CLIMATE RISKS AND SMES SUSTAINABILITY IN BAUCHI AND GOMBE STATES. DOES EARLY WARNING SYSTEM SERVICE MATTERS?

***Usman Ahmed Hafiz**

****Murtala Garba**

*****Ladan Sirajo**

Abstract

Small and medium-sized enterprises (SMEs) have continuously been at the forefront of supporting inclusive and sustainable economic growth in both developed and developing economies. However, SMEs are more vulnerable to climate risks due to their limited resources and low resilience capability. Despite the vulnerability, there are limited empirical studies regarding the impact of some particular hazards on the sustainability of these enterprises in Sub-Saharan Africa. This paper explores how floods, droughts, and heatwaves impact the sustainability of SMEs in the Northeast of Nigeria, Bauchi and Gombe State, and evaluate whether Early Warning Systems (EWS) moderate the linkages. The data were collected using structured questionnaires from 380 SMEDAN-registered SMEs and analysed based on structural equation modelling (SEM) with AMOS 26.0. Findings indicate that heatwaves ($\beta = -0.610$, $p < 0.01$), droughts ($\beta = -0.451$, $p < 0.01$), and floods ($\beta = -0.228$, $p < 0.01$) significantly undermine SME sustainability, with the model explaining 68% of variance ($R^2 = 0.680$). The results of moderation indicate that EWS have a significant negative effect on drought (= -0.233, p = 0.01) and heatwaves (= 0.608, p = 0.01), but not floods (CR = -1.336, p = 0.182), indicating that the EWS alleviates the impact of negative weather but not floods. Basing this research on the theory of Climate Change Adaptation and Sustainable Livelihoods Framework, EWS is found to be more effective in response to certain hazards. It advises that SMEs should consider weather warnings as strategic intelligence and policymakers should develop hazard-specific warning systems.

Keywords: Climate risk, Drought, Flood, Heatwave, Early warning, Sustainability

1.0 INTRODUCTION

Small and medium-sized enterprises (SMEs) have continuously been in the forefront supporting inclusive and sustainable economic growth in both developed and developing economies. Although, no evidence attributes the unprecedented economic development of developed countries solely to the support towards well-built SME sector (Endris & Kassegn, 2022). It is apparent these countries continue to sustain and prioritize SMES (Polas, Raju, Muhibbullah, & Tabash, 2022). Taking cognizance of the significance of this sector, most developing economies have recognized SMEs sector as essential driver for their sustainable development (Pu, Qamruzzaman, Mehta, Naqvi & Karim, 2021).

In Nigeria, SME sector is a central to its economic growth and development goal. The sector is the largest employer of labour with 82% workforce (Gumel, 2023). Over the past 50 years many

*Department of Accounting and Finance Technology, Abubakar Tafawa Balewa University, Bauchi, Nigeria
Email: elhafizlame@gmail.com
**Department of Accounting and Finance Technology, Abubakar Tafawa Balewa University, Bauchi, Nigeria.
Email: mourgab79@gmail.com
**Department of Accounting and Finance Technology, Abubakar Tafawa Balewa University, Bauchi, Nigeria.
Email: sirajoladan84@gmail.com

programmes were put in place to support the growth of the sector (Garba, Salleh, Hafiz, Nasidi & Abu Bakar, 2022; CBN, 2020). These efforts resulted to 41.5 million registered MSMEs and 73,081 SMEs (SMEDAN, 2021). However, 50% of these SMEs experienced a momentary shutting down in their early stages (between 1-12 months), while 95% permanently closed down before reaching five years of operation (Moniepoint, 2023). As a result, many households undergo economic and social hardships such as poverty, social vises, economic dependence and the decline in the country's GDP. (Garba, Salleh, & Hafiz, 2024). Moreover, KPMG (2023) report shows the Nigeria's unemployment rate as 37.7%, which is among the highest in the world. This condition can partly be attributed to the sustainability failure of small businesses.

Climate risks are mostly concerned to SMEs' sustainability because of the consequences of desertification, drought, flood and heat waves on their smooth operations (Aina et al., 2024; Garba et al., 2022b). For example, climate disaster could alter demand and supply-chain of SMEs, limit their operations, cause financial losses, and damage their physical infrastructures. Hence, climate risks challenge the capabilities and capacities of small and medium enterprises (SMEs) to withstand their increasing frequency and destructive power (Kapitsa, 2020).

Garba, Salleh, Hafiz & Bakar (2022) reported that sustainability index scores Nigeria's 49.3 that ranked her 160 out of 166 available data of member states of the United Nation's sustainable development index. However, this score is below the Sub Sahara Africa region's average of 53.1.

Northeast region of Nigeria has undergone convergence of manifold of climate change related challenges (Oyewo, 2023), resulting to loss of lives, low productivity and dislodgments (International Crisis Group, 2023). Moreover, the region has been struggling with huge number of socio-economic challenges, including poverty, insecurity, and limited infrastructure. OCHA (2021) highlighted that besides the attributed human cost, infrastructures were also severely disrupted. Climate change has made these challenges worse, leading to more frequent and severe risks of droughts, floods, and other extreme weather calamities, posing significant risks to the sustainability of Small and Medium-sized Enterprises (SMEs) in the region. This condition has contributed to the region's cycle of poverty and vulnerability, making resilience building complicated. According to the World Bank (2021), climate change inaction could cost Nigeria between $100 to $460 billion US Dollars by 2050.

Literature shows that small and micro enterprises risk mitigation ability is an enabler to the achievement of organizational goals and lasting sustainability (Virglerova, Conte, Amoah & Massaro, 2020). However, SMEs need expertise, effective communication and risk intelligence strategies to guard against or lessen loss and damages from risks. For instance, an effective climate risk mitigation strategy like Early Warning Systems (EWS) can improve businesses resilience and break the cycle of business failure by communicating risks alert information in advance. According to Hafiz, Salleh, Garba and Rashid (2022) enhancing SMEs capacity to manage risk can significantly reduce their vulnerability. Supporting this, Aina, Thiam, and Dinar (2023) maintained that implementation of climate change adaptation strategies is a crucial component of enhancing the economic and business sustainability of SMEs. Tianrong and LiChu (2024) have successfully explored how the relationship between learning behaviors and learning outcomes is influenced by early warning system. SMEs are therefore admonished to embrace risks in their strategic plan for their survival. While most researches on climate risks focuses on agriculture and ecosystems, there is a gap in understanding its effects on business sustainability (Barnes et al., 2020; Mbanasor et al., 2024; Elisha, Patrick & Jude, 2023). Additionally, existing climate risk studies primarily examines direct relationships, uses secondary data (Churchill et al., 2024; Olawuyi & Mushunje, 2024), and concentrates on other geographical regions (Akuwudike, Mac-Ozigbo & Igbokwe-Ibeto, 2020; Elisha et al., 2023), neglecting the Northeast region of Nigeria and possible influence of early warning system that may affect the influence of climate risks on SMEs (Hölzel et al., 2011).

Hence, this study seeks to advance general understanding of the complex interaction between climate risks, early warning system, and sustainability among SMEs in Bauchi and Gombe states. By exploring these relationships through moderation analysis, this study aims to inform evidence-based interventions that promote SMEs survival and enhance their overall climate risks resilience in Nigeria.

2.0 LITERATURE REVIEW

2.1 Theoretical Conceptualization

2.1.1 Sustainability

Measuring sustainability is critical to SMEs' decisions. This sector plays a significant role in sustaining Nigeria's economic growth and creating employment opportunities for the largest share of its population. However, a generally accepted definition of sustainability remains contested among scholars, attracting over seventy dissimilar definitions (Yusoff et al., 2018). The initial emergence of the concept of sustainability related to development was in the report about the limits to growth published in 1972 (Gunilla, 2014; Wanner, 2015). It later appeared in the Brundtland Report of 1987, published in 1989 by the World Commission on Environment and Development (WCED). Therefore, sustainability refers to achieving current development without compromising future needs (Barkemeyer et al., 2014; Yusoff et al., 2018). This definition implies the need to achieve economic objectives without damaging the present or future environment (Garba et al., 2022).

Previous studies have measured the sustainability concept from divergent perspectives. For instance, Gross-Golacka et al. (2020) viewed sustainable businesses as those that prioritize environmental and social responsibility principles in their managerial plans and integrate them into their business plans. Caputo et al. (2018) suggested that, at the primary level, sustainable development requires an environmental sustainability plan, sound economic coordination, agile organization, and a skilled workforce. Ayanda and Laraba (2011) opined that sustainability is the ability of a business to transform and minimize detrimental ecological and social effects in its operating environment. According to Garba et al. (2022), sustainability is the ability of companies to "maintain their business activities, retain their original ownership, and remain financially solvent. Hence, this proposed study measures sustainability from the perspective of business continuity and financial solvency among SMEs in Bauchi and Gombe States, Northeast Nigeria.

2.1.2 Climate risks

Climate risks are climate change induced catastrophes as result of atmospheric and environmental disruptions that persist for a decade or more. According to Oyewo (2023), these risks encompass natural upheavals like gulley erosion and landslides, wildfires, strong windstorms and thunderstorms, earthquakes, tsunamis and volcanic eruptions. Akuwudike, Mac-Ozigbo and Igbokwe-Ibeto (2020) identified additional global environmental risks such as global warming, extremities of temperatures, rainfall, snowfall, desertification, drought, distorted ocean currents, strong windstorms, and thunderstorms. These risks can lead to emergence of new diseases affecting both humans and plant species which are responsible for the poor or low agricultural yields, thick dust haze, fog and midst. Additionally, risks cause direct business interruptions and additional indirect effects on supply chain (Quan, John & Mark, 2022) like disruptions of transportation system.

Some of the reasons for massive failure of SMEs in Nigeria and specifically this study area (Bauchi and Gombe States), were due to lack of adequate knowledge of impact of climate risks on their survival. However, SME proprietors are expected to be resilient to catastrophes in order to ensure their sustainability. Scholars' have noted that drought, flooding, market disruption and increased operational costs are some of the characteristics associated with climate risks that affect businesses (Aina, Ayinde, Thiam, & Miranda, 2024; Garba et al., 2022; Ogbuabor & Egwuchukwu, 2017).

2.2 Hypotheses Development

2.2.1 Drought

Growing evidence suggests that severity and frequency of drought are consequences of climate change. Drought disaster is a complex, recurring natural hazard characterized by a prolonged period of below-

average rainfall leading to water shortages and environmental stress (Meza et al., 2021). Drought can have significant socio-economic, environmental, and agricultural impacts, affecting ecosystems, water resources, food security, and livelihoods of various households and the population at large (Olawuyi & Mushunje, 2024). Scholars have conceptualized drought into Meteorological, Agricultural, Socio-Economic and Hydrological droughts, each with distinct effects on households with different livelihood activities.

Meteorological drought is characterized by a prolonged period of below-average precipitation in an area. It is the most commonly recognized type of drought and typically assessed based on meteorological data such as rainfall patterns, temperature, and evaporation rates (Van Loon, 2015). This contributes to agricultural drought and water stress, which affect crop yield, reduce income, and trigger food insecurity conditions (Chivangulula, Amraoui, & Pereira, 2023). Agricultural drought occurs when there is a lack of moisture in the soil, affecting plant growth, crop yields, and livestock grazing conditions. This can be triggered by land use and land cover changes (Bahta & Myeki, 2022). Prolonged periods of below-average rainfall can lead to soil moisture deficits, affecting crop growth and agricultural productivity, while increased temperatures can also accelerate evaporation rates, leading to increased soil moisture deficits and reduced agricultural productivity. In addition, land degradation, deforestation, and changes in land use and land cover can simultaneously alter local climate conditions, reduce soil moisture levels, and exacerbate drought conditions. Socio-economic drought refers to the impact of reduced water availability and agricultural productivity on human populations, communities, and economies (Olawuyi & Mushunje, 2024). This often leads to water shortages and reduced agricultural productivity, which consequently leads to food insecurity, poverty, unemployment, and economic hardship, thereby exacerbating socio-economic vulnerability (Mbanasor et al., 2024). Hydrological drought refers to the impact of reduced water availability in rivers, lakes, reservoirs, and groundwater sources on water supply, water quality, and changes in aquatic ecosystems (Bahta & Myeki, 2022). Findings from the study of Churchill et al. (2024) revealed that an increase in extreme climate risk in the preceding period is related with a decrease in the likelihood of self-employment in the subsequently period. Based on this relationship, the present study assumes that:

H1: Drought negatively influences SMEs sustainability in Bauchi and Gombe States

2.2.2 Flood

Floods are described as the overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Flood is a temporary outpouring of all or part of the plain or temporary localized inundation occurring when surface water runoff moves via surface flow, gutters and sewers (Cirella & Iyalomhe, 2018). It may be referred to as a comparatively high flow of water that overtops the natural or artificial banks in any reach of stream. Flooding is also regarded as an overflow or inundation that comes from a river or other body of water and causes or threatens to damage (Glago, 2020). Its occurrence is usually due to the increase in volume within a water body which causes it to exceed drainage channel capacity and overflow its bounds (Glago, 2019). Flooding in various parts of Nigeria have forced millions to relocate, destroyed businesses, polluted water resources and increased health risk (Akuwudike et al., 2020). Moreover, extreme rain falls incidences have reduced the contributions of businesses to the economy in respect to employment, income, and investment not least by diverting funds from long-term investments to short-term crisis management (Churchill et al., 2024). Similarly, literature suggests that flood shocks negatively influence health and employment (Churchill et al., 2024; Mishra, 2021). Therefore, in view of prevailing literature conclusions this study hypothesizes that:

H_2: Flood negatively influences SMEs sustainability in Bauchi and Gombe States.

2.2.3 Heat wave

The World Meteorological Organization (WMO) defines refers heat wave as a period in which the daily highest temperature for more than five days consecutively exceeds the common maximum temperature by 9 degrees Fahrenheit (IFRC, 2016). In most countries, heat waves incidences have significantly increased that seriously caused public health issues, low crop yields, and socioeconomics downturn. Chen et al. (2022) have identified heat wave as a key factor contributing to unemployment, poverty and

general inequality among people. Excess heat wave increases SMEs employees' work-related risks and vulnerability (ILO, 2019). These risks can range from minor health issues like headache, blighted cognition; depress emotions to severe loss of productivity, heat stroke, dehydration and death (Chen et al., 2022). While consistent studies' findings documented a negative effect of extreme heat on employees' productivity (Somanathan et al., 2021; Zhang et al., 2018), there is dearth of studies that examine the effect of heat wave on SMEs sustainability. Hence, this study follows the general literature conclusions and hypothesizes that:

H_3: Heat wave negatively influences SMEs sustainability in Bauchi and Gombe States.

2.2.4 Early Warning Systems,

Early warning systems (EWS) are defined as "A set of capacities needed to generate and disseminate timely and meaningful warning information; to enable individuals, communities and organizations threatened by hazards to prepare and to act appropriately the possibility of harm or loss" (UNISDR, 2009). Expert such as climatologists, meteorologists, geologists viewed EWS as a linear chain from the risk analysis to possible risk alert dissemination to the most likely vulnerable groups, which is mostly regarded to as "End-to-End" (or E2E) model (Ali & Aziz, 2024). Ahsan et al. (2020) maintained that EWS can effectively improve the preparedness of individuals and businesses before any misfortune incidence. This preparation provides an opportunity for these groups to reduce the severity of risk incidence by enhancing their coping mechanisms and adaptive capacity (Glantz & Baudoin, 2014; Hall, 2007). Notable scholars have highlighted the importance of EWS for risk management (Cuevas 2012; Ghoneem & Elewa, 2013; Fakhruddin & Schick, 2019). Early Warning Systems have the ability to improve information dissemination with local communities, and can fast tract effective emergency measures during heat waves, droughts and floods, thereby reducing the impact of these climate risks on economic activities (Baudoin et al., 2014). This idea is in line with the climate change adaptation theory that assumed disaster as not just a natural incident but also a consequence of human activity that requires holistic approach of recognizing the complex societal and political factors that shape the management and response to the disaster (Guddo, 2024; Olawuyi & Mushunje, 2024). Therefore, effective EWS are not just an approach to climate risk mitigation but crucial framework for strengthening of small businesses resilience and sustainability in the economy. This leads to the moderation hypothesis:

H_4: EWS moderates the relationship between Climate risks and SMEs sustainability: EWS reduces the negative influence of drought, flood and heat wave on SMEs sustainability in Bauchi and Gombe States.

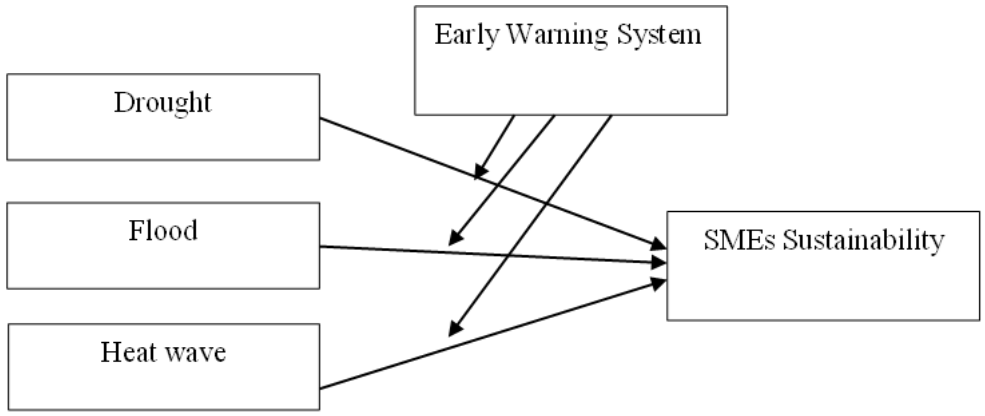

Figure 1: Conceptual Framework

Source: Researchers, 2024

2.3 Empirical Studies

2.3.1 Climate risks and SMEs sustainability

Barnes et al. (2020) assessed the Social determinants of adaptive and transformative responses to climate change in Papua New Guinean. The study found that social organization encourages both

adaptive and transformative actions. Churchill et al. (2024) using household panel data from the Household, Income and Labour Dynamics in Australia (HILDA) survey and satellite re-analysis temperature and rainfall data, examine the impact of weather shocks on entrepreneurship. The study measure temperature and rainfall shocks at the postcode level, and found that an increase in weather shocks in the previous period is associated with a decline in the probability of self-employment in the next period. The study also found suggestive evidence that health, cognitive functioning and economic activity are mechanisms through which temperature shocks transmit to entrepreneurship. The key insight of this study is that it is less likely that those directly affected by climate events will act entrepreneurially, at least in the short run. However, the area of departure with this proposed study is that, their study was limited to temperature and rainfall data ignoring the drought which is key climate change risk factor. Moreover, besides the sample size and location of the study, this study differs in the data analysis approach, where panel data regression was adopted in their case, while in the case of this study, SEM-AMOS will be used.

Olawuyi and Mushunje (2024) investigated the livelihood impacts of drought on households and organizations in the Western Cape Province of South Africa, utilizing a secondary dataset collected by the Human Sciences Research Council of South Africa. Descriptive statistics were used to describe and explore the dataset. Likewise, heterogeneous choice modeling was applied to investigate the factors influencing the levels of livelihoods impacts of drought among household and organizations. The findings underscored households' greater vulnerability to drought compared to organizations across all the levels of drought impacts. Many households reported considerable and major impacts, which were largely due to differentials in adaptive capacity. Factors that significantly influenced the levels of drought impacts include age, institutional engagement of water restrictions, livelihood areas impacted by drought, and perceptions on water consumption rate. The study recommends heightened awareness of water conservation, compliance with restrictions, investment in infrastructure, and embracing community-based adaptation and disaster risk reduction initiatives. For organizations, emergency response plans, business continuity planning, and stakeholder engagement will be helpful to bolster resilience to drought. Their study deviated in the area of study since it was conducted in South Africa, while this study will be conducted in Nigeria where is proposing to assess the influence of climate risks influence on SMEs sustainability.

In Nigeria, Elisha, et al. (2023) assessed the farmers' perceived impact of climate change on Crop production and resilience toward food security in Benue. The study found that mixed cropping, use of early maturing crop varieties and use of acclimatized crop varieties are the most effective resilient strategies. Mbanasor et al. (2024) examined Climate Smart Agriculture practices by crop farmers: Evidence from south east Nigeria. The key determinants of CSA adoption identified in the study include gender, household size, farming experience, education level. Ogbuabor and Egwuchukwu (2017) examined the impact of climate change on the overall growth of the Nigerian economy. The ordinary least squares (OLS) estimation technique and data for the period 1981-2014 were used. Changes in annual rainfall, carbon emission and forest depletion were used to capture climate change, while changes in government expenditure, domestic private investment and exchange rate were used as control variables. The results indicate that both in the long-run and short-run, carbon emissions affect growth adversely. In addition, forest depletion impacts negatively on growth in the short- run. However, the research design of these studies departure from this proposed study. Moreover, there is variation in variables operationalization and methodology between these researches with the proposed study.

2.4 Theoretical Review

2.4.1 Sustainable Livelihoods Framework (SLF)

SLF provides a suitable approach to understanding the various factors that affect livelihoods, including vulnerability to crisis and shocks like drought and how individuals build resilience against risks. In terms of drought, flood and heat wave the key components of the SLF are: assets, vulnerability context, transforming structures and processes, and livelihood strategies which incorporate the coping and adaptation strategies employed by SMEs to maintain their livelihoods. As emphasized earlier, climate episodes can lead to depletion of natural assets (e.g., water, land), financial assets (e.g., income loss),

and physical assets (e.g., business premises damage), reduced access to water and food, increased food prices, and health risks (Olawuyi & Mushunje, 2024). All these are entry points and pathways to understanding how businesses adapt to and cope with climate risks impacts.

2.4.2 Climate Change Adaptation Theory

Equally important is the climate change adaptation theory and/or action theory of climate change (Redman & Kinzig, 2003). This theory focuses on the strategies and actions like the EWS that can be taken to reduce vulnerability and enhance resilience to climate-related risks, including drought, flood and heat wave. The application of the theories has to do with ability to adjust to changing climatic conditions, and measures (coping and adaptation strategies implemented by households and organizations) take to reduce vulnerability and enhance resilience, as emphasized by Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2007).

3.0 METHODOLOGY

3.1 Method

This study employed quantitative research design in line with the norms of social and management sciences analysis approach of numerical field survey data (Tracy, 2019). The design allows to assess the relationships between variables, questions, or hypotheses that are specific, defined, observable and measurable, (Saunders et al., 2019). A structural equation modelling (CB-SEM) was used to analysed the data. This technique permits the assessment of structural relationship between variables and latent constructs (Awan, 2017). The method is preferred by researchers due to its robustness and the ability to perform multiple operations in one analysis. However, a sufficient sample size should be used in any research employing structural equation modelling (SEM), which should be five times (a minimum) or ten times (a maximum) the number of construct elements being examined. Furthermore, Hair et al. (2021) suggested ratios of 15:1 or 20:1. Therefore, the entire 34,773 registered SMEs registered with the Small and Medium Enterprise Development Agency of Nigeria (NBS, 2021) in Bauchi and Gombe States are the target population of this study. This decision was informed by the central role that SMEs play in general socioeconomic development in Nigeria and need to over their sustainability challenges (Aina et al., 2024; Garba et al., 2022; CBN, 2020).

The sample size of 380 was determined using the Krejcie and Morgan (1970) sampling table. The respondents were selected using random sampling technique from the study area. This technique ensures inclusiveness of different business sectors such as agriculture, manufacturing, services, among others in the sampled population.

Following past studies in the fields of climate risk, sustainability and small businesses, the study adapted structured questionnaires for data collection (Akuwudike, Mac-Ozigbo, & Igbokwe-Ibeto, 2020; Amjad et al., 2025; Churchill et al., 2024; Feng et al., 2018; Garba et al., 2022; Izumi et al., 2019; Nazakat et al., 2025; Olawuyi & Mushunje, 2024; Sass et al., 2024; Thao et al., 2019; Triyanti & Chu, 2018).

4.0 Results

4.1 Harman Single Factor Test

Harman’s one factor test is used in survey research to identify the common method variance. Common Method Variance (CMV) is the systematic error variance shared among variables measured using the same source or method (Podsakoff, 2024). In this study, all the items underwent an Exploratory Factor Analysis (EFA) and principal components unrotated factor solution, resulting in a TVE of 48.02%. Table 1, shows that Harman's single-factor test only accounts for less than 50% of the overall variation in the study data set with an eigenvalue of 15.849, this suggests that CMV does not exist.

Table 1: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.849	48.028	48.028	15.849	48.028	48.028

Extraction Method: Principal Component Analysis.

4.2 Measurement Model

The Flood construct exhibits good internal consistency (Cronbach alpha: 0.900; composite reliability: 0.895) with sufficient convergent validity of 0.587AVE and satisfactory indicator reliability of outer loadings between 0.730 to 0.800, indicating the construct meets the required thresholds. Drought has outer loadings of between 0.74 to 0.84), internal consistency (Cronbach alpha: 0.938; composite reliability: 0.938) and convergent validity (AVE: 0.655). Heatwaves possesses outer loadings of between 0.670 to 0.830), internal consistency (Cronbach alpha: 0.911; composite reliability: 0.905) and convergent validity (AVE: 0.616). Similarly, Early Warning System realizes measurement quality with the outer loadings ranging between 0.660 to 0.880, an internal consistency of 0.970 Cronbach alpha; composite reliability of 0.895 and the highest convergent validity 0.633 AVE. Lastly, the SME Sustainability construct meets all the minimum thresholds with the internal consistency (Cronbach alpha: 0.677; composite reliability: 0.889), convergent validity (AVE: 0.670), and outer loadings ranging between 0.740 to 0.900. Therefore, Table 2 shows that the study constructs have meet the required thresholds of indicator reliability, internal consistency, and convergent validity, demonstrating instruments of the study psychometric strength (Hair Jr et al., 2020). This outcome increases confidence in the structural analysis and relationships among the study variables of interest.

Table 2: Measurement Model

Constructs	**Items Description**	**Items label**	**Indicator Reliability**	**Internal Consistency**		**Convergent Validity**
			Outer Loading>0.5	**Cronbach's Alpha (Above 0.7)**	**Composite Reliability (Above 0.6)**	**AVE (Above 0.5)**
Flood	Physical infrastructure damage	FL1	0.79	0.900	0.895	0.587
	Human capital displacement	FL2	0.78			
	Business interruption and revenue decline	FL4	0.73			
	Compliance and post-disaster cleanup cost	FL5	0.73			
	Local customer base erosion	FL6	0.80			
	Business interruption and revenue decline	FL7	0.75			
Drought	Water resource scarcity	DR1	0.79	0.938	0.938	0.655
	Utility price surges	DR2	0.83			
	Primary agricultural input contraction	DR3	0.84			
	Soil and arable land degradation	DR4	0.84			
	Rural-to-urban labor migration	DR5	0.76			
	Credit and financial asset erosion	DR6	0.83			
	Civil conflict and resource competition	DR7	0.84			
	Local labor supply	DR8	0.74			

	availability					
Heatwaves	Human labor productivity drops	HW1	0.75	0.911	0.905	0.616
	Cooling and power consumption surges	HW2	0.69			
	Energy grid infrastructure failure	HW3	0.77			
	Perishable stock spoilage	HW4	0.82			
	Occupational health and liability risks	HW5	0.83			
	Faultlessly machinery operations	HW6	0.83			
Early Warning System	Real-time meteorological monitoring	EWS2	0.74	0.907	0.895	0.633
	Warning alert dissemination channels	EWS3	0.66			
	Continuous preparedness training	EWS4	0.63			
	Business preparation and action planning	EWS5	0.86			
	Stakeholder response network	EWS6	0.84			
SME Sustainability	Business funds impairment	SME2	0.88	0.677	0.889	0.670
	Climate-resilient investments	SME3	0.90			
	Difficult financial shield and insurance	SME4	0.75			
	Sufficient government support	SME5	0.74			

4.2.1 Discriminant Validity

Fornell-Larcker method analyse the correlations between variables (off-diagonal items) and the square root of the average variance extracted (AVE) for each variable (diagonal items) (Hair Jr et al., 2021). This method accesses the discriminant validity of the study constructs. Table 3 shows that the study construct pairs sufficiently pass the discriminant validity test, meaning each construct has a greater share of variance with its indicators than with the other constructs. In particular, Flood (0.766), Drought (0.809), EWS (0.796), Heatwaves (0.785) and Sustainability (0.818) are the square roots of the AVEs.

Table 3: Fornell-Larcker criterion

Constructs	Flood	Drought	EWS	Heatwaves	SME_Sust.
Flood	**0.766**				
Drought	0.730	**0.809**			
EWS	-0.059	0.718	**0.796**		
Heatwaves	0.651	-0.122	0.155	**0.785**	
SME_Sust.	0.711	0.432	0.234	0.682	**0.818**

The R-square values in Table 4 indicate that the predictor variables, Flood, Drought, and Heatwaves explain 68% of the variance in the SMEs' sustainability. Given the adjusted R-square of 67.8%, this study concludes that the model has not been overfitted. However, this still implies that 32% of the variability is not accounted for, suggesting that other factors are important in determining the survival of SMEs; in this case, the model is not providing a comprehensive picture.

Table 4: R-Square

Variable	R-square	R-square adjusted
Sustainability	0.680	0.678

Source: Standardised Structural Equation Model Output (2026)

4.3 Structural Model

Figure 2 presents the standardised structural equation model (SEM) connecting Flood, Drought, and Heatwaves with the SMEs' sustainability. The results of the standardised structural model point out robust and reliability across the entire construct indicators, although with different loadings that fall within the acceptable thresholds. The model explains 68% of the variability of the SMEs' sustainability, with flood, drought, and heatwaves accounting to an R-squared value of 0.68. Moreover, the model's estimation confirmed a strong fit to the data. As presented from the fit indices, the P-value is significant at 1%, the RMSEA value is 0.062, the CFI is 0.946, the TLI is 0.956, and the chi-square ratio to degrees of freedom is 3.939. These indices indicate that the latent constructs are sufficiently assessed.

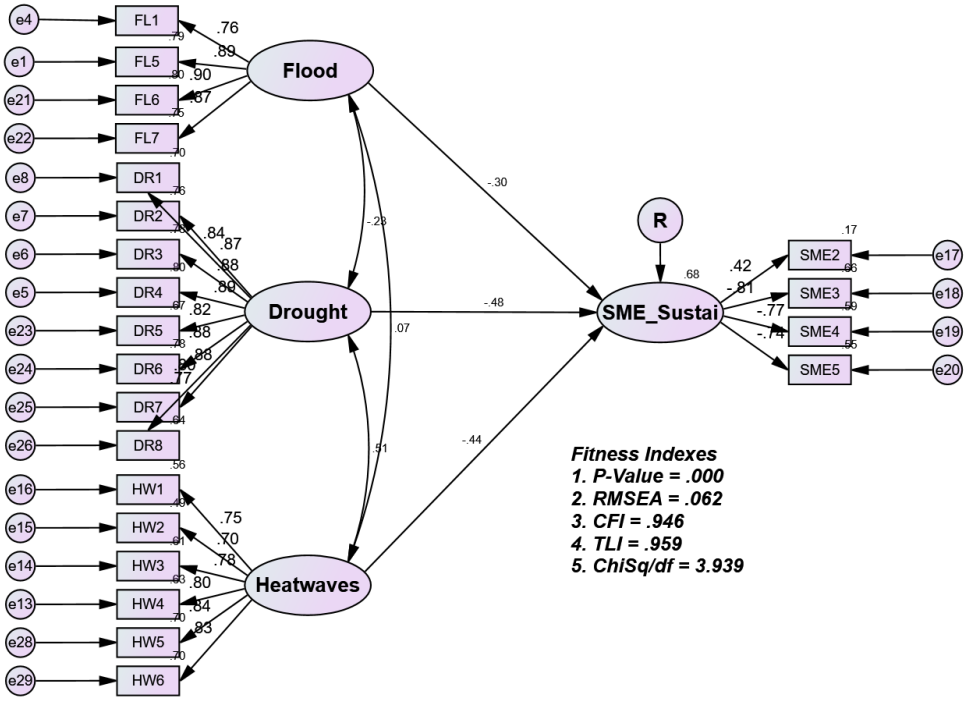

Figure 2: Standardised Structural Model

Figure 3 presents the unstandardised regression estimates of the path coefficients among the study's constructs, Flood, Drought, and Heatwaves with the SMEs' sustainability, are shown in. The regression path coefficients indicate the extent to which the exogenous constructs influenced the endogenous construct. Among the paths of three exogenous constructs, Heatwaves to Sustainability has the most statistically significant direct effect, with a coefficient value of -0.610 at $p < 0.01$. In a similar vein, Drought coefficient value of -0.451 has a statistical significant negative effect on the SMEs sustainability with $p < 0.01$. Furthermore, flood exerts a negative effect on SMEs sustainability with a coefficient value of -0.228 and $p < 0.01$. Hence, the findings revealed that these climate risk factors are among the major impediments of SMEs sustainability. The loadings of the entire indicators demonstrate that the fitness of the measurement model have exceeded the recommended minimum thresholds, Table 5 presents the causative effects of the study constructs.

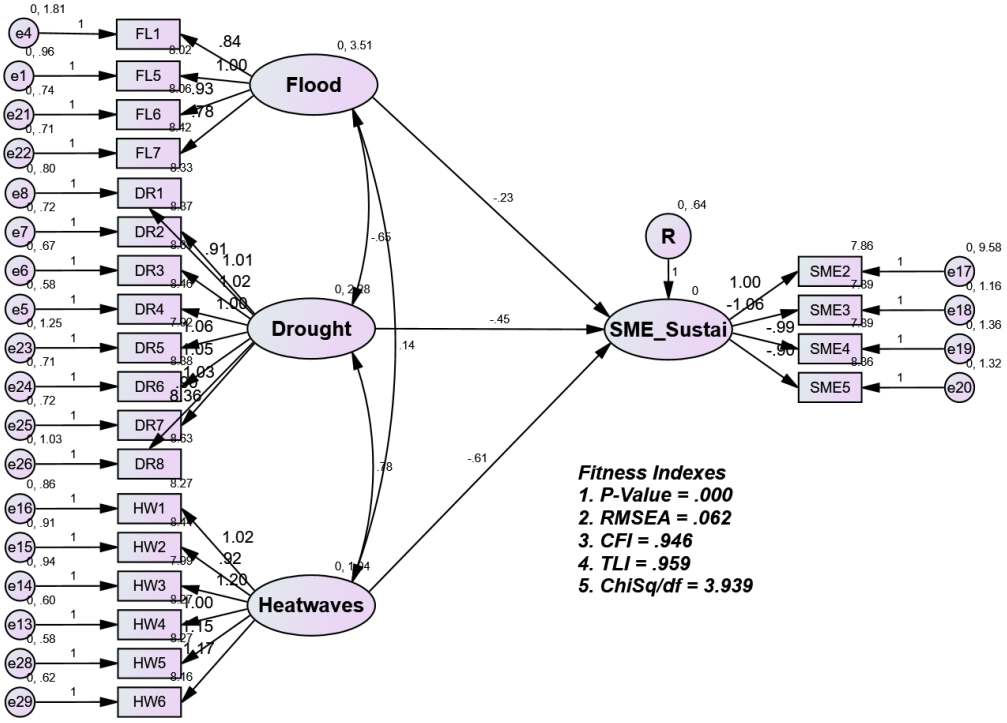

Figure 3: Unstandardised Structural Model

Table 5 presents the study's hypotheses regression load for each path analysis. This path analysis model determines the statistical significant relationship between the study's constructs and confirm whether the formulated hypotheses are supported or not supported. The result in table revealed that all the three constructs have a direct and negative significant effect on SMEs sustainability.

Table 5: Hypotheses Testing

Hypotheses			Estimate	S.E.	C.R.	P	Remarks
SME Sustainability	<---	Flood	-.228	0.0265	-8.615	***	Supported
SME Sustainability	<---	Drought	-.451	0.093	-4.851	***	Supported
SME Sustainability	<---	Heatwaves	-.610	0.182	-3.348	***	Supported

Source: Unstandardised Structural Equation Model Output (2026)

4.3.1 Hypotheses Testing

The structural model's hypothesis testing results, displayed in Table 5, shows that among the paths of three exogenous constructs, Heatwaves to Sustainability has the most statistically significant direct effect, with a coefficient value of -0.610 and the p-value of 0.000 less than 0.05 level of significance. This result indicates that the proposed hypothesis one is supported. In a similar vein, Drought with coefficient value of -0.451 and the p-value of 0.000 less than 0.05 level of significance has a statistically significant negative effect on the SMEs sustainability. This result suggests that hypothesis two is supported. Meaning that the lower the drought, the higher the chances of SMEs sustainability. Lastly, flood exerts a negative effect on SMEs sustainability with a coefficient value of -0.228 and the p-value less than 0.05 level of significance. This adverse finding implies that SMEs sustainability depends on how effective the SME owners are able manage risks associated with flood. Hence, hypothesis three as formulated is supported.

4.3.2 Moderation Analysis

Early Warning System is used as a continuous variable in this study for the indirect effect analysis. The moderation occurs if the interaction term path (XM → DV) is statistically significant P-value <0.05 or the critical ration (CR) is > $\pm$ 1.96 if (Awang, 2015; Collie, 2020).

Table 6: Standardised Regression Weights: (Moderation)

Hypotheses			Estimate	S.E.	C.R.	P	Remarks
ZSME_Sustai	→	ZCEWS	.350	0.132	-2.661	0.008	Sig.
ZSME_Sustai	→	ZCEWS_Flood	-.057	0.0428	-1.336	0.182	InSig.
ZSME_Sustai	→	ZCEWS_Drought	-.233	0.082	-2.842	0.004	Sig.
ZSME_Sustai	→	ZCEWS_Heatwaves	-.608	0.182	-3.345	0.001	Sig.

Table 6 shows the results of the moderation test for all the constructs with early warning system. According to Collie (2020), the finding is significant as the Critical Ratio (CR) values are -2.661, 2.842, and 3.345, greater than $\pm$ 1.96 and the p-values are <0.05, with the exception of CR) value of -1.336 and p-value 0.1872 for the interaction path ZSME_Sustai → ZCEWS_Flood. Hence, the final hypothesis test for the moderation of early warning system on the effect of flood, drought and heatwave on SMEs' sustainability, has been summarized in Table 7. The table reveals that the moderating variable has supports two (2) of the proposed hypotheses.

Table 7: Moderation Table

Hypotheses			Interpretation
ZSME_Sustainability	→	ZCEWS	Significant Main (negative) effect
ZSME_Sustainability	→	ZCEWS_Flood	Not Significant (No Moderation)
ZSME_Sustainability	→	ZCEWS_Drought	Significant Moderation Effect
ZSME_Sustainability	→	ZCEWS_Heatwaves	Significant Moderation Effect

5.0 Discussion

The structural equation modelling analysis presented in the results section provides a nuanced understanding of the effect of flood, drought, and heatwaves on SMEs' sustainability with a keen focus on Bauchi State, and Gombe State. This study also highlights the importance of early warning systems in enhancing SMEs sustainability. Implying that effective and timely rolling out of early warnings could reduce the devastating impact of climate risks on sustainability.

From the direct structural equation modelling analysis, the regression path coefficients indicate the extent to which the exogenous constructs influenced the endogenous construct. Among the paths of three exogenous constructs, Heatwaves to Sustainability has the most statistically significant direct effect, with a coefficient value of -0.610. The results indicate that excessive heatwave impair the sustainability of SMEs. This finding in support with outcomes of other established studies (ILO, 2019; Somanathan et al., 2021; Zhang et al., 2018). In a similar vein, Drought coefficient value of -0.451 has a statistical significant negative effect on the SMEs sustainability, indicating that the lower the drought, the higher the chances of SMEs sustainability. Churchill et al. (2024) revealed that an increase in extreme climate risk in the preceding period is related with a decrease in the likelihood of self-employment in the subsequently period. This result suggests the need for the SME owners to adopt innovative proactive approaches to improve their sustainability through early warning systems and extreme weather adaptive strategies. Furthermore, flood exerts a negative effect on SMEs sustainability with a coefficient value of -0.228. This adverse finding indicates that SMEs sustainability depends on how effective SME owners are able management risks associated with flood. Akuwudike et al. (2020) noted that flooding has forced millions of people to relocate and damaged many businesses in various parts of Nigeria. This is in line with extant studies that established the negative influence of flood on health and employment (Churchill et al., 2024; Mishra, 2021) across various sectors with no exception to SMEs. Hence, the findings revealed that these climate risk factors are among the major impediments of SMEs sustainability. The loadings of the entire indicators demonstrate the fitness of the measurement model having exceeded the recommended minimum thresholds. However, the R-squared value captures the influence of the study variables while other factors approximately affecting the on SMEs sustainability are unknown within the scope of this study.

The moderation results show a positive relationship early warning system and SMEs' sustainability. This finding is consistent with Baudoin et al. (2014) who submitted that effective early warning systems could improve coping mechanisms thereby fostering livelihood resilience. The introduction of early

warning systems into the model weakens the coefficients values of the relationship between heatwave, drought and SMEs' sustainability. Therefore, early warning systems has a moderating effect between heatwave, drought and SMEs' sustainability. Similarly, the introduction of early warning systems between flood and SMEs' sustainability changed the negative relationship into nonsignificant. Thus, early warning systems has weakened adverse effect of flood on SMEs sustainability. These findings are in line with the climate change adaptation theory that assumed disaster as not just a natural incident but also a consequence of human activity that requires holistic approach of recognizing the complex societal and political factors that shape the management and response to the disaster (Okafor, 2024; Olawuyi & Mushunje, 2024). Moreso, Ahsan et al. (2020) noted that EWS could effectively improve business readiness before occurrence of climate risks incidence. Glantz and Baudoin (2014) connoted that this preparation enhances adaptive capacity.

6.0 Conclusion

This study confirms the adverse effect of climate risk factors with specific focus on drought, heatwaves, and flood on sustainability of SMEs. The study revealed that the adverse effect of these climate risks could be reduced. The empirical support for the moderating role of Early Warning Systems (EWS) demonstrates that timely, accurate, and actionable information serves as a critical resilience buffer. When SMEs are integrated into robust warning networks, the negative relationship between climate risks and SMEs sustainability is significantly weakened. hence, SME sustainability in a climate change environment not only depends on financial capital, but on informational capital and the capacity to hinge operations before a disaster strikes. The findings of this paper yield some interesting theoretical and practical contributions. Theoretically, this study validates the climate change adaptation theory (Redman & Kinzig, 2003) by confirming that SMEs sustainability does not rely on internal financial management, but deeply rooted the adaptive capacity. This theory has to do with business ability to adjust to changing climatic conditions, and measures to reduce vulnerability and enhance resilience. Practically, SME owners should view extreme weather early warnings as strategic business intelligence that can be utilized to gain competitive edge by improving operational efficiency. Policy Implications, government should ensure that data must reach the SME owners in an actionable manner and climate risks sensors and other resilience mechanism be subsidized weighing the economic consequences of climate risks. Notwithstanding the significant findings of this study, it was not without limitation. Therefore, future study should access Sector Specific Analysis rather than generic SMEs businesses by investigating whether EWS moderates these climate risks differently across different business lines

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