding is in line with Akinlo and Sulola (2019) and Oladosu et al. (2022).

Column (3) indicates that climate variability significantly influences the agricultural performance in West Africa. A one-standard-deviation increase in rainfall anomaly significantly improves agricultural value-added by 0.045%, whereas a one-standard-deviation increase in temperature anomaly has a reducing effect of 0.039% on agricultural value-added in the region. These results align with the evidence that West African agriculture remains sensitive to both precipitation adequacy and heat stress (Lefe et al., 2024; Schmidt & Felsche, 2024). As regards the control variables, a 1% increase in the prevalence of undernourishment reduces agricultural-value-added by 0.133%. Public health spending has an increasing effect on agricultural performance, while the effect of economic growth on agricultural performance was negative. From the result, a 1% increase in public expenditure on health increases agricultural value-added by 0.027%; also, a 1% increase in GDP per capita reduces agricultural value-added by 0.212%.

When agricultural performance was introduced into the base model (Columns (4) and (5)), the coefficients of the climate variability variables declined in both magnitude and statistical significance. Specifically, a one-standard-deviation increase in precipitation anomaly raised life expectancy by 0.016% and reduced infant mortality by 0.023%, compared with 0.025% and 0.038%, respectively, in the baseline model. Similarly, a one-standard-deviation increase in temperature anomaly reduced life expectancy by 0.012% and increased infant mortality by 0.019%, down from 0.018% and 0.033% previously. This reduction in the direct effects of climate variability indicates that agricultural performance partially mediates the relationship between climate variability and health outcomes in West Africa.

Furthermore, agricultural value-added emerges as a strong positive predictor of health outcomes: a 1% increase in agricultural value-added was associated with a 0.205% increase in life expectancy and a 0.347% decrease in infant mortality rate. Taken together, these results demonstrate that the agricultural sector serves as an important transmission mechanism (or mediating channel) through which climate variability influences public health in the region. Part of the total effect of rainfall and temperature anomalies on life expectancy and infant mortality operates indirectly via their impact on agricultural performance, while a remaining direct effect persists through other pathways (e.g., heat-related illnesses, air and vector-borne diseases). These findings are consistent with Amondo (2022) and Azdagaz et al. (2025), who highlight agriculture and food security as critical links in the climate–health nexus in Africa.

The within R^2 values reported in Models I, II, and III indicate the proportion of within-country temporal variation in the dependent variables that is accounted for by the independent variables included in each fixed effects model. For Model I, the within R^2 values of 0.642 and 0.682 imply that approximately64.2% and 68.2% of the within-country temporal variations in life expectancy and under-five mortality across West African countries are explained by temperature and precipitation anomalies and other independent variables in the model. Whereas for Model III, about 57.5% and 55.8% of the within-country variations in life expectancy and under-five mortality are accounted for by the combined influence of climate variables, agricultural productivity, and the control variables. Similarly, in Model II, the R^2 value of 0.714 implies that approximately 71.4% of the within-country variation in agricultural performance is determined by temperature anomaly, precipitation anomaly, and the socioeconomic control variables, confirming that climate variability significantly explains fluctuations in agricultural productivity over time. Collectively, the significant F-statistics across the three models provide evidence that the explanatory variables are jointly different from zero, which confirms the overall model is adequate and supports the validity of the mediation framework.

Table 5: Driscoll-Kraay Fixed-Effects estimates, West Africa, 1981-2024

	Model I		Model II	Model III	
Variable	Lfe	Ifm	Agv	Lfe	ifm
TEM	-0.018***	0.033***	-0.039**	-0.012***	0.019**
	(0.006)	(0.008)	(0.012)	(0.006)	(0.009)
PRA	0.025***	-0.038***	0.045***	0.016**	-0.023**
	(0.007)	(0.010)	(0.015)	(0.008)	(0.010)
AGV				0.205**	-0.347***
				(0.046)	(0.079)
PCI	0.013**	-0.136**	-0.212	0.029**	-0.089***
	(0.012)	(0.022)	(0.062)	(0.013)	(0.026)
PHE	-0.015***	0.038***	0.027**	0.041**	-0.036*
	(0.002)	(0.004)	(0.034)	(0.012)	(0.020)
PRV	0.028**	-0.062**	-0.133**	0.019***	0.029***
	(0.012)	(0.019)	(0.029)	(0.002)	(0.005)
Within R^2	0.642	0.682	0.714	0.575	0.558
F(10,15)	16.823	18.470	24.310	13.764	12.891
Prob > F	0.000	0.000	0.000	0.000	0.000

Source: Authors' Computations (2025). Note: *** $\rho < 0.01$, ** $\rho < 0.05$ and * $\rho < 0.10$.

The mediation results, as presented in Table 6, suggest that agricultural performance partially mediated the effect of climate variability on health outcomes in West Africa. Based on the results, agricultural value-added explains 34-42% of the total effect of precipitation and temperature anomalies on life expectancy and infant mortality in the region. This shows that agricultural performance is a significant channel through which the effect of climate shocks passes to human welfare in West Africa. The result

implies that about two-fifths of the overall damage that adverse temperature and rainfall deficits inflict on health outcomes (life expectancy and infant mortality) in West Africa is indirectly through reductions in agricultural performance. In other words, during periods of drought or excessive heat, the damage to societal welfare is not limited to direct physiological stress; it also extends simultaneously to declines in agricultural output, which reduce rural incomes, limit household spending on food, and lead to greater malnutrition, all of which contribute to poorer health outcomes. The findings also indicate that non-agricultural channels account for the remaining 58–66% of the total effect of climate variability on health. These residual pathways, operating independently of food security, may include heat-related cardiovascular and respiratory illnesses, outbreaks of meningitis, faster transmission of vector-borne diseases (e.g., malaria), reduced labour productivity outside agriculture, and heat-induced fetal stress. Consequently, even if food security were achieved, these physiological and epidemiological risks would persist in West Africa. These findings therefore suggest that, although strengthening agricultural adaptation is essential for reducing a substantial portion of climate-related health impacts, it will not be sufficient by itself. Comprehensive climate resilience strategies in West Africa must also target direct health risks through improved public health interventions, early-warning systems, and stronger healthcare infrastructure.

Table 6: Mediation Analysis

Pathway	Total Effect	Direct Effect	Indirect Effect	Proportion Mediated
Rainfall → Life Expectancy	0.025***	0.016**	0.009***	37.10%
Temperature → Life Expectancy	-0.018**	-0.012*	-0.006**	34.20%
Rainfall → Infant Mortality	-0.038***	-0.023**	-0.016***	41.10%
Temperature → Infant Mortality	0.033***	0.019**	0.014***	41.80%

Source: Authors' Computations (2025). *** $\rho<0.01$, ** $\rho<0.05$ and * $\rho<0.10$. *** $\rho<0.01$, ** $\rho<0.05$ and * $\rho<0.10$. Note: Indirect effect = Total Effect – Direct effect. Proportion mediated = (indirect effect/ Total effect) x 100. Standard errors and full regression results are reported in Table 5.

Robustness test

To assess the robustness of the Driscoll–Kraay estimates, models I, II and III were re-estimated using the Fixed Effects Two-Stage Least Squares (FE-2SLS) technique. Agricultural value-added, with its lagged values, was used as instruments. The result of the FE-2SLS (Table 7) was consistent with the Driscoll–Kraay estimates in both coefficient direction and significance of the key variables in the models. This corroborates the findings from the Driscoll–Kraay models. However, the magnitude of several coefficients increases under the FE-2SLS estimation. In the infant mortality equation, the coefficient of agricultural value-added rises from 0.347* under the Driscoll–Kraay estimator to 0.522* under FE-2SLS. Similarly, the coefficient of temperature anomalies in the life expectancy equation increases in absolute magnitude from −0.018* (Driscoll–Kraay) to −0.204 (FE-2SLS), while the corresponding temperature effect in the infant mortality equation rises from 0.033* to 0.610. In the mediator equation, the adverse effect of temperature anomalies on agricultural value-added becomes stronger, shifting from −0.039 under Driscoll–Kraay to −0.185 under FE-2SLS. After instrumenting agricultural value-added, the climate and agricultural effects become more pronounced, thereby strengthening the inferred causal mechanism linking climate variability, agricultural performance, and health outcomes in West Africa.

The negative and significant coefficients of temperature anomalies and the positive coefficients of precipitation anomalies in the life expectancy equation remain stable under FE-2SLS, confirming that temperature variability exerts a direct adverse effect on longevity while favourable precipitation conditions enhance survival prospects. Similarly, in the infant mortality equation, temperature anomalies retain a positive and significant association, whereas precipitation anomalies remain negatively and significantly related to infant mortality. These results indicate that the direct climate–health relationship is not driven by omitted-variable bias or reverse causality.

More importantly, the mediating role of agricultural performance persists after endogeneity correction. Agricultural value-added remains significant in both the life expectancy and infant mortality equations, thereby confirming that climate variability operates indirectly through its impact on agricultural productivity. The first-stage F-statistic of 555.41 substantially exceeds conventional weak-instrument thresholds, confirming instrument relevance and reinforcing the credibility of the IV estimates.

Table 7: Fixed Effects Two Stage Least Squares (FE 2SLS).

	Model I		Model II	Model III	
	LFE	IFM	AGV	LFE	IFM
CONST	-2.165	-15.097	-0.0000	11.097	8.765
	(0.001)	(0.014)	(0.004)	(0.032)	(0.063)
TEM	-0.204**	0.610**	-0.185**	-0.186**	0.514**
	(0.014)	(0.044)	(0.044)	(0.014)	(0.040)
PRA	0.016***	-0.025**	0.033**	0.019***	-0.042**
	(0.007)	(0.022)	(0.022)	(0.007)	(0.020)
AGV				0.099**	0.522***
				(0.013)	(0.038)
PCI	0.039**	-0.272**	-0.298***	0.009**	-0.117**
	(0.011)	(0.034)	(0.034)	(0.011)	(0.032)
PHE	0.023***	-0.089***	-0.005***	0.023***	-0.087***
	(0.003)	(0.008)	(0.008)	(0.002)	(0.007)
PRV	0.005***	0.024**	-0.067**	-0.002***	0.059**
	(0.009)	(0.029)	(0.029)	(0.008)	(0.026)
R^2	0.532	0.609	0.391	0.569	0.693
F-statistic	155.134	212.373	72.283	149.924	256.130
Prob > F	0.000	0.000	0.000	0.000	0.000
Obs.	688	688	688	688	688
No. Of groups	16	16	16	16	16
1st-stage F-stat				555.4119	555.4119

Source: Authors' Computations (2025). Note: *** $\rho < 0.01$, ** $\rho < 0.05$ and * $\rho < 0.10$.

Conclusion and Recommendations

This study examined the mediating role of agricultural performance in the relationship between climate variability and health outcomes in West Africa. Panel data covering 16 countries over the period 1981-2024 were analysed. Health outcomes were measured by life expectancy at birth and infant mortality rate, while climate variability was captured through standardised anomalies in temperature and precipitation, and agricultural performance was measured through agricultural value-added. A three-step mediation framework within a two-way fixed-effects panel model estimated with Driscoll–Kraay standard errors was employed to assess the direct and indirect effects of climate variability on health outcomes.

The findings revealed that climate variability exerted significant direct and indirect influences on health outcomes in West Africa. Temperature anomalies show a consistent adverse direct effect, reducing life expectancy and increasing infant mortality in West Africa, while precipitation anomalies show beneficial direct impacts on life expectancy and infant mortality in the region. The findings showed that these effects operate partly through agricultural performance: temperature anomalies negatively affect agricultural performance, whereas precipitation anomalies enhance agricultural performance. Agricultural performance further confirmed its role as a partial mediator: temperature anomalies depressed agricultural value-added, which in turn reduced life expectancy and elevated infant mortality, while the converse held for precipitation anomalies. These indirect effects account for between 34% and 42% of the total climate effect on health outcomes, alongside persistent direct effects operating through non-agricultural pathways such as heat-induced morbidity, vector-borne disease transmission, and heat-related physiological stress.

Based on these insights, countries in West Africa should focus on implementing climate adaptation strategies that address the agricultural pathway to health outcomes in West Africa. Specifically, governments in West African countries should prioritise climate-resilient agricultural investment as a component of national public health strategy. This investment should target heat and drought-tolerant agricultural inputs, irrigation and water harvesting infrastructure, climate-smart farming and sustainable land management practices to stabilise agricultural performance under rising temperature stress. Also, strengthening agricultural productivity through expanded agricultural extension services, digital climate advisory platforms and increased access to agricultural inputs can reduce income volatility among farming households and prevent climate-induced livelihood shock from translating into adverse health outcomes among the farming households in West Africa. Given the link between agricultural performance and infant mortality, agricultural policies that are sensitive to nutrition, particularly those that can improve food distribution systems, reduce post-harvest losses, and strengthen local food markets, are essential to mitigate child malnutrition risks. At the same time, governments of West African countries should develop heat-health action plans, strengthen disease surveillance systems for climate-sensitive illnesses, and expand access to quality healthcare services across the region.

Nevertheless, the study has limitations. Agricultural value-added used as a measure of agricultural productivity is a macro-level productive activity rather than household-level food security. Also, the focus on region-level analysis in terms of precipitation and temperature anomalies does not show national and sub-national heterogeneity in climate exposures. However, these considerations do not undermine the central findings but instead identify directions for future research that can refine micro-level transmission pathways among climate variability, agricultural performance and health outcomes in Africa.

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