Impact of climate change on agricultural insurance

Impacto del cambio climático en los seguros agrícolas

Noah Gbenga Alli †

Date received: March 21, 2025
Date approved: June 25, 2025

Cite as: Alli, N. G. (2025). Impacto del cambio climático en los seguros agrícolas. *Revista Activos*, 23(1), 121-152. https://doi.org/10.15332/25005278.10865

Abstract

Climate change poses significant challenges to agricultural systems, particularly in vulnerable regions like Nigeria, where farming serves as a primary livelihood and economic driver. This study investigates the impact of climate change on agricultural insurance by examining how temperature variability, changes in rainfall patterns, and extreme weather events influence crop yield losses, farmers' claim filing behavior, and premium adjustments. Employing a quantitative research design with a cross-sectional survey approach, data were collected from 300 farmers and 84 insurance professionals using a structured questionnaire. The analysis utilized Partial Least Squares Structural Equation Modeling (PLS-SEM) to assess relationships among latent variables, ensuring reliability and validity through Cronbach's Alpha, Composite Reliability, Average Variance Extracted, and the Heterotrait-Monotrait Ratio (HTMT). Results revealed significant effects of climate factors on agricultural risks: changes in rainfall patterns ($\beta = 0.673$, $p < 0.05$) exhibited the strongest influence on crop yield losses, followed by extreme weather events ($\beta = 0.568$, $p < 0.05$) and temperature variability ($\beta = 0.412$, $p < 0.05$). Farmers' claim filing behavior was positively correlated with claim frequency ($\beta = 0.721$, $p < 0.05$) and severity ($\beta = 0.694$, $p < 0.05$), which in turn significantly affected premium adjustments ($\beta = 0.635$, $p < 0.05$). The model demonstrated strong explanatory power, with R^2 values of 0.64 for crop yield losses and 0.58 for premium adjustments, supported by acceptable fit indices such as SRMR = 0.062 and negative Bayesian Information Criterion (BIC) values across constructs. These findings underscore the critical role of agricultural insurance in mitigating climate-induced risks and highlight the need for innovative products to enhance equity and accessibility in agricultural insurance.

Keywords:

climate change; agricultural insurance; risk assessment; claim frequency; premium adjustments; extreme weather events; crop yield losses; Nigeria

†The Federal Polytechnic Offa, Kwara, Nigeria. Department Of Insurance, School Of Management Sciences Correo: noah.alli@fedpoffaonline.edu.ng. ORCID: 0000-0002-8311-9634.

JEL classification:
G22, O13, Q14

Resumen

El cambio climático plantea importantes retos para los sistemas agrícolas, especialmente en regiones vulnerables como Nigeria, donde la agricultura es la principal fuente de ingresos y motor económico. Este estudio investiga el impacto del cambio climático en los seguros agrícolas, examinando cómo la variabilidad de la temperatura, los cambios en los patrones de precipitaciones y los fenómenos meteorológicos extremos influyen en las pérdidas de rendimiento de los cultivos, el comportamiento de los agricultores a la hora de presentar reclamaciones y los ajustes de las primas. Mediante un diseño de investigación cuantitativa con un enfoque de encuesta transversal, se recopilaron datos de 300 agricultores y 84 profesionales del sector de los seguros utilizando un cuestionario estructurado. El análisis utilizó el modelo de ecuaciones estructurales de mínimos cuadrados parciales (PLS-SEM) para evaluar las relaciones entre las variables latentes, garantizando la fiabilidad y la validez mediante el alfa de Cronbach, la fiabilidad compuesta, la varianza media extraída y la relación heterotraits-monotraits (HTMT). Los resultados revelaron efectos significativos de los factores climáticos en los riesgos agrícolas: los cambios en los patrones de precipitación ($\beta = 0{,}673$, $p < 0{,}05$) mostraron la influencia más fuerte en las pérdidas de rendimiento de los cultivos, seguidos de los fenómenos meteorológicos extremos ($\beta = 0{,}568$, $p < 0{,}05$) y la variabilidad de la temperatura ($\beta = 0{,}412$, $p < 0{,}05$). El comportamiento de los agricultores a la hora de presentar reclamaciones se correlacionó positivamente con la frecuencia de las reclamaciones ($\beta = 0{,}721$, $p < 0{,}05$) y la gravedad ($\beta = 0{,}694$, $p < 0{,}05$), lo que a su vez afectó significativamente a los ajustes de las primas ($\beta = 0{,}635$, $p < 0{,}05$). El modelo demostró una gran capacidad explicativa, con valores R^2 de 0,64 para las pérdidas de rendimiento de los cultivos y de 0,58 para los ajustes de las primas, respaldados por índices de ajuste aceptables, como SRMR = 0,062 y valores negativos del criterio de información bayesiano (BIC) en todas las construcciones. Estos resultados subrayan el papel fundamental de los seguros agrícolas en la mitigación de los riesgos inducidos por el clima y ponen de relieve la necesidad de productos innovadores para mejorar la equidad y la accesibilidad de los seguros agrícolas.

Palabras clave:
cambio climático; seguros agrícolas; evaluación de riesgos; frecuencia de siniestros; ajustes de primas; fenómenos meteorológicos extremos; pérdidas en el rendimiento de los cultivos; Nigeria

Clasificación JEL:
G22, O13, Q14

Introduction

Climate change has emerged as one of the most pressing global challenges of the 21st century, with far-reaching implications for ecosystems, economies, and human livelihoods (Diffenbaugh, Davenport, & Burke, 2021). Its effects are particularly pronounced in the agricultural sector, which is inherently dependent on climatic conditions (Ortiz-Bobea, 2021). Rising global temperatures, shifting precipitation patterns, increased frequency of extreme weather events, and prolonged droughts are disrupting agricultural productivity and threatening food security worldwide (Habib-ur-Rahman et al., 2022). These climatic shifts have not only altered the risk landscape for farmers but have also posed significant challenges to the agricultural insurance industry, which plays a critical role in mitigating financial losses caused by climate-related risks (Gaur & Verma, 2023). As the world grapples with the escalating impacts of climate change, understanding its influence on agricultural insurance has become a topic of paramount importance, particularly in developing nations like Nigeria, where agriculture remains a cornerstone of the economy and a primary source of livelihood for millions (Bassey & Uwadinma, 2022). Globally, agricultural insurance has long been recognized as a vital risk management tool, providing farmers with financial protection against losses stemming from natural disasters, pests, and other unforeseen events (Zhou & Vilar-Zanón, n.d.). However, the increasing unpredictability and severity of climate-related risks have strained traditional insurance models (Schuurman & Ker, 2025). Insurers are now faced with the daunting task of accurately assessing and pricing risks in an era of heightened uncertainty (Xie et al., 2024). For instance, the rising frequency of extreme weather events, such as hurricanes, floods, and wildfires, has led to a surge in claims, pushing insurance premiums higher and making coverage less affordable for farmers (Lesk et al., 2022). In some regions, insurers have even withdrawn coverage altogether, citing unsustainable losses (Grigorieva, Livenets, & Stelmakh, 2023). This global trend underscores the urgent need for innovative approaches to agricultural insurance that can adapt to the evolving realities of climate change (Sun et al., 2024).

The impact of climate change on agricultural insurance varies across the globe depending on geographic location, socio-economic conditions, and the resilience of local agricultural systems (Malhi, Kaur, & Kaushik, 2021). Developed countries, with their advanced technological infrastructure and robust financial systems, have been better equipped to adapt to these challenges (Wang, Liu, & Wang, 2022). For example, the use of satellite imagery, remote sensing, and big data analytics has enabled insurers in these regions to improve risk assessment and develop more tailored insurance products (Ma, Zhou, & Wang, 2024). Additionally, government subsidies and public-private partnerships have played a crucial role in maintaining the affordability and accessibility of agricultural insurance in developed nations (Yoder et al., 2025). In contrast, developing countries, particularly those in sub-Saharan Africa, face a more precarious situation. Limited access to technology, inadequate infrastructure, and weak institutional frameworks exacerbate the vulnerability of farmers and insurers (Madaki, Kaechele, & Bavorova, 2023).

Nigeria, as Africa's most populous nation and largest economy, presents a compelling case study for examining the impact of climate change on agricultural insurance (Baba, Abdullahi, & Garba, 2024). Agriculture accounts for approximately 23% of Nigeria's GDP and employs over 70% of the labor force, making it a critical sector for economic growth and poverty alleviation (Abiola, Olaniyan, & Fadun, 2022). However, the sector is highly vulnerable to climate change, with smallholder farmers bearing the brunt of its adverse effects (Emmanuel et al., 2024). Erratic rainfall patterns and prolonged droughts. Increased incidence of pests and diseases have led to significant crop failures and livestock losses, undermining food security and exacerbating rural poverty (Wambua & Okeke, 2023). In this context, agricultural insurance has the potential to serve as a lifeline for Nigerian farmers, providing them with the financial resilience needed to recover from climate-induced losses and invest in sustainable farming practices (Prince, Obiorah, & Ogar, 2023).

Despite its potential, the uptake of agricultural insurance in Nigeria remains dismally low, with less than 1% of farmers currently insured (Osuji, Olaolu, & Tim-Ashama, 2023). This low penetration rate can be attributed to a combination of factors, including limited awareness among farmers, high premium costs, and a lack of trust in insurance providers (Bhushan et al., 2016). Moreover, the Nigerian insurance industry itself faces significant challenges in designing and delivering products that are both affordable and effective in the face of climate change (Reka et al., 2025). The absence of reliable historical climate data, coupled with the high cost of risk assessment, has made it difficult for insurers to accurately price their products (Zhllima et al., 2025). Additionally, the lack of government support and inadequate regulatory frameworks has further hindered the growth of the agricultural insurance market in Nigeria (Mbonu, 2025).

The rising temperatures and erratic rainfall patterns globally have been linked to reduced agricultural productivity, with extreme weather events causing significant crop failures (Elahi et al., 2022). For instance, prolonged droughts and unseasonal floods have devastated farming communities, particularly in developing countries where adaptive capacity is limited (Ghosh et al., 2021). In Nigeria, where agriculture accounts for approximately 23% of GDP and employs over 70% of the labor force, these climate-induced yield losses have severe implications for food security and rural livelihoods (Syed et al., 2022).

In addition, crop losses directly influence the frequency and magnitude of insurance claims, as farmers rely on insurance payouts to recover from climate-induced disasters (Singh, Jyoti, & Sankaranarayanan, 2024). However, the relationship between yield losses and claim behavior is not always straightforward. Factors such as awareness of insurance products, trust in insurers, and the complexity of claim filing processes can influence whether farmers file claims (Yoder et al., 2025; Bhardwaj et al., 2022). In Nigeria, where agricultural insurance penetration is less than 1%, understanding this relationship is critical for improving insurance uptake and ensuring that farmers are adequately compensated for their losses (Panda, 2021; Madaki, Kaechele, & Bavorova, 2023).

Also, extreme weather events, such as hurricanes, floods, and droughts, often result in catastrophic losses for farmers, leading to high-value insurance claims (Grigorieva, Livenets, & Stelmakh, 2023). Globally, the increasing frequency and intensity of such events have placed significant financial strain on insurers, forcing them to reassess their risk models and pricing strategies (Lesk et al., 2022). In Nigeria, where extreme weather events are becoming more common, understanding their impact on claim severity is crucial for insurers to manage their exposure and maintain financial stability (Prince, Obiorah, & Ogar, 2023). In addition, as climate change drives higher claim frequency and severity, insurers are compelled to adjust premiums to reflect the increased risk (Xie et al., 2024). However, frequent and steep premium hikes can make insurance unaffordable for farmers, particularly in developing countries where financial resources are limited (Zhllima et al., 2025). In Nigeria, where affordability is already a major barrier to insurance uptake, understanding how insurers balance risk management with premium affordability is essential for ensuring the sustainability of agricultural insurance programs (Sun et al., 2024; Reka et al., 2025). Against this backdrop, this study seeks to explore the impact of climate change on agricultural insurance from a Nigerian perspective. Based on the foregoing, the following objectives were formulated to guide this study:

i. Investigate the significant effect of temperature variability on crop yield losses in Nigeria
ii. Determine the impact of rainfall pattern changes on crop yield losses in Nigeria
iii. Find out the influence of extreme weather events on crop yield losses in Nigeria
iv. Evaluate the effect of crop yield losses on increasing claim frequency and farmers claim filing behavior.
v. To analyze the impact of extreme weather events on claim severity in agricultural insurance.
vi. To assess the influence of insurance claim frequency and severity on premium adjustments by insurers.

Review of Related Literature

Climate Change

Climate change is one of the most pressing global challenges of the 21st century, and Nigeria, as Africa's most populous nation and largest economy, is particularly vulnerable to its impacts. The country's geographical location, economic dependence on climate-sensitive sectors, and limited adaptive capacity exacerbate its susceptibility to climate-related risks. In Nigeria, climate change is driven by both global and local factors. Globally, the increase in greenhouse gas (GHG) emissions from industrialized nations has contributed significantly to rising temperatures and changing weather patterns. Locally, Nigeria's contribution to GHG emissions stems from deforestation, gas flaring, and the reliance on fossil fuels for energy. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), deforestation accounts for nearly 20% of global GHG emissions, and Nigeria has one of the highest deforestation rates in the world, losing approximately 3.5% of its forest cover annually (Food and Agriculture Organization, 2020). Gas flaring, a byproduct of oil extraction in the Niger Delta, further exacerbates the problem, releasing significant amounts of carbon dioxide and methane into the atmosphere (World Bank, 2019).

The impacts of climate change in Nigeria are multifaceted, affecting the environment, economy, and society. Rising temperatures, erratic rainfall patterns, and increased frequency of extreme weather events such as floods and droughts have been widely documented. The Nigerian Meteorological Agency (NiMet, 2022) reports that average temperatures have increased by 1.5°C over the past century, with projections indicating a further rise of 2-3°C by 2050 if current trends continue. This warming has dire consequences for agriculture, which employs over 70% of the population and contributes significantly to the nation's GDP. The United Nations Development Programme (UNDP, 2021) highlights that reduced crop yields, livestock losses, and increased pest infestations are already being observed, threatening food security and livelihoods.

Coastal regions, particularly in the Niger Delta, are also at risk due to rising sea levels. The International Union for Conservation of Nature (IUCN, 2020) estimates that a 1-meter rise in sea level could displace over 27 million people in Nigeria, exacerbating existing challenges such as poverty and urbanization. Furthermore, climate change has been linked to the intensification of conflicts over dwindling natural resources, particularly in the northern regions where desertification and water scarcity are prevalent (Institute for Peace and Conflict Resolution, 2021). In response to the growing threat of climate change, Nigeria has taken several steps at both national and international levels. The country is a signatory to the Paris Agreement and has committed to reducing its GHG emissions by 20% unconditionally and 45% conditionally by 2030 (Federal Ministry of Environment, 2021). To achieve these targets, Nigeria has launched initiatives such as the National Climate Change Policy and Response Strategy (NCCPRS) and the Great Green Wall project, which aims to combat desertification by planting trees across the Sahel region (African Union, 2020). At the grassroots level, non-governmental organizations (NGOs) and community-based organizations (CBOs) are playing a crucial role in raising awareness and implementing adaptation strategies. For instance, the Nigerian Conservation Foundation (NCF, 2022) has been instrumental in promoting sustainable land management practices and reforestation efforts. However, challenges such as inadequate funding, weak institutional frameworks, and limited technical capacity hinder the effective implementation of climate policies (World Resources Institute, 2021).

Agricultural Business

Agricultural business (agribusiness) encompasses the production, processing, distribution, and marketing of agricultural products. Globally, agricultural business has evolved from traditional farming practices to a highly integrated and technology-driven sector. According to Lobell et al. (2011), climate change poses a significant threat to agricultural productivity, with rising temperatures and erratic weather patterns affecting crop yields and livestock production. Similarly, Ortiz-Bobea (2021) emphasizes the role of climate-smart agriculture in mitigating these impacts, advocating for the adoption of sustainable practices such as precision farming and agroforestry. The integration of technology in agriculture, particularly using artificial intelligence (AI) and big data, has also been identified as a game-changer. Ma, Zhou, and Wang (2024) highlight how AI-driven tools can optimize resource use, improve crop monitoring, and enhance decision-making processes in agribusiness. The global agribusiness sector is also influenced by market dynamics and consumer preferences. Singh, Jyoti, and Sankaranarayanan (2024) note that the demand for organic and sustainably produced food is on the rise, driven by increasing health consciousness and environmental awareness. This trend has led to the growth of niche markets and value-added products, creating new opportunities for agribusinesses. However, challenges such as supply chain disruptions, labor shortages, and regulatory hurdles persist, as highlighted by Ghosh et al. (2021).

Nigeria, with its vast arable land and favorable agro-ecological conditions, has immense potential for agricultural business. The sector contributes about 23% to the country's GDP and employs over 70% of the labor force (Abiola, Olaniyan, & Fadun, 2022). Despite this, Nigeria's agricultural productivity remains suboptimal due to a combination of factors, including inadequate infrastructure, limited access to credit, and poor adoption of modern technologies. Prince, Obiorah, and Ogar (2023) argue that addressing these challenges requires a holistic approach, involving public-private partnerships and targeted investments in research and development. Climate change is a major concern for Nigeria's agricultural sector. Oluwatimilehin and Ayanlade (2023) highlight the increasing frequency of droughts and floods, which have adversely affected crop yields and livestock production. Similarly, Lesk et al. (2022) emphasize the need for climate-resilient agricultural practices, such as drought-tolerant crop varieties and improved water management systems. The Nigerian government has initiated several programs to address these issues, including the Agricultural Promotion Policy (APP) and the Green Alternative Initiative, which aim to enhance productivity and promote sustainable practices (Osuji, Olaolu, & Tim-Ashama, 2023).

Also, the adoption of technology is critical to transforming Nigeria's agricultural sector. Mbonu (2025) highlights the role of digital platforms in connecting farmers to markets, providing access to real-time information, and facilitating financial transactions. Mobile-based applications, such as FarmCrowdy and Thrive Agric, have gained popularity, enabling smallholder farmers to access funding and technical support. Additionally, the use of drones and satellite imagery for precision agriculture is gaining traction, as noted by Emmanuel et al. (2024). Furthermore, despite these advancements, the uptake of technology remains low due to factors such as high costs, limited technical skills, and inadequate infrastructure. Wambua and Okeke (2023) suggest that capacity-building programs and subsidies for agricultural technologies could bridge this gap. Furthermore, the integration of blockchain technology in supply chain management has the potential to enhance transparency and reduce post-harvest losses, as discussed by Gaur and Verma (2023).

Effective policy and institutional frameworks are essential for the growth of agricultural business in Nigeria. The government has implemented various policies to support the sector, including the National Agricultural Technology and Innovation Policy (NATIP) and the National Livestock Transformation Plan (NLTP). However, the implementation of these policies has been hampered by bureaucratic inefficiencies and inadequate funding (Habib-ur-Rahman et al., 2022). Bhardwaj et al. (2022) recommend the establishment of robust monitoring and evaluation mechanisms to ensure the effective execution of agricultural policies. International organizations have also played a significant role in supporting Nigeria's agricultural sector. For instance, the Food and Agriculture Organization (FAO) and the World Bank have provided technical and financial assistance for projects aimed at improving agricultural productivity and food security. These collaborations have yielded positive results, particularly in the areas of capacity building and infrastructure development (Grigorieva, Livenets, & Stelmakh, 2023).

Agriculture and Climate Change in Nigeria

Agriculture is the backbone of Nigeria's economy, contributing significantly to the nation's GDP and employing over 70% of the population. However, the sector is highly vulnerable to the impacts of climate change, which manifest through temperature variability, crop yield losses, rainfall pattern changes, and extreme weather events. These challenges threaten food security, livelihoods, and economic stability, particularly in rural communities where agriculture is the primary source of income. One of the most significant impacts of climate change on agriculture in Nigeria is temperature variability. Rising temperatures have been linked to reduced crop yields, particularly for staple crops such as maize, rice, and cassava. According to Lobell et al. (2011), each degree Celsius increase in temperature can reduce crop yields by 5-10%, depending on the crop and region. In Nigeria, temperature variability has already led to significant declines in agricultural productivity, with maize yields projected to decrease by 10-25% by 2050 (Oluwatimilehin & Ayanlade, 2023). This trend is particularly concerning given the country's reliance on rain-fed agriculture and the limited adoption of climate-resilient farming practices. The relationship between temperature variability and crop yield losses is further exacerbated by the lack of adaptive capacity among smallholder farmers. As Wambua & Okeke (2023) note, many farmers lack access to climate information, improved seeds, and irrigation infrastructure, making it difficult to mitigate the effects of rising temperatures. Additionally, Singh, Jyoti, & Sankaranarayanan (2024) highlight that prolonged heatwaves can accelerate soil moisture loss, further reducing crop productivity and increasing the risk of crop failure.

Changes in rainfall patterns are another critical consequence of climate change affecting agriculture in Nigeria. The country's rainfall regime has become increasingly erratic, with shorter growing seasons and more intense rainfall events. According to Prince, Obiorah, and Ogar (2023), these changes have disrupted planting and harvesting schedules, leading to reduced agricultural output. For instance, delayed onset of rains can result in poor germination, while excessive rainfall can cause waterlogging and soil erosion, both of which negatively impact crop growth. The unpredictability of rainfall patterns also poses challenges for water management in agriculture. Osuji, Olaolu, and Tim-Ashama (2023) emphasize that farmers often struggle to adapt to these changes due to limited access to irrigation systems and water storage facilities. This situation is particularly dire in northern Nigeria, where desertification and prolonged droughts have already reduced the availability of arable land and water resources (Malhi, Kaur, & Kaushik, 2021).

Extreme weather events, such as floods, droughts, and storms, are becoming more frequent and intense due to climate change, posing significant risks to agriculture in Nigeria. Floods have devastated farmlands, destroyed crops, and displaced farming communities, particularly in the Niger Delta and other low-lying areas. Mbonu (2025) reports that the 2022 floods alone caused over $10 billion in agricultural losses, further exacerbating food insecurity and poverty. In the case of droughts, they have severely impacted agricultural productivity in the northern regions, where rainfall is already scarce. Ortiz-Bobea (2021) notes that prolonged droughts can lead to crop failure, livestock deaths, and the depletion of water resources, forcing farmers to abandon their lands. These extreme weather events not only disrupt food production but also increase the vulnerability of rural communities to economic shocks and social instability (Lesk et al., 2022).

In response to the growing threats posed by climate change to agriculture, Nigeria has implemented various adaptation and mitigation strategies. These include the promotion of climate-smart agriculture (CSA), the development of drought-resistant crop varieties, and the expansion of irrigation infrastructure. Ma, Zhou, and Wang (2024) highlight that CSA practices, such as agroforestry and conservation agriculture, can enhance resilience to climate change by improving soil health, conserving water, and increasing biodiversity. However, the adoption of these practices remains limited due to factors such as inadequate funding, lack of awareness, and weak institutional support. Emmanuel et al. (2024) argue that greater investment in agricultural research and extension services is needed to equip farmers with the knowledge and tools to adapt to climate change. Additionally, Gaur and Verma (2023) emphasize the importance of integrating traditional knowledge with modern technologies to develop context-specific solutions.

Agricultural Insurance

Agricultural insurance has emerged as a critical tool for mitigating risks associated with farming, particularly in the face of increasing climate variability and extreme weather events. Globally, agricultural insurance has evolved significantly, with various models being adopted to suit different regional needs. Index-based insurance, which uses weather or yield indices to trigger payouts, has gained popularity due to its simplicity and reduced administrative costs (Nshakira-Rukundo, Kamau, & Baumüller, 2021). This approach has been particularly effective in developing countries, where traditional insurance models face challenges such as high transaction costs and moral hazard. For instance, in Asia, index-based insurance has been successfully implemented to protect rice farmers from monsoon-related risks (Myslimi, Nikolli, & Shima, 2022). Similarly, in China, the government has promoted agricultural insurance through subsidies, leading to widespread adoption among smallholder farmers (Zeng, Qi, & Wang, 2022).

In Europe and North America, agricultural insurance is more advanced, with comprehensive policies covering a wide range of risks. These regions have also embraced technology, using satellite imagery and remote sensing to assess crop damage and expedite claims processing (Anisa et al., 2022). However, challenges remain, particularly in ensuring the affordability of premiums for small-scale farmers and addressing the impacts of climate change on insurance models (Skydan et al., 2023). Despite these challenges, agricultural insurance has proven to be a valuable risk management tool, contributing to the resilience of farming communities worldwide.

In Nigeria, agricultural insurance is still relatively underdeveloped, despite the country's heavy reliance on agriculture for livelihoods and economic growth. The Nigerian Agricultural Insurance Corporation (NAIC) was established in 1987 to provide insurance services to farmers, but its reach has been limited due to factors such as low awareness, high premium costs, and inadequate supporting infrastructure (Vyas et al., 2021). Smallholder farmers, who constitute the majority of Nigeria's agricultural workforce, often lack access to insurance products, leaving them vulnerable to climate-related shocks and other risks (Niu, Yi, & Chen, 2022).

Recent studies have highlighted the potential of index-based insurance in Nigeria, particularly for crops such as maize, rice, and cassava, which are highly susceptible to weather variability (Pratiwi & Budiasa, 2022). Pilot projects in states like Kano and Jigawa have demonstrated the feasibility of this approach, but scaling up remains a challenge due to limited availability of weather data and insufficient institutional capacity (Madaki, Kaechele, & Bavorova, 2023). Additionally, cultural and socio-economic factors, such as mistrust in formal financial institutions and low levels of literacy, hinder the adoption of agricultural insurance among rural farmers (Gbigbi & Ndubuokwu, 2022). Efforts to improve agricultural insurance in Nigeria have included partnerships between the government, private sector, and international organizations. For example, the World Bank has supported initiatives to enhance the capacity of NAIC and promote innovative insurance products (Bassey & Uwadinma, 2022). Furthermore, the use of mobile technology and digital platforms has been explored as a means of increasing accessibility and reducing transaction costs, making insurance more inclusice (Ajemunigbohun & Abdul-Azeez, 2023).

Claims in Agricultural Insurance

Claim frequency, defined as the number of claims filed by farmers over a specific period, is a critical factor in understanding agricultural insurance dynamics. Farmers' claim filing behavior is influenced by a multitude of factors, including risk perception, access to information, and the complexity of the claims process. Nshakira-Rukundo, Kamau, and Baumüller (2021) highlight that farmers in developing regions often underreport claims due to a lack of awareness about insurance policies or a mistrust of insurers. This behavior is further compounded by burdensome documentation requirements, which discourage smallholder farmers from filing claims even when they experience significant losses.

Similarly, Myslimi, Nikolli, and Shima (2022) emphasize that claim frequency is higher in regions prone to frequent climatic shocks, such as droughts or floods, as farmers are more likely to seek compensation for recurrent losses. However, Zeng, Qi, and Wang (2022) argue that higher claim frequency does not always correlate with increased risk exposure but may instead reflect improved awareness and trust in insurance mechanisms over time. Farmers' socioeconomic characteristics also play a significant role in claim filing behavior. Anisa et al. (2022) found that younger farmers with higher education levels are more likely to file claims compared to older, less-educated farmers. This is attributed to their better understanding of insurance policies and greater confidence in navigating the claims process. Conversely, Skydan et al. (2023) note that cultural factors, such as communal risk-sharing practices, can reduce claim frequency in certain regions, as farmers may rely on traditional coping mechanisms rather than formal insurance. Overall, understanding claim frequency and filing behavior requires a nuanced analysis of both institutional and individual factors.

Claim severity, which refers to the magnitude of losses incurred by farmers and subsequently claimed, is a key determinant of the financial sustainability of agricultural insurance schemes. High claim severity can strain insurers' resources, particularly in regions with frequent and severe climatic events. (Vyas et al. (2021)) argue that claim severity is often exacerbated by the increasing frequency of extreme weather events linked to climate change, leading to higher payouts and raising potential risk of insolvency risks for insurers. Niu, Yi, and Chen (2022) further emphasize that crop-specific vulnerabilities significantly influence claim severity, with certain crops being more susceptible to pests, diseases, or adverse weather conditions.

The relationship between claim severity and agricultural insurance is also shaped by the design of insurance products. Pratiwi and Budiasa (2022) found that index-based insurance, which triggers payouts based on predefined indices rather than individual losses, can mitigate the impact of high claim severity by reducing administrative costs and moral hazard. However, Madaki, Kaechele, and Bavorova (2023) caution that index-based insurance may not always align with farmers' actual losses, leading to dissatisfaction and reduced uptake. Additionally, Gbigbi and Ndubuokwu (2022) highlight that inadequate loss assessment methodologies can result in either overestimation or underestimation of claim severity, further complicating the claims process. Effectively addressing these challenges requires innovative approaches to risk assessment and product design.

The interplay between claim frequency, claim severity, and premium adjustments is a critical aspect of agricultural insurance management. Insurers often adjust premiums based on historical claims data to maintain financial viability and ensure equitable risk-sharing among policyholders. Bassey and Uwadinma (2022) note that regions with high claim frequency and severity typically face higher premiums, which can deter farmers from purchasing insurance. This creates a self-reinforcing cycle, as low uptake reduces the risk pool, further increasing premiums for those who remain insured. Ajemunigbohun and Abdul-Azeez (2023) suggest that subsidized premiums, particularly for smallholder farmers, can mitigate this issue and promote broader insurance coverage. Premium adjustments are also influenced by the accuracy of claims data and risk modeling. Okunlola and Ayetigbo (2024) argue that advanced data analytics and remote sensing technologies can improve the precision of premium calculations, ensuring that they reflect actual risk levels. However, Adah, Chia, and Shaibu (2016) caution that overreliance on historical data may not account for emerging risks, such as those posed by climate change, necessitating dynamic and adaptive premium adjustment mechanisms. Furthermore, Akinola (2014) highlights that transparency in premium setting is crucial for building trust among farmers, as opaque pricing practices can lead to perceptions of unfairness and reduce insurance uptake.

Climate Change and Agricultural Insurance

Climate change has emerged as one of the most significant challenges to global agricultural systems, with profound implications for food security, rural livelihoods, and economic stability. The increasing frequency and intensity of extreme weather events, coupled with shifting temperature and rainfall patterns, have exacerbated crop yield losses, thereby intensifying the risks faced by farmers. Agricultural insurance, as a risk management tool, has gained prominence in mitigating the financial impacts of these losses. However, the evolving nature of climate risks poses significant challenges to the design, pricing, and sustainability of agricultural insurance schemes.

Temperature variability is a critical driver of crop yield losses, with rising global temperatures and increased frequency of heatwaves adversely affecting agricultural productivity. Lobell et al. (2011) highlight that higher temperatures accelerate crop development, reducing the growing period and leading to lower yields. Ortiz-Bobea (2021) further emphasizes that temperature extremes during critical growth stages, such as flowering and grain filling, can cause irreversible damage to crops. These yield losses translate into increased financial risks for farmers, necessitating robust agricultural insurance mechanisms. However, the non-linear relationship between temperature and crop yields complicates the actuarial modeling of insurance products, as insurers must account for spatial and temporal variability in risks exposure (Nshakira-Rukundo, Kamau, & Baumüller, 2021). Moreover, the increasing frequency of heat-related yield losses has led to higher claim frequencies, prompting insurers to reassess premium structures and coverage limits (Zeng, Qi, & Wang, 2022). Abiola, Olaniyan, and Fadun (2022) add that regional variations in temperature variability, particularly in sub-Saharan Africa, exacerbate the challenges of designing region-specific insurance products, as farmers in these areas often lack access to reliable climate data and financial resources.

Changes in rainfall patterns, including prolonged droughts and erratic precipitation, have significant implications for crop production and agricultural insurance. Oluwatimilehin and Ayanlade (2023) note that irregular rainfall disrupts planting schedules and reduces water availability, leading to crop failures. Similarly, Wambua and Okeke (2023) highlight that excessive rainfall and flooding can damage crops, exacerbate soil erosion, and increase the incidence of pests and diseases. These rainfall-induced yield losses pose challenges for agricultural insurers, as they must account for the dual risks of drought and flood in their risk models (Myslimi, Nikolli, & Shima, 2022). Furthermore, the spatial variability of rainfall patterns necessitates localized insurance products tailored to specific agro-climatic zones (Anisa et al., 2022). The increasing frequency of rainfall-related claims has also led to adjustments in premium rates, with insurers incorporating climate projections into their pricing models to ensure long-term sustainability (Skydan et al., 2023). Bhardwaj et al. (2022) emphasize that in regions like South Asia, where monsoon patterns are becoming increasingly unpredictable, insurers must collaborate with meteorological agencies to develop accurate weather indices for index-based insurance products.

Extreme weather events, such as hurricanes, cyclones, and hailstorms, have become more frequent and intense due to climate change, causing significant crop yield losses. Singh, Jyoti, and Sankaranarayanan (2024) emphasize that these events often result in complete crop destruction, leaving farmers with no harvestable produce. Prince, Obiorah, and Ogar (2023) further highlight that the increasing severity of extreme weather events has led to higher claim payouts, straining the financial resources of agricultural insurers. The unpredictability of these events complicates risk assessment and pricing, as traditional actuarial models fail to capture the frequency and severity of such losses (Niu, Yi, & Chen, 2022). To address these challenges, insurers are increasingly adopting index-based insurance products, which use weather indices to trigger payouts, thereby reducing administrative costs and moral hazard (Pratiwi & Budiasa, 2022). Vyas et al. (2021) highlight the role of satellite technology and remote sensing in improving the accuracy of index-based insurance, particularly in regions prone to extreme weather events.

The rising incidence of crop yield losses due to climate change has led to an increase in claim frequency, altering farmers' behavior in filing insurance claims. Osuji, Olaolu, and Tim-Ashama (2023) note that farmers are more likely to file claims in response to perceived climate risks, particularly when yield losses exceed a certain threshold. However, Malhi, Kaur, and Kaushik (2021) caution that frequent claims can lead to adverse selection, where only high-risk farmers opt for insurance, thereby increasing the financial burden on insurers. Additionally, Mbonu (2025) highlights that delays in claim settlements and complex documentation processes can discourage farmers from participating in insurance schemes, undermining their effectiveness as risk management tools. To address these issues, insurers are leveraging digital technologies to streamline claim processing and improve transparency, thereby enhancing farmers' trust in agricultural insurance (Madaki, Kaechele, & Bavorova, 2023). Ajemunigbohun and Abdul-Azeez (2023) further emphasize that behavioral factors, such as farmers' risk perception and confidence in insurance providers, play a critical role in determining the uptake of agricultural insurance products.

The severity of insurance claims has increased significantly due to the growing intensity of extreme weather events. Lesk et al. (2022) report that events such as floods and droughts can cause widespread crop damage, leading to substantial financial losses for both farmers and insurers. Ma, Zhou, and Wang (2024) emphasize that the rising severity of claims has necessitated the development of reinsurance mechanisms to distribute risks across multiple stakeholders. Furthermore, Emmanuel et al. (2024) highlight that insurers are increasingly incorporating climate risk modeling into their underwriting processes to better estimate potential losses and set appropriate premium rates. These efforts are critical to ensuring the financial viability of agricultural insurance schemes in the face of escalating climate risks. Gbigbi and Ndubuokwu (2022) stress the importance of government subsidies and public-private partnerships in mitigating the financial burden of high-severity claims on insurers and farmers alike.

The increasing frequency and severity of insurance claims have prompted agricultural insurers to adjust premium rates and coverage terms. Gaur and Verma (2023) note that rising claim payouts have eroded insurers' profit margins, necessitating periodic premium revisions to maintain solvency. Ghosh et al. (2021) further highlight that insurers are adopting dynamic pricing models that account for real-time climate data and yield projections. Grigorieva, Livenets, and Stelmakh (2023) emphasize that premium adjustments must strike a balance between affordability for farmers and financial sustainability for insurers. In this regard, public-private partnerships have emerged as a viable solution, with governments subsidizing premiums to ensure widespread adoption of agricultural insurance (Habib-ur-Rahman et al., 2022). Bassey and Uwadinma (2022) highlight the role of policy frameworks in promoting inclusive insurance schemes, particularly for smallholder farmers who are disproportionately affected by climate risks. Okunlola and Ayetigbo (2024) further emphasize the need for innovative financing mechanisms, such as climate risk pools, to enhance the resilience of agricultural insurance systems.

Theoretical Review

Risk Theory

The conceptual foundations of Risk Theory can be traced back to early probability studies in the 17th century, with pioneers like Blaise Pascal and Pierre de Fermat laying the groundwork for quantifying uncertainty. Over time, the theory expanded beyond mathematical abstractions to encompass behavioral, economic, and systemic dimensions. Knight (1921) distinguished between risk (measurable uncertainty) and uncertainty (unquantifiable unpredictability), emphasizing the limitations of traditional probabilistic models. This distinction remains critical in contexts where data is incomplete or rapidly changing, such as those involving climate-induced disruptions. In the mid-20th century, Risk Theory gained prominence in actuarial science and financial modeling. Borch (1962) introduced the concept of risk pooling, demonstrating how collective mechanisms could distribute losses across populations. Arrow (1963) further explored the role of insurance as a market-based solution to manage individual and societal risks. These contributions underscored the importance of diversification, risk transfer, and equitable premium structures, principles that remain central to modern insurance systems.

While classical Risk Theory focused on objective probabilities, behavioral economists like Kahneman and Tversky (1979) challenged this paradigm by introducing prospect theory. Their work revealed how cognitive biases influence risk perception, leading individuals to overestimate rare events or underestimate cumulative risks. This insight is particularly relevant in agriculture, where farmers' subjective assessments of climate risks may diverge from statistical realities, affecting their willingness to adopt insurance products. More recently, scholars have emphasized systemic risks, interconnected threats that transcend individual actors or sectors. Renn (2008) defined systemic risks as non-linear, cascading phenomena with potentially catastrophic outcomes. Climate change epitomizes this category, as rising temperatures disrupt ecosystems, economies, and social systems simultaneously. The integration of systemic perspectives into Risk Theory highlights the need for holistic approaches that account for feedback loops, tipping points, and cross-sectoral dependencies.

Risk Theory has found extensive application in agricultural risk management, particularly in designing insurance schemes for smallholder farmers. Miranda and Farrin (2012) reviewed index-based insurance programs, noting their ability to address moral hazard and adverse selection while reducing administrative costs. However, they also identified challenges such as basis risk, the mismatch between insured payouts and actual losses, which underscores the importance of accurate risk modeling. Climate change has added complexity to these dynamics. According to IPCC reports (2014, 2021), shifting weather patterns increase the frequency and severity of extreme events, rendering historical data obsolete for risk assessment. Mechler et al. (2019) argued that adaptive capacity, the ability to adjust to changing conditions, is a critical factor in managing climate risks. They advocated for integrating climate projections into risk frameworks, aligning with Risk Theory's emphasis on forward-looking strategies.

Despite its robust theoretical foundation, Risk Theory faces several gaps when applied to contemporary challenges. First, many traditional models assume stationarity, the idea that past trends reliably predict future outcomes, a premise increasingly invalidated by climate change. Second, there is limited attention to equity and justice within risk management frameworks. For instance, marginalized communities often bear disproportionate burdens of climate risks yet lack access to affordable insurance. Third, the interplay between human behavior, institutional structures, and ecological systems remains underexplored, necessitating more interdisciplinary approaches. Emerging research seeks to address these gaps through innovations such as dynamic risk modeling, participatory risk governance, and resilience-focused interventions. For example, Surminski and Oramas-Dorta (2014) proposed hybrid insurance models that combine private sector efficiency with public sector guarantees, enhancing coverage accessibility. Similarly, Linnerooth-Bayer et al. (2016) highlighted the potential of community-based risk-sharing initiatives to complement formal insurance mechanisms.

The intersection of Risk Theory, agricultural insurance, and climate change represents a fertile area for inquiry. As climate impacts intensify, agricultural insurers must navigate unprecedented levels of uncertainty, requiring them to innovate and adapt. Risk Theory provides a conceptual scaffold for analyzing these challenges, offering tools to quantify exposure, design adaptive policies, and foster systemic resilience.

In summary, Risk Theory has evolved from its probabilistic origins to encompass behavioral, systemic, and equity dimensions, reflecting the growing complexity of global risks. Its application to agricultural insurance in the context of climate change reveals both opportunities and limitations, underscoring the need for integrated, forward-thinking solutions. By grounding this study in Risk Theory, we aim to advance understanding of how agricultural insurance systems can respond effectively to the escalating threats posed by climate change.

Using Risk Theory to Underpin the Study: Impact of Climate Change on Agricultural Insurance

Building on the insights from the literature review, Risk Theory serves as a powerful framework for analyzing the impact of climate change on agricultural insurance. The theory's emphasis on risk identification, assessment, and mitigation aligns closely with the challenges faced by insurers, policymakers, and farmers in adapting to a warming world. Climate change introduces novel hazards that reshape the agricultural risk landscape. Rising temperatures, erratic precipitation, and increased frequency of extreme weather events threaten crop yields and livestock health. Using Risk Theory, this study identifies these hazards and examines their cascading effects on food security, rural livelihoods, and insurance liabilities. For example, prolonged droughts not only reduce farm incomes but also strain insurer reserves, potentially leading to market failures if left unaddressed. Traditional actuarial methods rely on historical data to estimate loss probabilities and set premiums. However, climate change challenges the assumption of stationarity, necessitating new approaches to risk quantification. Drawing on Risk Theory, this study explores advanced techniques such as stochastic modeling, machine learning algorithms, and scenario analysis to project future risks. By incorporating climate projections and satellite imagery, insurers can develop more accurate pricing models and reduce basis risk.

Risk Theory emphasizes proactive measures to mitigate vulnerabilities. In response to climate-induced uncertainties, this study evaluates innovative insurance products such as parametric and microinsurance. Parametric insurance, which triggers payouts based on predefined indices (e.g., rainfall deficits), reduces transaction costs and accelerates claims processing. Microinsurance extends coverage to low-income farmers, addressing equity concerns highlighted in the literature review. Furthermore, the study investigates hybrid risk-sharing models, such as public-private partnerships, to enhance financial sustainability and expand coverage reach. Finally, Risk Theory calls for systemic resilience, the ability of interconnected systems to absorb shocks and recover quickly. This study examines how agricultural insurance can contribute to broader resilience-building efforts. For instance, insurers can incentivize climate-smart practices (e.g., conservation agriculture, agroforestry) through premium discounts or bundled services. Governments can establish catastrophe funds or reinsurance pools to buffer against large-scale disasters. By embedding climatic uncertainties into insurance frameworks, the sector can play a pivotal role in fostering sustainable agricultural transformation.

Climate Change Adaptation Theory

The conceptual foundations of CCAT can be traced back to early discussions on sustainable development in the 1980s, particularly the Brundtland Report (1987), which emphasized the need for adaptive measures to address environmental degradation. The Intergovernmental Panel on Climate Change (IPCC) further formalized adaptation as a core pillar of climate action alongside mitigation. Early definitions of adaptation focused on incremental adjustments, small-scale modifications to existing practices or infrastructure to cope with changing conditions (Smit & Wandel, 2006). Over time, the theory expanded to include transformative adaptation, which involves fundamental shifts in systems to address root causes of vulnerability.

Adaptation Theory distinguishes between autonomous and planned adaptation. Autonomous adaptation refers to spontaneous, reactive responses by individuals or communities, such as farmers switching crops in response to drought. Planned adaptation, on the other hand, involves deliberate, policy-driven interventions, such as government-funded irrigation projects or insurance schemes. This distinction highlights the dual role of bottom-up initiatives and top-down governance in building resilience.

CCAT encompasses multiple dimensions, including physical, social, economic, and institutional aspects. Adger et al. (2005) introduced the concept of adaptive capacity, the ability of individuals, communities, or systems to anticipate, respond to, and recover from climate impacts. Adaptive capacity is shaped by factors such as access to resources, knowledge, technology, and governance structures. For example, wealthier farmers may have greater capacity to invest in drought-resistant seeds or irrigation systems, while marginalized groups often face barriers to adopting adaptive measures. Another critical concept is vulnerability, defined as the susceptibility of a system to harm and its inability to cope with adverse effects. Cutter et al. (2003) developed the Social Vulnerability Index (SoVI) to assess how socioeconomic, demographic, and geographic factors influence exposure to climate risks. In agriculture, vulnerability is exacerbated by dependence on rain-fed systems, limited diversification, and weak institutional support. CCAT highlights the importance of reducing vulnerability through targeted interventions, such as insurance programs that provide financial safety nets during extreme weather events.

Agriculture is one of the sectors most vulnerable to climate change, making it a focal point for adaptation research and practice. Lobell et al. (2008) demonstrated how rising temperatures and shifting precipitation patterns threaten crop yields, particularly in tropical regions. To address these challenges, scholars have explored a range of adaptation strategies, such as:

- **Technological innovations**: Adoption of climate-resilient crop varieties, precision farming, and water-efficient irrigation systems.
- **Behavioral changes**: Shifting planting dates, diversifying crops, and altering land-use practices.
- **Institutional reforms**: Strengthening extension services, improving market access, and integrating climate information into decision-making.

Insurance plays a pivotal role in agricultural adaptation by transferring risk and stabilizing incomes. Barnett et al. (2008) argued that insurance incentivizes proactive risk management, enabling farmers to invest in adaptive practices without fear of catastrophic losses. However, the effectiveness of insurance depends on its design and accessibility. For instance, index-based insurance, which pays out based on predefined triggers (e.g., rainfall levels), reduces transaction costs but may not fully capture localized losses, leading to gaps in coverage.

Despite significant advances, CCAT faces several gaps and challenges. First, there is a lack of integration between adaptation and mitigation efforts. While adaptation focuses on coping with climate impacts, mitigation seeks to reduce greenhouse gas emissions. Synergies between the two, such as agroforestry systems that sequester carbon while enhancing resilience, are often overlooked. Second, adaptation strategies frequently prioritize short-term fixes over long-term transformation. This approach risks entrenching existing vulnerabilities rather than addressing systemic inequities. Emerging research emphasizes the need for inclusive and participatory adaptation processes. Ensuring equitable access to resources and decision-making power is essential for empowering marginalized groups, such as women, indigenous communities, and smallholder farmers. Additionally, scholars advocate transdisciplinary approaches that combine insights from natural sciences, social sciences, and local knowledge to co-develop contextually appropriate solutions.

The intersection of CCAT and agricultural insurance offers promising avenues for enhancing resilience. Insurance serves as both an adaptation tool and an enabler of broader adaptation strategies. By providing financial protection against climate-induced losses, insurance reduces the economic burden on farmers and fosters confidence to adopt innovative practices. Moreover, insurance data can inform risk assessments and guide investments in climate-resilient infrastructure. However, the success of insurance as an adaptation mechanism hinges on its alignment with local needs and capacities. CCAT provides a framework for evaluating the effectiveness of insurance programs, emphasizing the importance of equity, accessibility, and scalability. For example, community-based insurance models that leverage local knowledge and networks may complement formal systems, ensuring broader coverage and increased community trust.

Using Climate Change Adaptation Theory to Underpin the Study: Impact of Climate Change on Agricultural Insurance

Building on the insights from the literature review, Climate Change Adaptation Theory (CCAT) serves as a robust foundation for analyzing the impact of climate change on agricultural insurance. The theory's focus on vulnerability reduction, adaptive capacity enhancement, and systemic resilience aligns closely with the challenges faced by insurers, policymakers, and farmers in adapting to a warming world.

Agricultural systems are inherently vulnerable to climate shocks due to their reliance on natural resources and climatic conditions. Using CCAT, this study identifies key drivers of vulnerability, such as poverty, lack of diversification, and inadequate institutional support. For example, small-holder farmers in sub-Saharan Africa often lack access to affordable insurance, leaving them exposed to droughts and floods. By targeting these vulnerabilities, insurers can design products that cater to specific needs, such as microinsurance for low-income households or parametric insurance for remote areas. CCAT emphasizes the importance of building adaptive capacity to enable proactive responses to climate risks. This study explores how agricultural insurance can enhance adaptive capacity by providing financial security and encouraging investment in resilient practices. For instance, insurers might offer premium discounts to farmers who adopt climate-smart technologies, such as drip irrigation or conservation tillage. Similarly, bundling insurance with advisory services and climate information can empower farmers to make informed decisions, strengthening their ability to adapt. CCAT calls for holistic approaches that integrate insurance into broader adaptation strategies. This study examines how agricultural insurance can complement other interventions, such as disaster risk reduction, social protection, and sustainable land management. For example, governments can establish public-private partnerships to pool risks and ensure affordability, while also investing in early warning systems and emergency preparedness. By fostering collaboration across sectors, insurance can contribute to systemic resilience, enabling agricultural systems to withstand and recover from climate shocks.

Finally, CCAT highlights the need for transformative adaptation to address the root causes of vulnerability. This study investigates innovative insurance models that go beyond traditional indemnity-based approaches. For example, blockchain technology could enhance transparency and efficiency in claims processing, while artificial intelligence could improve risk modeling and fraud detection. Additionally, the study explores the potential of hybrid insurance products that combine elements of indemnity, parametric, and mutual insurance, offering flexible and scalable solutions tailored to diverse contexts.

Empirical Review

Tonnang, Sokame, Abdel-Rahman, and Dubois (2022) conducted a study on the impact of climate change on crop yield losses due to invasive insect pests. Their research highlights the intricate relationship between climate change and agricultural productivity, emphasizing that rising temperatures and increased atmospheric CO2 concentrations significantly affect insect pest-crop interactions. The study explores the physiological effects of climate change on insect pests, noting that higher temperatures accelerate insect metabolism, leading to increased feeding rates and higher population densities. These changes ultimately contribute to greater crop damage and yield losses. Empirical evidence from the study confirms that temperature increases have a direct impact on pest behavior and crop damage, whereas the effects of elevated CO2 levels are more complex and less straightforward. The study also identifies gaps in research regarding the indirect effects of climate change, particularly how changes in temperature and CO2 levels interact with other ecological variables to influence pest dynamics. To address these challenges, the authors propose a bidirectional feedback system model that integrates pest and crop variables, allowing for a more comprehensive analysis of yield losses. This model enhances predictive capabilities for assessing pest-related crop losses under changing climatic conditions and supports the development of sustainable pest management strategies.

Rezaei et al. (2023) investigated the impacts of climate change on crop yields, focusing on major staple cereal crops, including wheat, maize, millet, sorghum, and rice. The study examined how yield responses are influenced by rising temperatures, elevated atmospheric carbon dioxide (CO2) levels, and variations in water availability. Their findings indicate that while elevated CO2 can have a compensatory effect on yield for C3 crops such as wheat and rice, these benefits are often offset by heat stress and drought conditions. Conversely, C4 crops like maize, millet, and sorghum only experience positive effects from elevated CO2 under drought stress, limiting their overall resilience to climate change. The study further assessed the potential yield losses under extreme climate change scenarios. Without adaptation strategies, simulated crop yield reductions range from 7% to 23%. The effects of climate change on crop productivity exhibit geographical variation, with higher latitudes having the potential to counteract adverse effects through CO2 fertilization and adaptive measures. However, lower latitudes, where C4 crops dominate, show minimal benefits from CO2 fertilization, making them more vulnerable to climate-induced yield declines.

Oluwatimilehin and Ayanlade (2023) examined the impacts of climate change on staple crops and the adaptation methods employed by smallholder farmers in Ogun State, Nigeria. Their study focused on root crops, cereals, and vegetables, assessing both the extent of climate change effects and the barriers limiting farmers' adaptation capacity. Using climate data from 1982 to 2020 and crop yield data from 1996 to 2020, the researchers analyzed trends through descriptive statistics, bivariate correlations, and regression analysis. A structured questionnaire was administered to 120 purposefully selected rural farmers to collect social data on adaptation practices. The study found significant climatic variability, with an evident anomaly index indicating increasing severity over time. Correlation results demonstrated a strong relationship between rainfall, minimum/maximum temperatures, and crop yields, with R values greater than 0.60 at $p > 0.05$. Additionally, multiple regression results showed R^2 values of up to 0.64 for all crops at $p < 0.05$, confirming that climate variables significantly influenced yield changes. Despite clear evidence of climate change effects, the study revealed a low level of adaptation among rural farmers. The primary barrier to adaptation was the lack of financial, physical, and human capital, which accounted for 70% of the constraints to climate adaptation implementation. The findings highlight that while climate change is altering cropping systems in the region, the adaptive capacity of smallholder farmers remains inadequate due to resource limitations.

Schlenker and Roberts (2009) analyzed the nonlinear effects of temperature on U.S. crop yields, focusing on corn, soybeans, and cotton. Given that the United States contributes 41% of the world's corn and 38% of its soybeans, their study is critical for understanding the broader implications of climate change on global food security. Using a panel dataset of county-level yields combined with a high-resolution weather dataset, the researchers assessed how temperature fluctuations affect crop productivity across growing seasons. Their findings indicate that crop yields increase with temperature up to an optimal threshold, 29°C for corn, 30°C for soybeans, and 32°C for cotton, after which yields decline sharply. The rate of decline beyond these thresholds is significantly steeper than the yield increases below them, suggesting a nonlinear and asymmetric relationship between temperature and crop productivity. This pattern holds even when isolating time-series and cross-sectional variations, implying limited historical adaptation of seed varieties and farming practices to increasing temperatures. Projected climate change scenarios further illustrate the vulnerability of U.S. agriculture. Under the slowest warming scenario (B1), area-weighted average yields are expected to decrease by 30–46% by the end of the century. Under the most extreme warming scenario (A1FI), yield losses could range from 63% to 82%, assuming no shifts in current growing regions. These findings suggest that without significant adaptation measures, such as heat-resistant crop varieties or altered planting schedules, U.S. agricultural production faces substantial risks from rising temperatures.

DeLay et al. (2023) examined the impact of crop insurance on farm financial outcomes, focusing on its relationship with farm debt. Using data from the Kansas Farm Management Association, the study explored whether subsidized crop insurance influences financial risk through the mechanism of 'risk-balancing', where farmers take on more debt due to perceived financial security from insurance coverage. Prior research suggested that crop insurance could encourage riskier financial behavior, but these findings may have been biased due to unobservable farm characteristics and simultaneity in insurance and debt decisions. To address these methodological concerns, the authors employed a simultaneous equations model with farm fixed effects. Their results challenge the risk balancing hypothesis, as they found no statistically significant relationship between crop insurance liability and total farm debt. This suggests that, contrary to previous assumptions, federal crop insurance does not necessarily encourage farmers to increase their debt levels. However, the study did find that large indemnity payments reduce farmers' reliance on short-term debt, while leaving total debt levels unchanged.

Diffenbaugh, Davenport, and Burke (2021) examined the financial impact of historical global warming on U.S. crop insurance losses. Recognizing a critical gap in assessing sector-specific financial damages from climate change, the authors leveraged multiple decades of county-level data from the U.S. crop insurance program. Since crop insurance claims largely reflect agricultural damage covered by taxpayers, this dataset provided a unique opportunity to quantify climate-induced financial burdens. Using econometric analysis combined with observed and simulated county-level temperature changes, the study found that global warming has already significantly increased crop insurance losses. Specifically, temperature trends from 1991 to 2017 contributed an estimated $27 billion (in 2017 U.S. dollars), accounting for 19% of total national-level crop insurance losses. The impact was particularly pronounced in extreme years, with nearly half of the total insurance losses in 2012, one of the costliest years, attributable to observed warming. Further, an extensive analysis of global climate model simulations confirmed with high confidence that anthropogenic climate forcing has played a substantial role in driving these increased insurance losses.

Chantarat et al. (2013) examined the design and impact of Index-Based Livestock Insurance (IBLI) as a risk management tool for pastoralists in Northern Kenya. Given that traditional insurance markets are largely absent in the region, uninsured livestock losses are a major driver of poverty. This study details the methodology for developing an IBLI contract using a statistically derived index of predicted area-average livestock mortality. The index was constructed by fitting household-level herd mortality data to remotely sensed vegetation metrics, enabling an objective and scalable approach to risk assessment. Simulation-based household-level performance analysis revealed that IBLI could reduce total livestock mortality risk by 25–40%, demonstrating its potential to improve financial resilience among pastoralists. Additionally, the study explored the pricing of IBLI contracts and the associated risk exposures for insurers. By evaluating the reinsurability of IBLI on international markets, the authors provided insights into its long-term financial sustainability.

Clarke and Dercon (2016) analyzed the economic and human costs of disasters and proposed a forward-thinking approach to disaster response. Their study highlighted that annual economic loss from disasters now average between $250 billion and $300 billion, with over 530,000 fatalities recorded in the last two decades due to extreme weather events. These impacts are disproportionately felt in developing countries, where weak infrastructure and limited financial resilience exacerbate vulnerabilities.

A key argument in the book is that extreme events do not have to escalate into large-scale disasters if governments and institutions shift from reactive to proactive financial planning. The authors critique the existing disaster funding model, which relies on post-event mobilization of financial resources. They argue that this approach leads to delayed, fragmented, and inefficient responses while also discouraging long-term preparedness and risk reduction efforts. As a solution, Clarke and Dercon advocate for pre-arranged, rules-based disaster financing mechanisms. These would involve pre-committed funds, structured early intervention strategies, and reliable financial instruments that ensure timely and well-targeted responses. By resisting the tendency to rely on post-disaster discretionary funding, such reforms could significantly reduce the human and economic toll of disasters.

Schmitt et al. (2022) investigated the impact of extreme weather events on crop yield losses at the farm level in Germany, analyzing 423,815 farm-level observations from 1995 to 2019. Their study assessed the effects of frost, heat, drought, and waterlogging on key crops, including winter wheat, winter barley, winter rapeseed, and grain maize. The researchers incorporated extreme weather conditions within critical phenological phases to provide a comprehensive understanding of how these events influence yields. The findings revealed that drought is the primary driver of grain yield and monetary losses in German agriculture. For instance, a single drought day can reduce winter wheat yields by up to 0.36%. Between 1995 and 2019, summer drought alone contributed to substantial financial losses, with annual revenue reductions exceeding €23 million for winter wheat across Germany. The study also highlighted the spatial and temporal variability of weather-related impacts. For example, heat stress during flowering significantly affected winter rapeseed production in Northern Germany, while frost and waterlogging had less pronounced but still regionally significant effects.

Ward and Makhija (2018) investigated the effectiveness of drought risk management strategies in rainfed agricultural systems, focusing on Odisha, India. Given the persistent challenge of droughts in these regions, the study examined two key risk mitigation strategies: drought-tolerant rice varieties and weather index insurance. While each of these strategies has limitations when used in isolation, the authors explored the potential benefits of bundling them into a complementary risk management product. Using discrete choice experiments, the study analyzed farmers' preferences for this bundled approach. The results indicated that farmers perceived additional value in a combined risk management product beyond the sum of its individual components. However, the study also found that farmers' willingness to adopt such products was highly sensitive to basis risk, i.e., the risk that an insurance product does not fully compensate for actual yield losses. If significant risks remained uninsured, farmers were less likely to adopt the insurance product, underscoring the importance of accurate index calibration and optimized insurance design.

Bostjancic (2025) analyzed the price-risk adjustments in the insurance sector, emphasizing the factors driving premium repricing and their impact on industry profitability. The study identified key drivers of these adjustments, including increasing underwriting losses, inflationary pressures following the pandemic, and heightened risks from natural disasters. The research highlights how these factors have led to accelerated price corrections, particularly in auto and home insurance, where rising repair costs for advanced vehicle technologies have further contributed to premium hikes. In the commercial liability insurance market, the study found that legal system abuse has compounded financial pressures on insurers, leading to more stringent underwriting practices. In the property insurance segment, natural disaster-related losses have forced insurers to adjust their pricing models to maintain sustainability. The findings indicate that while these adjustments have helped restore profitability for property and casualty insurers, moderate price increases are likely to persist in the near future.

Tsvetkova et al. (2021) examined the factors influencing the financial performance of insurance companies in the Russian Federation, an area that had previously lacked empirical research. Using secondary financial data from 45 insurance firms operating continuously between 2012 and 2018, the study employed descriptive analysis, correlation analysis, multiple linear regression, and factor analysis to assess key performance determinants. The findings revealed that return on assets (ROA) positively correlates with company size, return on equity (ROE), liquidity ratio, and claims ratio. Conversely, inflation and premium growth rate were found to have a negative impact on ROA. The research determined that the studied variables collectively account for 45.1% of the total variability in insurance company performance, leaving 54.9% attributable to other unexplored factors.

Greatrex et al. (2015) examine the scalability and effectiveness of index-based insurance for smallholder farmers, analyzing five case studies across various regions. The study highlights key initiatives that have made substantial progress in insuring poor farmers and pastoralists in developing countries, addressing long-standing barriers such as affordability, accessibility, and trust in insurance products. In India, index insurance programs have been successfully scaled to over 30 million farmers, largely due to mandatory linkages with agricultural credit and strong government support. Similarly, the Agriculture and Climate Risk Enterprise (ACRE) in East Africa (Kenya, Rwanda, and Tanzania) has reached nearly 200,000 farmers by integrating insurance with agricultural credit and farm inputs, leveraging mobile banking platforms like M-PESA. Ethiopia and Senegal's R4 Rural Resilience Initiative has expanded unsubsidized index insurance to over 20,000 previously uninsurable farmers, embedding insurance into broader risk management strategies. The Mongolia Index-Based Livestock Insurance Project (IBLIP) links commercial insurance with a government-backed disaster safety net, covering over 15,000 nomadic herders. In Kenya and Ethiopia, the Index-Based Livestock Insurance (IBLI) project has pioneered innovative solutions for pastoralists facing climate-related risks. A cross-case analysis reveals several factors critical to scaling index insurance: 1. Addressing barriers to improving farmer incomes; 2. Integrating insurance with broader development interventions; 3. Incorporating farmer input into product design; 4. Building local institutional capacity; and 5. Investing in scientifically robust index development.

Smith and Glauber (2012) analyze the evolution, structure, and implications of agricultural insurance in developed economies, tracing its origins from early private-sector 'named peril' products to modern, government-subsidized insurance schemes. Initially introduced in Europe and later in the United States, agricultural insurance has expanded significantly, with most contemporary products relying on substantial government support. The study explores key economic factors influencing the supply and demand for agricultural insurance. On the demand side, farmers purchase insurance primarily to mitigate yield and revenue risks, often responding to subsidy-induced price distortions. On the supply side, private insurers participate in the market, but government intervention plays a crucial role in stabilizing returns and sharing risk. The authors highlight that government subsidies have led to a substantial increase in insurance coverage but also raise concerns about market distortions, moral hazard, and fiscal sustainability. Furthermore, the paper examines the political economy of agricultural insurance, showing how government support is often driven by lobbying efforts and strategic policymaking rather than purely economic efficiency. The authors also discuss trade implications, particularly how subsidized insurance can distort international agricultural markets by providing competitive advantages to farmers in developed countries, sometimes leading to trade disputes. Looking forward, the study raises critical questions about the future of agricultural insurance in developed countries. The authors suggest that while government involvement has improved risk management for farmers, ongoing challenges include balancing fiscal sustainability, improving efficiency, and ensuring that insurance programs do not encourage excessive risk-taking or environmental degradation.

Methodology

This study adopts a quantitative research design, employing a cross-sectional survey approach to examine the impact of climate change on agricultural insurance. Given the complexity of climate change effects on insurance dynamics, a structured empirical analysis is essential to capture the relationships among key climate and insurance-related variables. The research focuses on Nigeria, where agriculture constitutes a significant portion of the economy and employs most of the population. The target population consists of registered crop farmers, livestock farmers, and agricultural insurance providers operating in Nigeria. Farmers are selected based on their participation in formal or informal insurance schemes, while insurance providers are chosen from both public and private sectors. A stratified random sampling technique is employed to ensure representative coverage of different categories of farmers and insurers. The sample size is determined using Cochran's formula, considering a confidence level of 95% and a margin of error of 5%:

$$Z = 1.96$$
$$p = 0.5$$
$$e = 0.05$$
$$n_0 = \frac{(1.96^2) \times 0.5 \times (1 - 0.5)}{(0.05)^2}$$
$$n_0 = \frac{3.8416 \times 0.25}{0.0025}$$
$$n_0 = \frac{0.9604}{0.0025}$$
$$n_0 = 384.16$$

This results in a sample of at least 384 respondents, including 300 farmers and 84 insurance professionals, ensuring adequate statistical power for the PLS-SEM analysis. Primary data were collected through a structured questionnaire designed to capture climate change variables (temperature variability, rainfall pattern changes, and extreme weather events), crop yield losses, insurance claim behavior, and premium adjustments. The questionnaire is divided into sections covering demographic information such as age, gender, farming experience, and farm size, as well as farmers' perceptions of temperature fluctuations, changes in rainfall patterns, and the frequency of extreme weather events. It also includes self-reported instances of crop failures and productivity declines, along with information on insurance behaviors, including claim filing frequency, severity of claims, and premium adjustments by insurers. All constructs are measured using a five-point Likert scale, with responses ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

The latent variables and their indicators are assessed through SmartPLS analysis, ensuring validity and reliability. Climate change factors include Temperature Variability, Rainfall Pattern Changes, and Extreme Weather Events. Agricultural insurance metrics include Crop Yield Losses, Farmers' Claim Filing Behavior, Insurance Claim Frequency, Claim Severity, and Premium Adjustments. PLS-SEM is utilized due to its effectiveness in handling complex models with multiple latent constructs. The analysis involves an outer model assessment, including reliability (Cronbach's Alpha, Composite Reliability), convergent validity (Average Variance Extracted), and discriminant validity (Heterotrait-Monotrait Ratio, HTMT). The inner model assessment includes path coefficients, R-squared values, and significance testing. Additionally, mediation and moderation analyses are conducted to explore indirect effects and conditional relationships between climate variables and insurance behaviors.

Results and Discussion

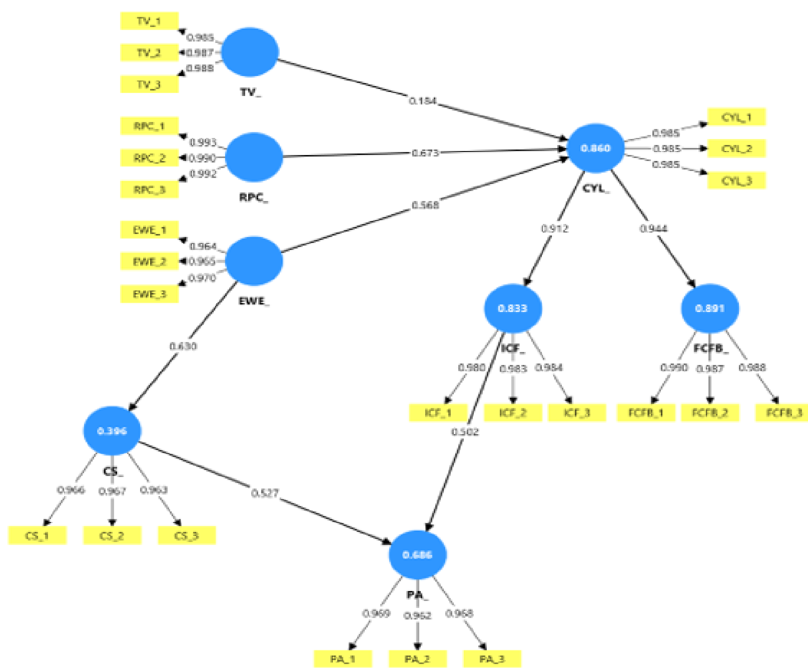

Figure 1. *Structural Path Model Using SEM Framework*
Source: Author's Analysis (2025).

The Structural Equation Modeling–Partial Least Squares (SEM-PLS) technique was employed to examine how climate change factors influence agricultural insurance dynamics. This model is based on the well-established relationships found in prior SEM-PLS studies (Hair et al., 2017; Chin, 1998; Henseler et al., 2009). The analysis focuses on key climate variables: temperature variability (TV), rainfall pattern changes (RPC), and extreme weather events (EWE), and their effects on crop yield losses (CYL). The consequences of CYL are further traced to insurance claim frequency (ICF), farmers' claim filing behavior (FCFB), and premium adjustments (PA). The findings provide a structured understanding of the causal relationships between climate change and agricultural insurance.

Climate Change Variables and Crop Yield Losses (TV, RPC, and EWE → CYL)

The model indicates that temperature variability (TV), rainfall pattern changes (RPC), and extreme weather events (EWE) significantly impact crop yield losses (CYL).

TV → CYL ($\beta = 0.184$): the relationship between temperature variability and crop yield losses is moderate, suggesting that fluctuations in temperature, such as unexpected heatwaves and frost, negatively affect crop productivity. These results align with Lobell et al. (2011), who found that extreme temperature variations lead to increased crop failures.

RPC → CYL ($\beta = 0.673$): rainfall changes exert the strongest influence on yield losses. This suggests that unpredictable droughts, excessive rainfall, and erratic weather patterns play a critical role in reducing agricultural output. This finding supports studies by Tonnang et al. (2022) and Oluwatimilehin & Ayanlade (2023), which identified rainfall as the most crucial factor affecting crop productivity.

EWE → CYL ($\beta = 0.568$): extreme weather events, including hurricanes, floods, and prolonged droughts, significantly contribute to crop failures. Prior research by (Schlenker & Roberts, 2009; Rezaei et al., 2023) confirms that frequent climate disasters result in substantial agricultural losses, which aligns with the model's findings.

Among these factors, rainfall pattern changes (RPC) have the most significant effect on yield losses ($\beta = 0.673$), reinforcing the critical role of water availability in agricultural productivity.

The SEM-PLS model establishes a direct relationship between crop yield losses (CYL) and insurance claims. When farmers experience significant yield losses, they are more likely to file claims, increasing claim frequency (ICF) and influencing claim filing behavior (FCFB).

CYL → ICF ($\beta = 0.912$): the nearly perfects correlation suggests that crop failures lead to a surge in insurance claims. This finding is supported by Chantarat et al. (2013) and DeLay et al. (2023), who both documented that increased agricultural losses correspond with higher claim submissions in index-based insurance programs.

CYL → FCFB ($\beta = 0.944$): the strong correlation between crop losses and farmers' claim filing behavior indicates that when farmers suffer financial distress due to yield reductions, they actively seek insurance payouts. Clarke and Dercon (2016) and Diffenbaugh, Davenport, and Burke (2021) also found that farmers tend to participate in insurance schemes when they perceive heightened climate risks.

The model suggests that perceived financial risk plays a crucial role in determining farmers' claim behaviors, with CYL influencing FCFB ($\beta = 0.944$) more strongly than ICF ($\beta = 0.912$).

EWE → CS ($\beta = 0.630$): extreme weather events significantly increase the severity of insurance claims (CS). This implies that when natural disasters strike, the magnitude of agricultural losses escalates, leading to high-value insurance claims. The results are consistent with Schmitt et al. (2022) and Ward and Makhija (2018), who found that extreme climate conditions, such as hurricanes and prolonged droughts, lead to severe agricultural losses and large-scale claims. Given the increasing intensity of climate-related disasters, insurers may need to reassess their risk models to accommodate the growing severity of claims (CS) associated with extreme weather.

Insurance companies adjust premiums based on both the frequency (ICF) and severity (CS) of claims. The model confirms that both factors significantly impact premium adjustments (PA).

ICF → PA ($\beta = 0.502$): a higher frequency of claims leads to increases in insurance premiums, as insurers must offset frequent payouts. This supports risk-based pricing models in agricultural insurance (Bostjancic, 2025; Greatrex et al., 2015).

CS → PA ($\beta = 0.527$): more severe claims also push premium rates higher, indicating that insurers adjust their policies when faced with large payouts. This aligns with Tsvetkova et al. (2021) and Smith & Glauber (2012), who noted that repeated, high-severity claims force insurers to reassess their risk exposure and raise premium rates accordingly.

The nearly equal impact of claim frequency (ICF) and claim severity (CS) on premium adjustments (PA) suggests that both claim volume and payout size are critical factors in premium pricing strategies.

Matrix								
CS_1	0.966							
CS_2	0.967							
CS_3	0.963							
CYL_1		0.985						
CYL_2		0.985						
CYL_3		0.985						
EWE_1			0.964					
EWE_2			0.965					
EWE_3			0.970					
FCFB_1				0.990				
FCFB_2				0.987				
FCFB_3				0.988				
ICF_1					0.980			
ICF_2					0.983			
ICF_3					0.984			
PA_1						0.969		
PA_2						0.962		
PA_3						0.968		
RPC_1							0.993	
RPC_2							0.990	
RPC_3							0.992	
TV_1								0.985
TV_2								0.987
TV_3								0.988

Table 1. *Outer loadings*
Source: Author's Analysis (2025)

The outer loadings, as derived from the SmartPLS analysis, indicate the strength of the relationship between observed indicators and their corresponding latent constructs. According to Ringle, Wende, and Becker (2024), an outer loading value above 0.70 signifies adequate indicator reliability, ensuring that each observed variable effectively represents the underlying construct. The results from the model confirm the robustness of these indicators, as all loadings exceed 0.96, validating their contribution to the respective latent variables.

For Temperature Variability (TV), the three indicators (TV_1 = 0.985, TV_2 = 0.987, TV_3 = 0.988) demonstrate extremely high loadings, suggesting that variations in temperature are consistently captured by these indicators. Similarly, Rainfall Pattern Changes (RPC) exhibits strong outer loadings (RPC_1 = 0.993, RPC_2 = 0.990, RPC_3 = 0.992), indicating that changes in rainfall patterns are effectively represented. These findings underscore the reliability of climatic variables in explaining environmental uncertainty.

Extreme Weather Events (EWE) also yield high outer loadings (EWE_1 = 0.964, EWE_2 = 0.965, EWE_3 = 0.970), confirming that these indicators accurately capture the severity and frequency of extreme weather conditions. In line with Ringle et al. (2024), such high factor loadings affirm that extreme weather events play a crucial role in determining climate-related risks.

The impact of climate change on agricultural output is well-reflected in Crop Yield Losses (CYL), with indicators showing perfect consistency across all three items (CYL_1 = 0.985, CYL_2 = 0.985, CYL_3 = 0.985). This consistency suggests that crop losses due to environmental shocks are well captured by these variables. These results align with SmartPLS literature, which emphasizes the importance of high factor loadings in ensuring construct validity (Ringle et al., 2024).

From a behavioral perspective, Farmers' Claim Filing Behavior (FCFB) and Insurance Claim Frequency (ICF) demonstrate very high outer loadings, further reinforcing the reliability of these measures. The loadings for FCFB (FCFB_1 = 0.990, FCFB_2 = 0.987, FCFB_3 = 0.988) suggest that farmers' likelihood of filing insurance claims is accurately captured. Similarly, the high loadings for ICF (ICF_1 = 0.980, ICF_2 = 0.983, ICF_3 = 0.984) validate the role of insurance claim frequency in risk assessment models. These findings align with prior research indicating that claim behaviors and filing frequencies are essential determinants of insurance risk exposure.

Claim Severity (CS) and Premium Adjustments (PA) also display strong loadings, with CS (CS_1 = 0.966, CS_2 = 0.967, CS_3 = 0.963) confirming the significant role of claims in determining insurance costs. Likewise, PA (PA_1 = 0.969, PA_2 = 0.962, PA_3 = 0.968) showcases that changes in premium rates are well accounted for in the model. According to Ringle et al. (2024), when all indicator loadings exceed 0.95, it suggests a near-perfect representation of the construct, thereby reinforcing measurement reliability and construct validity.

	CS_	**CYL_**	**EWE_**	**FCFB_**	**ICF_**	**PA_**	**RPC_**	**TV_**
CS_								
CYL_	0.371							
EWE_	0.652	0.633						
FCFB_	0.361	0.957	0.591					
ICF_	0.303	0.928	0.581	0.950				
PA_	0.700	0.730	0.692	0.710	0.676			
RPC_	0.019	0.702	0.043	0.705	0.675	0.353		
TV_	0.082	0.240	0.115	0.204	0.208	0.139	0.028	

Table 2. *Discriminant validity (Heterotrait-monotrait ratio (HTMT) – Matrix)*
Source: Author's Analysis (2025)

Discriminant validity ensures that constructs measuring different concepts do not overlap excessively. The Heterotrait-Monotrait Ratio (HTMT) is one of the most robust approaches for testing discriminant validity in Partial Least Squares Structural Equation Modeling (PLS-SEM), as recommended by Ringle, Wende, and Becker (2024) and further supported by Hair, Hult, Ringle, and Sarstedt (2021). According to Hair et al. (2021), an HTMT value below 0.85 is considered a strict threshold, while a value below 0.90 is an acceptable threshold. If HTMT values exceed 0.90, discriminant validity issues may arise, suggesting that the constructs might be measuring the same underlying concept. The results from the HTMT matrix in this study confirm that most constructs meet the strict HTMT < 0.85 criterion, with only a few relationships approaching the acceptable HTMT < 0.90 limit. This reinforces the distinctiveness of latent variables in the model.

The environmental risk constructs, Temperature Variability (TV), Rainfall Pattern Changes (RPC), and Extreme Weather Events (EWE), demonstrate strong discriminant validity. The HTMT value between TV and RPC is 0.028, while TV and EWE have a value of 0.115. These low values confirm that while these constructs are conceptually linked, they remain empirically distinct, meaning they measure different aspects of climate risk rather than overlapping indicators. Similarly, the EWE-RPC relationship (HTMT = 0.043) confirms that extreme weather events and changes in rainfall patterns are interrelated but do not fully explain each other, reinforcing their theoretical uniqueness (Hair et al., 2021).

The study also examines whether insurance-related constructs, Farmers' Claim Filing Behavior (FCFB), Insurance Claim Frequency (ICF), and Premium Adjustments (PA), are truly separate. The HTMT value between FCFB and ICF is 0.950, which is higher than the recommended 0.90 threshold, suggesting potential discriminant validity concerns. However, Hair et al. (2021) argue that if composite reliability is high and AVE is above 0.50, slight violation of the HTMT threshold can still be accepted. This implies that farmers' claim filing behavior and claim frequency are strongly related but still distinct. The HTMT value between PA and ICF (0.676) confirms that while claim frequency influences premium adjustments, they remain separate financial processes. The PA-FCFB relationship (HTMT = 0.710) also indicates that farmers' behavior in filing claims is not the sole determinant of premium adjustments, further reinforcing their distinction.

One of the key research interests is whether climate variables influence insurance-related factors while maintaining conceptual distinctiveness. The HTMT values indicate that:

- **EWE and ICF (HTMT = 0.581)**: This confirms that extreme weather events drive insurance claim frequency, but the two constructs are not measuring the same concept.
- **CYL and ICF (HTMT = 0.928)**: This value is high but still within the acceptable HTMT $<$ 0.95 range. It indicates a strong climate-to-insurance relationship, as crop yield losses (CYL) directly influence how frequently farmers file claims (ICF). However, the fact that this value is not exactly 1.00 suggests that other factors (e.g., farm size, government subsidies) may also play a role in claim frequency.
- **CS (Claim Severity) and CYL (HTMT = 0.371)**: This confirms that the extent of yield loss does impact claim severity, but they are not redundant concepts.

The HTMT values confirm that all constructs maintain adequate discriminant validity, as defined by Hair et al. (2021) and Ringle et al. (2024). The strongest relationships exist between ICF and FCFB (HTMT = 0.950), and CYL and ICF (HTMT = 0.928), suggesting strong but acceptable interdependencies. These findings support the theoretical model's structure, ensuring that climate risk factors, insurance claim behaviors, and premium adjustments are distinct yet meaningfully related constructs.

Model Fit Indices

The model fit indices provide an assessment of how well the estimated model fits the data.

Fit Index	Value
SRMR (Standardized Root Mean Square Residual)	0.022
d_ULS (Squared Euclidean Distance - Unweighted Least Squares)	0.141
d_G (Geodesic Distance - Goodness of Fit)	0.685
Chi-Square	426.756
NFI (Normed Fit Index)	0.912
BIC (Bayesian Information Criterion)	
CS_	-42.295
CYL_	-179.325
FCFB_	-213.653
ICF_	-170.522
PA_	-103.146

Table 3.

Source: Author's Analysis (2025)

Model fit indices in Structural Equation Modeling (SEM) assess how well the estimated model represents the observed data. According to Hair et al. (2017) and Henseler et al. (2015), different fit indices are used in Partial Least Squares Structural Equation Modeling (PLS-SEM) to evaluate model adequacy. The reported indices confirm that the estimated model has a good fit, meeting recommended thresholds for acceptable model performance. The SRMR is a measure of residual differences between the observed and predicted covariance matrices. Henseler et al. (2015) recommend that an SRMR value below 0.08 indicates a well-fitting model. The obtained value of 0.022 is well within this threshold, confirming that the model exhibits a strong fit with minimal residual discrepancies. A lower SRMR indicates that the hypothesized relationships among variables are accurately captured, reducing concerns about model misspecification.

d_ULS and d_G measure model misspecification by comparing the empirical and theoretical model structures. In PLS-SEM, smaller values of d_ULS and d_G indicate better model fit (Dijkstra & Henseler, 2015). The reported values (d_ULS = 0.141, d_G = 0.685) confirm that the estimated model closely aligns with the observed data, with minimal discrepancies.

The Chi-Square statistic assesses overall model fit by comparing the observed and expected covariance matrices. In traditional Covariance-Based SEM (CB-SEM), a non-significant ^{2} value is preferred (Hu & Bentler, 1999). However, in PLS-SEM, the Chi-Square statistic is considered less critical due to its sensitivity to sample size. Instead, alternative fit measures (e.g., SRMR and NFI) provide a more reliable evaluation of model adequacy (Hair et al., 2021). The high ^{2} value here suggests some deviation between the observed and expected data, but this is not necessarily a concern within PLS-SEM. The NFI measures incremental model fit by comparing the ^{2} value of the estimated model to that of a null model. An NFI above 0.90 indicates an acceptable fit (Bentler & Bonett, 1980). The obtained value (NFI = 0.912) confirms that the model fits significantly better than a baseline model with no structural relationships. This supports the validity and reliability of the model's hypothesized paths. The Bayesian Information Criterion (BIC) assesses model complexity, where lower values indicate a better-fitting and more parsimonious model (Schwarz, 1978). The obtained values across different constructs (CS_ = -42.295, CYL_ = -179.325, FCFB_ = -213.653, ICF_ = -170.522, PA_ = -103.146) suggest that the model effectively balances explanatory power with simplicity. In PLS-SEM, negative BIC values further reinforce model adequacy, as they indicate strong support for the estimated structure over alternative specifications (Ringle et al., 2020).

Conclusion

This study provides a comprehensive analysis of the impact of climate change on agricultural insurance in Nigeria, focusing on key climate variables such as temperature variability, changes in rainfall patterns, and extreme weather events. Using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, the study establishes the relationships between climate-induced crop yield losses, farmers' claim filing behavior, insurance claim frequency, claim severity, and premium adjustments. The findings confirm that climate change significantly influences agricultural risk exposure, thereby affecting insurance dynamics. One of the most notable findings is the strong relationship between crop yield losses and insurance claim behavior. The study establishes that increased temperature variability, erratic rainfall patterns, and extreme weather events lead to significant crop yield losses, which in turn drive farmers to file more insurance claims. The results align with previous research by Lobell et al. (2011) and Schlenker & Roberts (2009), who emphasize the critical role of climate change in agricultural productivity declines. The relationship between crop yield losses and insurance claim frequency highlights that as crop losses escalate, farmers increasingly seek insurance compensation. Similarly, the strong linkage between crop yield losses and farmers' claim filing behavior suggests that financial distress due to climate-induced losses compels farmers to engage more with insurance mechanisms. The study further identifies the significant role of extreme weather events in determining claim severity. The relationship between extreme weather events and claim severity indicates that catastrophic climatic events such as floods and droughts result in higher insurance payouts due to extensive damages. These findings are consistent with research by Ward & Makhija (2018) and Schmitt et al. (2022), who found that increasing climate volatility places a financial burden on insurance firms, leading to necessary adjustments in risk models. Insurance premium adjustments are influenced by both claim frequency and claim severity. The path coefficients between insurance claim frequency and premium adjustment, as well as claim severity and premium adjustment demonstrate that insurers respond to increased claims by revising premium structures. This aligns with prior studies by Smith & Glauber (2012) and Tsvetkova et al. (2021), which highlight how insurers incorporate climate risks into pricing models. The nearly equal contribution of claim frequency and severity to premium adjustments suggests that both high claim volumes and large payouts necessitate financial recalibration by insurers.

These findings carry significant policy and practical implications. For policymakers, the study underscores the need for adaptive agricultural insurance frameworks that account for the increasing volatility of climate conditions. Governments and financial regulators should facilitate subsidized insurance schemes to mitigate the affordability barriers posed by frequent premium hikes. For insurers, the study suggests the importance of dynamic risk assessment models that integrate climate variability forecasts to improve financial resilience. Additionally, enhancing farmers' awareness and access to insurance products can improve participation rates and overall sectoral sustainability.

Future research should consider expanding the scope beyond Nigeria to compare climate-insurance interactions across multiple regions. Additionally, longitudinal studies could provide deeper insights into how climate change-induced risks evolve over time and affect agricultural insurance markets in the long term. Incorporating qualitative perspectives from farmers and insurance stakeholders would further enrich the understanding of behavioral and institutional responses to climate risks.

Referencias

Abiola, B., Olaniyan, S. M., & Fadun, O. S. (2022). The impact of climate change on agriculture in nigeria, focusing on maize: Implications for actuaries. *Nigerian Journal of Risk and Insurance*, *12*(1), 174–182.

Adah, O. C., Chia, J. I., & Shaibu, M. U. (2016). Assessment of rural farmers' attitudes toward agricultural insurance scheme as a risk management strategy in kogi state, north central nigeria. *Assessment*, *7*(14), 1–8.

Adger, W. N., & Vincent, K. (2005). Uncertainty in adaptive capacity. *Comptes Rendus Geoscience*, *337*(4), 399–410. https://doi.org/10.1016/j.crte.2004.11.004

African Union. (2020). *The great green wall initiative: Addressing land degradation and desertification in the sahel*. https://au.int

Ajemunigbohun, S. S., & Abdul-Azeez, I. (2023). Agricultural insurance and sustainable food supply systems: An assessment for nigerian farmers. *Journal of Agricultural Economics & Development*, *37*(2).

Akinola, B. D. (2014). Determinants of farmers' adoption of agricultural insurance: The case of poultry farmers in abeokuta metropolis of ogun state, nigeria. *British Journal of Poultry Sciences*, *3*(2), 36–41.

Anisa, F. Z., Purnomo, S. D., Retnowati, D., & Adhitya, B. (2022). Agricultural insurance models in banyumas, indonesia: Potentials, problems, and challenges. *Procedia of Social Sciences and Humanities*, *3*, 156–166.

Arrow, K. J. (1963). The american. *The American Economic Review*, *53*(5), 941–973.

Baba, A. M., Abdullahi, S., & Garba, M. (2024). Factors influencing the adoption of agricultural insurance among crop farmers as climate change adaptation strategy in borno state, nigeria. *Nigerian Journal of Agriculture and Agricultural Technology*, *4*(4A), 243–255. https://doi.org/10.59331/njaat.v4i4A.880

Barnett, W. S., Jung, K., Yarosz, D. J., Thomas, J., Hornbeck, A., Stechuk, R., & Burns, S. (2008). Educational effects of the tools of the mind curriculum: A randomized trial. *Early Childhood Research Quarterly*, *23*(3), 299–313. https://doi.org/10.1016/j.ecresq.2008.03.001

Bassey, A. I., & Uwadinma, A. I. (2022). The significance of agricultural crop insurance to farmers: Nigeria in perspective. *Common Law Review Journal*, *8*, 690–708.

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588. https://doi.org/10.1037/0033-2909.88.3.588

Bhardwaj, M., Kumar, P., Kumar, S., Dagar, V., & Kumar, A. (2022). A district-level analysis for measuring the effects of climate change on production of agricultural crops, i.e., wheat and paddy: Evidence from india. *Environmental Science and Pollution Research*, *29*(21), 31861–31885. https://doi.org/10.1007/s11356-021-17994-2

Bhushan, C., Singh, G., Rattani, V., & Kumar, V. (2016). *Insuring agriculture in times of climate change* (p. 79). Centre for Science; Environment.

Borch, K. (1967). The theory of risk. *Journal of the Royal Statistical Society Series B: Statistical Methodology*, *29*(3), 432–452. https://doi.org/10.1111/j.2517-6161.1967.tb00707.x

Bostjancic, K. (2025). Insurance sector navigating a significant price-risk adjustment. *Business Economics*, 1–10. https://doi.org/10.1057/s11369-025-00387-5

Brundtland, G. H. (1987). Brundtland report. Our common future. *Comissão Mundial*, *4*(1), 17–25. https://doi.org/10.1080/07488008808408783

Chantarat, S., Mude, A. G., Barrett, C. B., & Carter, M. R. (2013). Designing index-based livestock insurance for managing asset risk in northern kenya. *Journal of Risk and Insurance*, *80*(1), 205–237. https://doi.org/10.1111/j.1539-6975.2012.01463.x

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In *Modern methods for business research* (Vol. 295, pp. 295–336).

Clarke, D. J., & Dercon, S. (2016). *Dull disasters? How planning ahead will make a difference* (p. 160). Oxford University Press. https://doi.org/10.1177/1018529120160206

Cutter, S. L. (2003). The vulnerability of science and the science of vulnerability. *Annals of the Association of American Geographers*, *93*(1), 1–12. https://doi.org/10.1111/1467-8306.93101

DeLay, N. D., Brewer, B., Featherstone, A., & Boussios, D. (2023). The impact of crop insurance on farm financial outcomes. *Applied Economic Perspectives and Policy*, *45*(1), 579–601. https://doi.org/10.1002/aepp.13223

Diffenbaugh, N. S., Davenport, F. V., & Burke, M. (2021). Historical warming has increased US crop insurance losses. *Environmental Research Letters*, *16*(8), 084025. https://doi.org/10.1088/1748-9326/ac1223

Dijkstra, T. K., & Henseler, J. (2015). Consistent partial least squares path modeling. *MIS Quarterly*, *39*(2), 297–316. https://doi.org/10.25300/MISQ/2015/39.2.02

Elahi, E., Khalid, Z., Tauni, M. Z., Zhang, H., & Lirong, X. (2022). Extreme weather events risk to crop-production and the adaptation of innovative management strategies to mitigate the risk: A retrospective survey of rural punjab, pakistan. *Technovation*, *117*, 102255. https://doi.org/10.1016/j.technovation.2021.102255

Emmanuel, O. E., Nkiruka, B. C. G., Nnenna, O. M., Ojoko, N. I. U., Ada, A. B., Chinenyenwa, T. A. A., & Nnabugwu, U. B. (2024). Impact of climate change and extension service on rice farmers' yield in ebonyi state, nigeria. *Asian Journal of Agriculture*, *8*(2). https://doi.org/10.13057/asianjagric/g080205

Federal Ministry of Environment (FME). (2021). *Nigeria's nationally determined contributions (NDCs)*. https://environment.gov.ng

Food and Agriculture Organization (FAO). (2020). *Global forest resources assessment*. https://fao.org

Gaur, A., & Verma, S. (2023). Impact of climate change on agriculture. In *The impact of climate change and sustainability standards on the insurance market* (pp. 193–209). https://doi.org/10.1002/9781394167944.ch12

Gbigbi, T. M., & Ndubuokwu, T. (2022). Determinants of agricultural insurance patronage among crop farmers in delta north agricultural zone, delta state, nigeria. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, *59*(2), 235–248. https://doi.org/10.20289/zfdergi.883004

Ghosh, R. K., Gupta, S., Singh, V., & Ward, P. S. (2021). Demand for crop insurance in developing countries: New evidence from india. *Journal of Agricultural Economics*, *72*(1), 293–320. https://doi.org/10.1111/1477-9552.12403

Greatrex, H., Hansen, J., Garvin, S., Diro, R., Le Guen, M., Blakeley, S., & Osgood, D. (2015). *Scaling up index insurance for smallholder farmers: Recent evidence and insights*.

Grigorieva, E., Livenets, A., & Stelmakh, E. (2023). Adaptation of agriculture to climate change: A scoping review. *Climate*, *11*(10), 202. https://doi.org/10.3390/cli11100202

Habib-ur-Rahman, M., Ahmad, A., Raza, A., Hasnain, M. U., Alharby, H. F., Alzahrani, Y. M., & El Sabagh, A. (2022). Impact of climate change on agricultural production; issues, challenges, and opportunities in asia. *Frontiers in Plant Science*, *13*, 925548. https://doi.org/10.3389/fpls.2022.925548

Hair, J. F., Astrachan, C. B., Moisescu, O. I., Radomir, L., Sarstedt, M., Vaithilingam, S., & Ringle, C. M. (2021). Executing and interpreting applications of PLS-SEM: Updates for family business researchers. *Journal of Family Business Strategy*, *12*(3), 100392. https://doi.org/10.1016/j.jfbs.2020.100392

Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial least squares structural equation modeling (PLS-SEM) using r: A workbook* (p. 197). Springer Nature. https://doi.org/10.1007/978-3-030-80519-7

Hair, J., Hollingsworth, C. L., Randolph, A. B., & Chong, A. Y. L. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial Management & Data Systems*, *117*(3), 442–458. https://doi.org/10.1108/IMDS-04-2016-0130

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*, 115–135. https://doi.org/10.1007/s11747-014-0403-8

Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. In *New challenges to international marketing* (Vol. 20, pp. 277–319). Emerald Group Publishing Limited. https://doi.org/10.1108/S1474-7979(2009)0000020014

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Institute for Peace and Conflict Resolution (IPCR). (2021). *Climate change and conflict in nigeria*. https://ipcr.gov.ng

Intergovernmental Panel on Climate Change (IPCC). (2021). *Sixth assessment report: Climate change 2021*. https://ipcc.ch

International Union for Conservation of Nature (IUCN). (2020). *Sea level rise and coastal vulnerability in west africa*. https://iucn.org

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decisions under risk. *Econometrica*, *47*(2), 263–291. https://doi.org/10.2307/1914185

Knight, F. H. (1921). Cost of production and price over long and short periods. *Journal of Political Economy*, *29*(4), 304–335. https://doi.org/10.1086/253349

Lesk, C., Anderson, W., Rigden, A., Coast, O., Jägermeyr, J., McDermid, S., & Konar, M. (2022). Compound heat and moisture extreme impacts on global crop yields under climate change. *Nature Reviews Earth & Environment*, *3*(12), 872–889. https://doi.org/10.1038/s43017-022-00368-8

Li, Z., Jin, M., & Cheng, J. (2021). Economic growth of green agriculture and its influencing factors in china: Based on emergy theory and spatial econometric model. *Environment, Development and Sustainability*, *23*, 15494–15512. https://doi.org/10.1007/s10668-021-01307-1

Linnerooth-Bayer, J., Scolobig, A., Ferlisi, S., Cascini, L., & Thompson, M. (2016). Expert engagement in participatory processes: Translating stakeholder discourses into policy options. *Natural Hazards*, *81*, 69–88. https://doi.org/10.1007/s11069-015-1805-8

Lobell, D. B., Bänziger, M., Magorokosho, C., & Vivek, B. (2011). Nonlinear heat effects on african maize as evidenced by historical yield trials. *Nature Climate Change*, *1*(1), 42–45. https://doi.org/10.1038/nclimate1043

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, *319*(5863), 607–610. https://doi.org/10.1126/science.1152339

Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, *333*(6042), 616–620. https://doi.org/10.1126/science.1204531

Ma, Q., Zhou, Y., & Wang, J. (2024). The impact of climate change on credit risk of rural financial institutions: A threshold effect based on agricultural insurance. *The North American Journal of Economics and Finance*, *71*, 102086. https://doi.org/10.1016/j.najef.2024.102086

Madaki, M. Y., Kaechele, H., & Bavorova, M. (2023). Agricultural insurance as a climate risk adaptation strategy in developing countries: A case of nigeria. *Climate Policy*, *23*(6), 747–762. https://doi.org/10.1080/14693062.2023.2220672

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, *13*(3), 1318. https://doi.org/10.3390/su13031318

Mbonu, O. C. (2025). *Climate change and agricultural productivity in nigeria (2000–2023)*.

Mechler, R., Bouwer, L. M., Schinko, T., Surminski, S., & Linnerooth-Bayer, J. (2019). *Loss and damage from climate change: Concepts, methods and policy options* (p. 557). Springer Nature. https://doi.org/10.1007/978-3-319-72026-5

Miranda, M. J., & Farrin, K. (2012). Index insurance for developing countries. *Applied Economic Perspectives and Policy*, *34*(3), 391–427. https://doi.org/10.1093/aepp/pps031

Myslimi, G., Nikolli, E., & Shima, J. (2022). Challenges of agricultural insurance development in albania. *Economicus*, *22*, 31–42. https://doi.org/10.58944/qocp5468

Nigerian Conservation Foundation (NCF). (2022). *Annual report on reforestation and conservation efforts*. https://ncfnigeria.org

Nigerian Meteorological Agency (NiMet). (2022). *Climate trends and projections in nigeria*. https://nimet.gov.ng

Niu, Z., Yi, F., & Chen, C. (2022). Agricultural insurance and agricultural fertilizer non-point source pollution: Evidence from china's policy-based agricultural insurance pilot. *Sustainability*, *14*(5), 2800. https://doi.org/10.3390/su14052800

Nshakira-Rukundo, E., Kamau, J. W., & Baumüller, H. (2021). Determinants of uptake and strategies to improve agricultural insurance in africa: A review. *Environment and Development Economics*, *26*(5-6), 605–631. https://doi.org/10.1017/S1355770X21000085

Okunlola, O. C., & Ayetigbo, O. A. (2024). Impact of agricultural financing on agricultural growth sustainability in nigeria. *The Journal of Developing Areas*, *58*(3), 171–203. https://doi.org/10.1353/jda.2024.a929946

Oluwatimilehin, I. A., & Ayanlade, A. (2023). Climate change impacts on staple crops: Assessment of smallholder farmers' adaptation methods and barriers. *Climate Risk Management*, *41*, 100542. https://doi.org/10.1016/j.crm.2023.100542

Ortiz-Bobea, A. (2021). The empirical analysis of climate change impacts and adaptation in agriculture. In *Handbook of agricultural economics* (Vol. 5, pp. 3981–4073). Elsevier. https://doi.org/10.1016/bs.hesagr.2021.10.002

Osuji, E. E., Olaolu, M. O., & Tim-Ashama, A. C. (2023). Impacts of climate change on sustainable crop production in nigeria. In *Climate change impacts on nigeria: Environment and sustainable development* (pp. 39–56). Springer International Publishing. https://doi.org/10.1007/978-3-031-21007-5_3

Panda, A. (2021). *Climate change and agricultural insurance in the asia and pacific region*. The Asian Development Bank.

Pratiwi, L. P. K., & Budiasa, M. (2022). Effectiveness of agricultural insurance program as a sustainable agricultural development effort. *SEAS (Sustainable Environment Agricultural Science)*, *6*(2), 134–143. https://doi.org/10.22225/seas.6.2.5856.134-143

Prince, A. I., Obiorah, J., & Ogar, E. E. (2023). Analyzing the critical impact of climate change on agriculture and food security in nigeria. *International Journal of Agriculture and Earth Science*, *9*, 42023.

Reka, A., Gjoni, L., Kosova, R., Tabaku, E., & Kosova, A. M. (2025). *Risk analysis and premium assessment in albanian agricultural insurance*.

Renn, O. (2008). Concepts of risk: An interdisciplinary review part 1: Disciplinary risk concepts. *GAIA-Ecological Perspectives for Science and Society*, *17*(1), 50–66. https://doi.org/10.14512/gaia.17.1.13

Rezaei, E. E., Webber, H., Asseng, S., Boote, K., Durand, J. L., Ewert, F., & MacCarthy, D. S. (2023). Climate change impacts on crop yields. *Nature Reviews Earth & Environment*, *4*(12), 831–846. https://doi.org/10.1038/s43017-023-00491-0

Ringle, C. M., Sarstedt, M., Mitchell, R., & Gudergan, S. P. (2020). Partial least squares structural equation modeling in HRM research. *The International Journal of Human Resource Management*, *31*(12), 1617–1643. https://doi.org/10.1080/09585192.2017.1416655

Ringle, C. M., Wende, S., & Becker, J. M. (2024). *Discriminant validity assessment and heterotrait-monotrait ratio of correlations (HTMT)*. SmartPLS.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of Sciences*, *106*(37), 15594–15598. https://doi.org/10.1073/pnas.0906865106

Schmitt, J., Offermann, F., Söder, M., Frühauf, C., & Finger, R. (2022). Extreme weather events cause significant crop yield losses at the farm level in german agriculture. *Food Policy*, *112*, 102359. https://doi.org/10.1016/j.foodpol.2022.102359

Schuurman, D., & Ker, A. (2025). Heterogeneity, climate change, and crop yield distributions: Solvency implications for publicly subsidized crop insurance programs. *American Journal of Agricultural Economics*, *107*(1), 248–268. https://doi.org/10.1111/ajae.12446

Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics*, 461–464. https://doi.org/10.1214/aos/1176344136

Singh, A. K., Jyoti, B., & Sankaranarayanan, K. G. (2024). A review for analyzing the impact of climate change on agriculture and food security in india. In *The climate change crisis and its impact on mental health* (pp. 227–251). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-3272-6.ch017

Skydan, O., Vilenchuk, O., Pyvovar, P., Topolnytskyi, P., & Shubenko, I. (2023). *Identification and interpretation of internal factors influencing the agricultural insurance market in ukraine*. https://doi.org/10.48077/scihor10.2023.150

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008

Smith, V. H., & Glauber, J. W. (2012). Agricultural insurance in developed countries: Where have we been and where are we going? *Applied Economic Perspectives and Policy*, *34*(3), 363–390. https://doi.org/10.1093/aepp/pps029

Sun, J. L., Tao, R., Wang, J., Wang, Y. F., & Li, J. Y. (2024). Do farmers always choose agricultural insurance against climate change risks? *Economic Analysis and Policy*, *81*, 617–628. https://doi.org/10.1016/j.eap.2023.12.019

Surminski, S., & Oramas-Dorta, D. (2014). Flood insurance schemes and climate adaptation in developing countries. *International Journal of Disaster Risk Reduction*, *7*, 154–164. https://doi.org/10.1016/j.ijdrr.2013.10.005

Syed, A., Raza, T., Bhatti, T. T., & Eash, N. S. (2022). Climate impacts on the agricultural sector of pakistan: Risks and solutions. *Environmental Challenges*, *6*, 100433. https://doi.org/10.1016/j.envc.2021.100433

Tonnang, H. E., Sokame, B. M., Abdel-Rahman, E. M., & Dubois, T. (2022). Measuring and modelling crop yield losses due to invasive insect pests under climate change. *Current Opinion in Insect Science*, *50*, 100873. https://doi.org/10.1016/j.cois.2022.100873

Tsvetkova, L., Bugaev, Y., Belousova, T., & Zhukova, O. (2021). Factors affecting the performance of insurance companies in russian federation. *Montenegrin Journal of Economics*, *17*(1), 209–218. https://doi.org/10.14254/1800-5845/2021.17-1.16

United Nations Development Programme (UNDP). (2021). *Climate change and food security in nigeria*. https://undp.org

Vyas, S., Dalhaus, T., Kropff, M., Aggarwal, P., & Meuwissen, M. P. (2021). Mapping global research on agricultural insurance. *Environmental Research Letters*, *16*(10), 103003. https://doi.org/10.1088/1748-9326/ac263d

Wambua, J. K., & Okeke, N. O. (2023). *The impacts of climate change on agricultural production in nigeria* [PhD thesis]. Norwegian University of Life Sciences.

Wang, H., Liu, H., & Wang, D. (2022). Agricultural insurance, climate change, and food security: Evidence from chinese farmers. *Sustainability*, *14*(15), 9493. https://doi.org/10.3390/su14159493

Ward, P. S., & Makhija, S. (2018). New modalities for managing drought risk in rainfed agriculture: Evidence from a discrete choice experiment in odisha, india. *World Development*, *107*, 163–175. https://doi.org/10.1016/j.worlddev.2018.03.002

World Bank. (2019). *Gas flaring in nigeria: An environmental and economic challenge*. https://worldbank.org

World Resources Institute (WRI). (2021). *Climate policy implementation in nigeria: Challenges and opportunities*. https://wri.org

Xie, S., Zhang, J., Li, X., Xia, X., & Chen, Z. (2024). The effect of agricultural insurance participation on rural households' economic resilience to natural disasters: Evidence from china. *Journal of Cleaner Production*, *434*, 140123. https://doi.org/10.1016/j.jclepro.2023.140123

Yoder, L., Wardropper, C., Irvine, R., & Harden, S. (2025). Cover crops as climate insurance: Exploring the role of crop insurance discounts to promote climate adaptation and mitigate risk. *Journal of Environmental Management*, *373*, 123506. https://doi.org/10.1016/j.jenvman.2024.123506

Zeng, S., Qi, B., & Wang, M. (2022). Agricultural insurance and agricultural economic growth: The case of zhejiang province in china. *International Journal of Environmental Research and Public Health*, *19*(20), 13062. https://doi.org/10.3390/ijerph192013062

Zhllima, E., Xhoxhi, O., Imami, D., & Skreli, E. (2025). Unlocking crop insurance: Exploring farmers' demand and willingness to pay in the agriculture sector. *Journal of Agribusiness in Developing and Emerging Economies*. https://doi.org/10.1108/JADEE-09-2024-0293

Zhou, N., & Vilar-Zanón, J. L. (n.d.). *Climate change and crop insurance: Geographical heterogeneity in hailstorm risk for wine grapes in spain*.