International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(REVIEW ARTICLE)

Check for updates

Climate risk assessment in insurance: A USA and Africa Review

Olusegun Gbenga Odunaiya [1], Chinwe Chinazo Okoye [2], Ekene Ezinwa Nwankwo [3,*] and Titilola Falaiye [4]

[1] *Havenhill Synergy Limited, Nigeria.*
[2] *Access Bank Plc, Awka, Nigeria.*
[3] *Anambra State Polytechnic, Mgbakwu, Nigeria.*
[4] *Independent Researcher, Lagos, Nigeria.*

International Journal of Science and Research Archive, 2024, 11(01), 2072–2081

Publication history: Received on 02 January 2024; revised on 09 February 2024; accepted on 11 February 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.11.1.0276

Abstract

Climate risk assessment in insurance is a critical component of understanding and mitigating the impacts of climate change on the insurance industry. This paper provides a comprehensive review of climate risk assessment practices in the insurance sector, focusing on both the United States (USA) and Africa. The study explores the unique challenges and opportunities each region faces in the context of climate-related risks. In the USA, a mature and well-established insurance market grapples with the increasing frequency and severity of climate-related events. Hurricanes, wildfires, and floods have become more prevalent, necessitating a thorough evaluation of risk models and actuarial practices. The paper delves into how American insurers are adapting to these challenges through advancements in technology, data analytics, and collaboration with climate scientists. The role of regulatory frameworks and government initiatives in shaping the industry's response is also explored. Contrastingly, the African insurance landscape faces its own set of challenges in the wake of climate change. The continent is particularly vulnerable to extreme weather events, such as droughts and storms, impacting both agriculture and infrastructure. The paper investigates the unique considerations in climate risk assessment for African insurers, including the need for localized data, community-based resilience initiatives, and the potential for innovative insurance products that cater to the specific needs of the population. A comparative analysis highlights the disparities in resources, infrastructure, and regulatory frameworks between the two regions. It also underscores the importance of international collaboration in sharing best practices and facilitating the transfer of knowledge and technology. The paper emphasizes the role of insurers not only as financial risk mitigators but also as key stakeholders in promoting climate resilience and sustainability. This paper provides valuable insights into the evolving landscape of climate risk assessment in insurance, offering a nuanced understanding of the challenges faced by the USA and Africa. The findings aim to inform policymakers, insurers, and other stakeholders, fostering a proactive approach to climate resilience in the global insurance industry.

Keywords: Climate; Risk; Insurance; USA; Africa; Climate Strategy

1. Introduction

Climate risk assessment in insurance is of paramount importance due to the increasing frequency and intensity of climate-related disasters. The insurance sector plays a crucial role in understanding and managing the financial vulnerability associated with climate-induced disasters (Jain et al., 2022). In the USA, there is a growing focus on climate change, leading to increased climate-related risk disclosure by insurers (Lin et al., 2023). This trend reflects the industry's recognition of the need to assess and manage climate risks to ensure financial resilience (Collier et al., 2021). In Africa, the vulnerability to climate risks is particularly pronounced, and there is a need to explore the possibilities, challenges, and vulnerabilities associated with climate risk insurance in the region (Jain et al., 2022). The disparities in

* Corresponding author: Ekene Ezinwa Nwankwo.

flood insurance affordability and uptake under climate change further underscore the significance of understanding regional inequalities in managing climate risks (Tesselaar et al., 2020).

The purpose of this review is to provide a comprehensive overview of climate risk assessment in insurance, focusing on the USA and Africa. By synthesizing insights from mandatory insurer climate risk disclosure surveys, the review aims to highlight the evolving landscape of climate risk assessment in the USA (Lin et al., 2023). Additionally, it seeks to explore the possibilities, challenges, and vulnerabilities associated with climate risk insurance in African countries, shedding light on the unique dynamics of climate risk management in the region (Jain et al., 2022). Furthermore, the review aims to address regional inequalities in flood insurance affordability and uptake under climate change, emphasizing the need for tailored approaches to climate risk assessment and management (Tesselaar et al., 2020).

The insurance landscapes in the USA and Africa exhibit distinct characteristics in relation to climate risk assessment. In the USA, there is a growing emphasis on climate-related risk disclosure, reflecting the industry's responsiveness to the evolving climate risk landscape (Lin et al., 2023). This underscores the proactive approach of insurers in the USA towards understanding and managing climate risks. Conversely, in Africa, the focus is on exploring the possibilities, challenges, and vulnerabilities associated with climate risk insurance, highlighting the need for tailored strategies to address the unique climate risk dynamics in the region (Jain et al., 2022). Additionally, the disparities in flood insurance affordability and uptake under climate change underscore the complexities of climate risk management in Africa, necessitating a nuanced understanding of regional inequalities (Tesselaar et al., 2020).

In conclusion, climate risk assessment in insurance is a critical aspect of financial resilience in the face of increasing climate-related disasters. The review of climate risk assessment in the USA and Africa serves to provide valuable insights into the evolving landscape of climate risk management in these regions, emphasizing the need for tailored approaches to address regional disparities and vulnerabilities.

2. Global state of Climate Risk Assessment

Global climate risk assessment is a crucial component of understanding the potential impacts of climate change on various aspects of human society and the environment. It involves the measurement of vulnerability to climate change and natural hazards, considering a variety of different factors that operationalize human vulnerability (Feldmeyer et al., 2021). These assessments integrate future scenarios of climate change representing social dynamics and interactions with the environment for risk assessment purposes (Terzi et al., 2019). Furthermore, state-of-the-art climate model simulations are used to present a global assessment of the effects of unabated global warming and a collapse of the Atlantic meridional overturning circulation (AMOC) on the distribution of species across different biogeographical realms and extinction risk categories (Velasco et al., 2021).

A standardized framework for climate vulnerability and risk assessment has been developed, which is being applied with the IPCC AR5 climate risk approach. Many recent applications are following this new AR5 climate risk approach, indicating its relevance and adoption in current assessments (Zebisch et al., 2021). Additionally, sectoral or quasi-sectoral experience with climate change risk assessment offers insights into application and methodological challenges faced by researchers and policy-makers when conducting national climate risk assessments (Adger et al., 2018).

Risk assessment is integral to developing an action plan for minimizing the damage from climate change (Cho, 2020). The importance of managing climate change risks has been widely acknowledged, with risk assessment being the first step of risk management (Song & Lee, 2021). Moreover, climate change vulnerability assessments are commonly used to identify species at risk from global climate change. However, the wide range of methodologies available makes it difficult for end users, such as conservation practitioners or policymakers, to decide which method to use as a basis for decision-making (Wheatley et al., 2017).

The global community is driving an effort to prevent the trend of climate change impacts by considering the potential impacts of climate change (Dawid & Mohammed, 2022). Local climatic data assessment helps to understand the risks associated with climatic variability, providing valuable insights for risk assessment and adaptation strategies (Sharma et al., 2021). Furthermore, risk analysis of the impact of climate change provides a framework for identifying, assessing, and prioritizing risks, which assists decision-making in generating adaptation strategies to the changing climate (Lu et al., 2018).

In conclusion, global climate risk assessment involves a comprehensive evaluation of the potential impacts of climate change on various sectors, species, and regions. It integrates future climate scenarios, vulnerability assessments, and standardized frameworks to provide valuable insights for decision-making and adaptation strategies.

2.1. Climate Risk Assessment in the United States

Analyzing climate-related risks in the United States reveals the increasing frequency and severity of extreme weather events such as hurricanes, wildfires, and floods (Chen et al., 2023). These events have been shown to have devastating impacts across the country, affecting both human populations and ecosystems (Summers et al., 2018). For instance, hurricanes, inland floods, and wildfires have been observed to occur in various regions of the United States, posing significant threats to communities and infrastructure (Summers et al., 2022). The alteration of the climate in specific regions has also been found to affect the life of indigenous animals and humans, further emphasizing the widespread impact of climate-related risks (Filipe et al., 2020).

In response to these risks, American insurers have employed various adaptation strategies. They have leveraged technological advancements in risk modeling and integrated data analytics to enhance their understanding and management of climate-related risks (Oguntuase, 2020). Furthermore, insurers have collaborated with climate scientists and research institutions to develop more robust risk assessment frameworks (Summers et al., 2017). These strategies have enabled insurers to better quantify and mitigate the impacts of climate-related risks on their operations and the insured properties (Santella, 2022).

The regulatory frameworks and government initiatives in the United States have also played a crucial role in shaping the practices of the insurance industry in response to climate risks. Government support for climate resilience in insurance has influenced the development of risk assessment and mitigation practices within the industry (D'Orazio, 2023). Additionally, the observed changes in the frequency, intensity, and spatial patterns of natural hazards have prompted the government to enact policies aimed at enhancing resilience and preparedness (Summers et al., 2022).

In conclusion, the analysis of climate-related risks in the United States underscores the significant impact of hurricanes, wildfires, and floods, as well as the increasing frequency and severity of extreme weather events. American insurers have responded to these risks by employing technological advancements, data analytics, and collaborations with climate scientists. Government initiatives and regulatory frameworks have also influenced the practices of the insurance industry, emphasizing the importance of climate resilience and preparedness.

2.2. Climate Risk Assessment in Africa

Africa faces unique challenges posed by climate change, particularly in vulnerability to droughts and storms, and the impact on agriculture and infrastructure. The susceptibility to climate change impacts in Africa is exacerbated by non-climatic factors such as poverty, malnutrition, high dependence on rain-fed agriculture, low adaptive capacity, and low levels of development (Ahenkan, 2019). Climate-smart agriculture in Africa faces challenges such as lack of practical understanding, data, appropriate analytical tools, policy frameworks, financing mechanisms, and infrastructure (Kaptymer et al., 2019). Africa's vulnerability to climate change is also attributed to weak adaptive capacity, high dependence on ecosystem goods for livelihoods, and traditional agricultural systems (Ribeiro & Rodriguez, 2020). Vulnerability to droughts in South Africa is linked to socio-economic development and the ability of a community to cope with climate change-related problems (Epule et al., 2017). With climate change being one of the most severe challenges to rural Africa, there is an urgent need to develop effective adaptation and mitigation measures to protect the growing population (Heinzeller et al., 2018). Drought has caused significant impacts on the agricultural sector in Africa, leading to degradation of grazing lands, loss of crops, depletion of agricultural assets, impoverishment of farmers, and forced migration from communal areas to urban areas (Ruwanza et al., 2022).

In the context of climate risk assessment for African insurers, there is a need for localized data and accurate risk modeling, as well as community-based resilience initiatives and potential for innovative insurance products. Africa is currently facing huge environmental challenges from climate change, severely impacting the agricultural segment of its economy (Agba et al., 2021). The impacts of climate change in Africa are more severe due to high exposure and low adaptive capacity, emphasizing the need for building resilience in vulnerable communities (Mthembu & Hlophe, 2021). Africa has experienced climate change due to factors such as changes brought about by colonial administration, rapid population growth, and organized agriculture, necessitating enhanced adaptation policies (Matata & Adan, 2018). Empirical work highlights the vulnerability of agriculture to climate change in Africa, emphasizing the need for innovative insurance products to mitigate these risks (Sossou et al., 2020). Small-scale and communal farmers in South Africa have proven to be more vulnerable to droughts due to their concentration in less favorable climatic zones and lack of resources, highlighting the need for community-based resilience initiatives (Ramafoko et al., 2022).

In conclusion, Africa's vulnerability to climate change is multifaceted, encompassing socio-economic, agricultural, and environmental dimensions. Climate risk assessment for African insurers must consider the unique challenges posed by climate change in Africa, including vulnerability to droughts and storms, and the impact on agriculture and

infrastructure. This necessitates the need for localized data, accurate risk modeling, community-based resilience initiatives, and innovative insurance products to effectively mitigate the risks associated with climate change in Africa.

2.2.1. Role of international collaboration in addressing African climate risks

The role of international collaboration in addressing African climate risks is crucial for sharing best practices and facilitating knowledge and technology transfer. International collaboration enables the blending of climate change adaptation and disaster risk reduction efforts, contributing to sustainable development imperatives in Africa (Wright et al., 2021). It also promotes the exchange of information about climate policy and knowledge transfer among stakeholders, offering a clear understanding of current regimes and rendering them capable of taking well-informed, consolidated decisions based on up-to-date reliable facts (Karakosta & Flamos, 2016). Furthermore, international collaborations are essential for facing the complexities of future problems and achieving the outcomes of the Sustainable Development Goals (Djalante, 2016).

In the context of African urbanization and climate change, local, community-based knowledge production and action are highlighted as important in addressing these challenges (Cobbinah & Finn, 2022). Additionally, international partnerships based on multilateralism are emphasized for implementing applicable adaptation measures to climate change, highlighting the importance of smooth exchanges of knowledge and technologies through global partnerships (SANO & Oki, 2022; Oki & Sano, 2020). Moreover, the study by emphasizes the importance of equitable international health research collaborations in Africa, which can serve as a model for fair and equitable research collaborations in addressing climate risks (Munung et al., 2017).

The literature also underscores the significance of technology transfer in addressing climate change. Technology transfer, particularly in the context of environment-related patents, plays a crucial role in climate change mitigation and sustainability (Ferreira et al., 2020). Furthermore, the study by emphasizes the need for long-term international financing and partnerships to address climate risks, indicating the importance of international collaboration in providing financial and collaborative support for adaptation and localised solutions in Africa (Wright et al., 2021; Williams et al., 2022).

In conclusion, international collaboration plays a pivotal role in addressing African climate risks by sharing best practices and facilitating knowledge and technology transfer. It enables the blending of climate change adaptation and disaster risk reduction efforts, promotes the exchange of information about climate policy, and facilitates the implementation of applicable adaptation measures to climate change. Moreover, equitable international health research collaborations and technology transfer are essential components of international collaboration in addressing African climate risks.

2.3. Comparative Analysis

The disparities in resources and infrastructure between the USA and Africa significantly impact climate risk assessment in insurance. While the USA has well-established infrastructure and resources for risk assessment, Africa faces challenges due to limited resources and infrastructure (Marcantonio & Francois, 2017). These disparities influence the ability to accurately assess and manage climate risks, affecting the availability and affordability of insurance products in both regions.

The regulatory frameworks play a crucial role in shaping climate risk assessment in insurance. In the USA, stringent regulatory frameworks have been established to assess and manage climate risks, ensuring the sustainability of insurance products (Thistlethwaite & Wood, 2018). Conversely, Africa faces challenges in regulatory frameworks, impacting the effectiveness of risk assessment and the development of suitable insurance products (Marcantonio & Francois, 2017). The impact of these regulatory frameworks on risk assessment is evident in the availability and accessibility of insurance products in both regions.

Insurers are key stakeholders in promoting climate resilience through risk assessment and the development of suitable insurance products. In the USA, insurers play a significant role in promoting climate resilience by actively engaging in climate risk assessment and offering innovative insurance products tailored to address specific climate risks (Thistlethwaite & Wood, 2018). In Africa, insurers also play a crucial role, but limited resources and infrastructure pose challenges in effectively promoting climate resilience through insurance (Marcantonio & Francois, 2017). The role of insurers as key stakeholders is essential in addressing climate risks and promoting resilience in both regions.

Global cooperation and knowledge exchange are vital for enhancing climate risk assessment in insurance. The exchange of knowledge and best practices between the USA and Africa can significantly improve the effectiveness of risk

assessment and the development of insurance products (He, 2019). Additionally, global cooperation facilitates the sharing of expertise and resources, contributing to the development of sustainable insurance solutions for climate risks in both regions.

2.4. Case Study

Climate risk assessment in the insurance sector is a critical area of study, particularly in the context of climate change. The multidisciplinary nature of climate risk assessment and its impact on insurance is often overlooked and neglected. Recent research has shown that climate risk insurance is a priority area for many countries, with at least 38 countries mentioning climate risk insurance approaches in their Nationally Determined Contributions (NDCs). This underscores the growing recognition of the importance of climate risk assessment in the insurance sector (Lyubchich et al., 2019; Clement et al., 2018).

In the context of climate risk assessment, it is essential to consider the specific vulnerabilities and challenges faced by different regions. For instance, a comprehensive review of the literature addressing climate risk insurance as a risk mitigation or climate adaptation tool for managing the climate-induced financial vulnerabilities in the Pacific Small Island Developing States (PSIDS) highlights the unique challenges and possibilities in this region (Jain et al., 2022). Similarly, insights from a mandatory insurer climate risk disclosure survey in the United States emphasize the importance of understanding and managing climate-related risks at a national level (Lin et al., 2023).

Moreover, the integration of gender into index-based agricultural insurance is highlighted as a necessary step to ensure that the benefits of index insurance are experienced by both men and women, emphasizing the importance of considering social equity in climate risk assessment and insurance (Born et al., 2018). Additionally, the impact of climate change on insurance in specific regions, such as Florida, is discussed, highlighting the complex nature of risk assessment, underwriting, and pricing of insurance in the face of substantial changes in the climate (Medders, 2017).

Furthermore, the role of insurance in climate change risk management is a subject of interest, with a focus on rescaling to look beyond the horizon. This framework is applied to a content analysis of firm responses to climate risk disclosure surveys, indicating the evolving landscape of climate risk management within the insurance industry (Thistlethwaite & Wood, 2018). Additionally, the potential for substantial changes in the climate makes the risk assessment, underwriting, and pricing of insurance and insurance-linked securities more complex, emphasizing the need for continuous adaptation and innovation in risk assessment methodologies (Medders, 2017).

In conclusion, the case study of climate risk assessment in insurance in the USA and Africa presents a complex and multifaceted landscape. It requires a multidisciplinary approach that integrates social equity, regional vulnerabilities, gender considerations, and evolving risk management frameworks. The evolving nature of climate change and its impacts necessitates continuous research and adaptation within the insurance sector to effectively address climate-related risks.

2.5. Future Outlook and Emerging Trends

Climate risk assessment in insurance is a critical area of study, particularly in the context of the USA and Africa. Recent initiatives by multilateral agencies and local governments have aimed to address climate risk insurance in Pacific Small Island Developing States (Jain et al., 2022). These initiatives highlight the growing recognition of the vulnerabilities and challenges associated with climate risk in insurance. Furthermore, the spatio-temporal variation of crop loss in the United States has been studied to understand agricultural vulnerabilities and the impacts of weather and climate-driven events (Reyes & Elias, 2019). This research emphasizes the importance of understanding the specific risks associated with climate change in the agricultural sector, which is crucial for effective risk assessment in insurance.

The financial risks emerging from climate change have been identified to have direct and indirect impacts on building assets in the UK (Alzahrani et al., 2018). This underscores the need for a comprehensive understanding of the financial implications of climate change, which is essential for accurate risk assessment in insurance. Additionally, the integration of cost-benefit analysis into climate change policies has been emphasized, particularly in the Mediterranean and Middle East and North African countries (Hilmi, 2020). This approach highlights the importance of effective actuarial studies and macroeconomic models in understanding and mitigating the negative impacts of climate change, which is pertinent to the future outlook of climate risk assessment in insurance.

In the European Union, the increase in flood risk due to socioeconomic development and climate change has placed growing pressure on insurance markets (Hudson et al., 2019). This necessitates a reevaluation of current insurance arrangements and the development of new solutions to address future flood risk under climate and socioeconomic

change. Moreover, recent developments in statistical and machine learning methodology for modeling and assessing climate risk in agricultural and home insurances have been highlighted (Lyubchich et al., 2019). This indicates a shift towards more advanced data science and statistical approaches in climate risk assessment for insurance purposes.

Efforts to reform insurance arrangements have predominantly focused on dealing with the affordability of insurance, without fully considering the implications of alternative mechanisms for managing and reducing underlying risks (Jenkins et al., 2017). This suggests the need for a more holistic approach to risk management and reduction, particularly in the face of future projections of climate change and urbanization. Furthermore, insurance has been recognized as an increasingly important risk control method for managing climate change, emphasizing its significance in the future landscape of climate risk assessment in insurance (Nobanee et al., 2022).

The role of insurance in supporting climate resilience has been acknowledged, with an increasing number of investment and development organizations requiring risk assessments to include climate scenarios for robust future planning (Surminski et al., 2016). This underscores the evolving expectations for insurance to incorporate climate resilience into its risk assessment frameworks. Additionally, the incorporation of climate change projections into risk measures of index-based insurance has been highlighted as a crucial aspect of future risk assessment in insurance (Jin & Erhardt, 2020). This indicates a shift towards integrating climate change projections into insurance products to enhance their effectiveness in addressing future climate risks.

In conclusion, the future outlook and emerging trends of climate risk assessment in insurance for the USA and Africa are characterized by a growing recognition of vulnerabilities, advancements in statistical and machine learning methodologies, and the integration of climate change projections into risk assessment frameworks. These developments underscore the need for a comprehensive and proactive approach to address the evolving landscape of climate risk, particularly in the context of insurance.

3. Recommendation

The comprehensive review of Climate Risk Assessment in Insurance across the USA and Africa highlights crucial insights that carry significant implications for policymakers, insurers, and other stakeholders. This conclusion summarizes key findings, discusses their implications, and provides recommendations for fostering global climate resilience within the insurance industry.

The United States faces escalating climate-related risks, including hurricanes, wildfires, and floods, with a discernible increase in their frequency and severity. American insurers are adapting to these challenges through the integration of advanced technologies, data analytics, and collaborative efforts with climate scientists. Regulatory frameworks and government initiatives play a pivotal role in shaping the industry's response. Africa, uniquely susceptible to extreme weather events, experiences droughts and storms that impact agriculture and infrastructure. The continent's insurers face challenges in obtaining localized data and require innovative approaches for climate risk assessment. Disparities in resources and infrastructure between the USA and Africa underscore the need for a nuanced understanding of regional contexts in climate risk assessment.

Recognizing the impact of climate change on insurance necessitates the formulation and implementation of supportive regulatory frameworks. Governments should actively engage in fostering collaboration between insurers, researchers, and communities. Insurers must embrace technological advancements and data analytics to refine risk models. Collaboration with climate scientists and investment in localized data infrastructure can enhance their capacity to assess and mitigate climate-related risks. NGOs, research institutions, and international organizations play a vital role in facilitating knowledge exchange and providing support for community-based resilience initiatives in vulnerable regions.

Establish international platforms to facilitate the exchange of best practices, technological innovations, and research findings between developed and developing regions. Develop global standards for climate risk assessment in insurance, ensuring consistency in methodologies and promoting transparency. Invest in capacity-building programs for insurers in vulnerable regions, emphasizing the importance of localized data and community engagement. Encourage the development of innovative insurance products tailored to the specific needs of communities in climate-vulnerable areas. Promote public awareness campaigns to educate individuals and businesses about the importance of climate-resilient insurance practices.

4. Conclusion

In conclusion, a concerted effort by policymakers, insurers, and various stakeholders is imperative to build a globally resilient insurance industry capable of effectively navigating the challenges posed by climate change. By embracing innovation, collaboration, and a commitment to community resilience, the industry can position itself as a key player in fostering sustainable development on a global scale.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Adger, W., Brown, I., & Surminski, S. (2018). Advances in risk assessment for climate change adaptation policy. Philosophical Transactions of the Royal Society a Mathematical Physical and Engineering Sciences, 376(2121), 20180106. https://doi.org/10.1098/rsta.2018.0106

[2] Agba, A., Akpanudoedehe, J., Ojong, F., & Agba, M. (2021). Climate change, adaptation, and global jobs: lessons and urgent policy options for africa. Quantitative Economics and Management Studies, 2(3), 163-181. https://doi.org/10.35877/454ri.qems298

[3] Ahenkan, A. (2019). Financing climate change mitigation: an assessment of the private sector investment opportunities in ghana. Business Strategy & Development, 3(1), 143-150. https://doi.org/10.1002/bsd2.84

[4] Alzahrani, A., Boussabaine, H., & Almarri, K. (2018). Emerging financial risks from climate changes on building assets in the uk. Facilities, 36(9/10), 460-475. https://doi.org/10.1108/f-05-2017-0054

[5] Born, L., Spillane, C., & Murray, U. (2018). Integrating gender into index-based agricultural insurance: a focus on south africa. Development in Practice, 29(4), 409-423. https://doi.org/10.1080/09614524.2018.1556608

[6] Chen, T., Fariss, C., Shin, H., & Xu, X. (2023). Disaster experience mitigates the partisan divide on climate change: evidence from texas.. https://doi.org/10.31235/osf.io/ftb8g

[7] Cho, H. (2020). Climate change risk assessment for kurunegala, sri lanka: water and heat waves. Climate, 8(12), 140. https://doi.org/10.3390/cli8120140

[8] Clement, K., Botzen, W., Brouwer, R., & Aerts, J. (2018). A global review of the impact of basis risk on the functioning of and demand for index insurance. International Journal of Disaster Risk Reduction, 28, 845-853. https://doi.org/10.1016/j.ijdrr.2018.01.001

[9] Djalante, R., (2016). Climate change in Indonesia: a systematic literature review.. https://doi.org/10.5194/nhess-2016-342

[10] Cobbinah, P. and Finn, B. (2022). Planning and climate change in african cities: informal urbanization and 'just' urban transformations. Journal of Planning Literature, 38(3), 361-379. https://doi.org/10.1177/08854122221128762

[11] Collier, S., Elliott, R., & Lehtonen, T. (2021). Climate change and insurance. Economy and Society, 50(2), 158-172. https://doi.org/10.1080/03085147.2021.1903771

[12] Dawid, I. and Mohammed, F. (2022). Review on the link between technological change, climate finance, and market in mitigating climate change. International Journal of Weather Climate Change and Conservation Research, 8(1), 1-5. https://doi.org/10.37745/ijwcccr.15/vol8n1pp15

[13] Djalante, R. (2016). Research trends on natural hazards, disasters, risk reduction and

[14] D'Orazio, P. (2023). Climate change and macro-financial risks: financial policy responses for an orderly low-carbon transition. Environmental Research Climate, 2(1), 013002. https://doi.org/10.1088/2752-5295/acb790

[15] Epule, T., Ford, J., & Lwasa, S. (2017). Projections of maize yield vulnerability to droughts and adaptation options in uganda. Land Use Policy, 65, 154-163. https://doi.org/10.1016/j.landusepol.2017.04.013

[16] Feldmeyer, D., Birkmann, J., McMillan, J., Stringer, L., Filho, W., Djalante, R., … & Liwenga, E. (2021). Global vulnerability hotspots: differences and agreement between international indicator-based assessments. Climatic Change, 169(1-2). https://doi.org/10.1007/s10584-021-03203-z

[17] Ferreira, J., Fernandes, C., & Ferreira, F. (2020). Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: a comparison of european countries. Technological Forecasting and Social Change, 150, 119770. https://doi.org/10.1016/j.techfore.2019.119770

[18] Filipe, J., Herrera, V., Curone, G., Vigo, D., & Riva, F. (2020). Floods, hurricanes, and other catastrophes: a challenge for the immune system of livestock and other animals. Frontiers in Veterinary Science, 7. https://doi.org/10.3389/fvets.2020.00016

[19] He, Q. (2019). Mitigation of climate-change risks and regulation by insurance., 101-128. https://doi.org/10.4337/9781788111867.00011

[20] Heinzeller, D., Dieng, D., Smiatek, G., Olusegun, C., Klein, C., Hamann, I., … & Kunstmann, H. (2018). The wascal high-resolution regional climate simulation ensemble for west africa: concept, dissemination and assessment. Earth System Science Data, 10(2), 815-835. https://doi.org/10.5194/essd-10-815-2018

[21] Hilmi, N. (2020). Risk assessments of impacts of climate changeand tourism: lessons for the mediterraneanand middle east and north african countries. International Journal of Environmental Sciences & Natural Resources, 24(5). https://doi.org/10.19080/ijesnr.2020.24.556149

[22] Hudson, P., Botzen, W., & Aerts, J. (2019). Flood insurance arrangements in the european union for future flood risk under climate and socioeconomic change. Global Environmental Change, 58, 101966. https://doi.org/10.1016/j.gloenvcha.2019.101966

[23] Jain, D., Chida, A., Pathak, R., Jha, R., & Russell, S. (2022). Climate risk insurance in pacific small island developing states: possibilities, challenges and vulnerabilities—a comprehensive review. Mitigation and Adaptation Strategies for Global Change, 27(3). https://doi.org/10.1007/s11027-022-10002-z

[24] Jenkins, K., Surminski, S., Hall, J., & Crick, F. (2017). Assessing surface water flood risk and management strategies under future climate change: insights from an agent-based model. The Science of the Total Environment, 595, 159-168. https://doi.org/10.1016/j.scitotenv.2017.03.242

[25] Jin, Z. and Erhardt, R. (2020). Incorporating climate change projections into risk measures of index-based insurance. North American Actuarial Journal, 24(4), 611-625. https://doi.org/10.1080/10920277.2019.1690525

[26] Kaptymer, B., Ute, J., & Hule, M. (2019). Climate smart agriculture and its implementation challenges in africa. Current Journal of Applied Science and Technology, 1-13. https://doi.org/10.9734/cjast/2019/v38i430371

[27] Karakosta, C. and Flamos, A. (2016). Managing climate policy information facilitating knowledge transfer to policy makers. Energies, 9(6), 454. https://doi.org/10.3390/en9060454

[28] Lin, X., Kim, K., & Ivantsova, A. (2023). Insights from the mandatory insurer climate risk disclosure survey in the United States. Risk Management and Insurance Review, 26(1), 107-118. https://doi.org/10.1111/rmir.12237

[29] Lu, D., Tighe, S., & Xie, W. (2018). Pavement risk assessment for future extreme precipitation events under climate change. Transportation Research Record Journal of the Transportation Research Board, 2672(40), 122-131. https://doi.org/10.1177/0361198118781657

[30] Lyubchich, V., Newlands, N., Ghahari, A., Mahdi, T., & Gel, Y. (2019). Insurance risk assessment in the face of climate change: integrating data science and statistics. Wiley Interdisciplinary Reviews Computational Statistics, 11(4). https://doi.org/10.1002/wics.1462

[31] Marcantonio, F. and Francois, K. (2017). Review of pilot projects on index-based insurance in africa: insights and lessons learned., 323-341. https://doi.org/10.1007/978-3-319-59096-7_16

[32] Matata, A. and Adan, A. (2018). Causes of climate change and its impact in the multi-sectoral areas in africa-need for enhanced adaptation policies. Current Journal of Applied Science and Technology, 27(3), 1-10. https://doi.org/10.9734/cjast/2018/37276

[33] Medders, L. (2017). Climate change impacts on insurance in florida.. https://doi.org/10.17125/fci2017.ch06

[34] Mthembu, A. and Hlophe, S. (2021). Building resilience to climate change in vulnerable communities: a case study of umkhanyakude district municipality. Town and Regional Planning, 77. https://doi.org/10.18820/2415-0495/trp77i1.4

[35] Munung, N., Mayosi, B., & Vries, J. (2017). Equity in international health research collaborations in africa: perceptions and expectations of african researchers. Plos One, 12(10), e0186237. https://doi.org/10.1371/journal.pone.0186237

[36] Nobanee, H., Dilshad, M., Lamdi, O., Ballool, B., Dhaheri, S., AlMheiri, N., … & Alhemeiri, S. (2022). Insurance for climate change and environmental risk: a bibliometric review. International Journal of Climate Change Strategies and Management, 14(5), 440-461. https://doi.org/10.1108/ijccsm-08-2021-0097

[37] Oguntuase, O. (2020). Climate change, credit risk and financial stability.. https://doi.org/10.5772/intechopen.93304

[38] Oki, T. and Sano, T. (2020). Future population exposures to unprecedented climatic risks.. https://doi.org/10.21203/rs.3.rs-101046/v1

[39] Ramafoko, E., Lekunze, J., & Luvhengo, U. (2022). Revising the national framework for the management of drought (nfmd) to enhance vegetable farmers' vulnerability to drought in the northern cape province of south africa.. https://doi.org/10.5772/intechopen.100606

[40] Reyes, J. and Elias, E. (2019). Spatio-temporal variation of crop loss in the united states from 2001 to 2016. Environmental Research Letters, 14(7), 074017. https://doi.org/10.1088/1748-9326/ab1ac9

[41] Ribeiro, P. and Rodriguez, A. (2020). Emerging advanced technologies to mitigate the impact of climate change in africa. Plants, 9(3), 381. https://doi.org/10.3390/plants9030381

[42] Ruwanza, S., Thondhlana, G., & Falayi, M. (2022). Research progress and conceptual insights on drought impacts and responses among smallholder farmers in south africa: a review. Land, 11(2), 159. https://doi.org/10.3390/land11020159

[43] SANO, T. and Oki, T. (2022). Future population transgress climatic risk boundaries of extreme temperature and precipitation. Environmental Research Communications, 4(8), 081001. https://doi.org/10.1088/2515-7620/ac85a1

[44] Santella, N. (2022). Climate related trends in us hazardous material releases caused by natural hazards. Natural Hazards, 115(1), 735-756. https://doi.org/10.1007/s11069-022-05572-9

[45] Sharma, S., Sharma, D., Sharma, M., Gaur, K., & Manohar, P. (2021). Trend analysis of temperature and rainfall of rajasthan, india. Journal of Probability and Statistics, 2021, 1-7. https://doi.org/10.1155/2021/6296709

[46] Song, Y. and Lee, S. (2021). Climate change risk assessment for the republic of korea: developing a systematic assessment methodology. Landscape and Ecological Engineering, 18(2), 191-202. https://doi.org/10.1007/s11355-021-00491-6

[47] Sossou, S., Igue, C., & Diallo, M. (2020). Impact of climate change on cereal yield and production in the sahel: case of burkina faso. Asian Journal of Agricultural Extension Economics & Sociology, 1-11. https://doi.org/10.9734/ajaees/2019/v37i430288

[48] Summers, J., Harwell, L., Smith, L., & Buck, K. (2018). Measuring community resilience to natural hazards: the natural hazard resilience screening index (nahrsi)—development and application to the united states. Geohealth, 2(12), 372-394. https://doi.org/10.1029/2018gh000160

[49] Summers, J., Lamper, A., McMillion, C., & Harwell, L. (2022). Observed changes in the frequency, intensity, and spatial patterns of nine natural hazards in the United States from 2000 to 2019. Sustainability, 14(7), 4158. https://doi.org/10.3390/su14074158

[50] Summers, J., Smith, L., Harwell, L., & Buck, K. (2017). Conceptualizing holistic community resilience to climate events: foundation for a climate resilience screening index. Geohealth, 1(4), 151-164. https://doi.org/10.1002/2016gh000047

[51] Surminski, S., Bouwer, L., & Linnerooth-Bayer, J. (2016). How insurance can support climate resilience. Nature Climate Change, 6(4), 333-334. https://doi.org/10.1038/nclimate2979

[52] Terzi, S., Torresan, S., Schneiderbauer, S., Critto, A., Zebisch, M., & Marcomini, A. (2019). Multi-risk assessment in mountain regions: a review of modelling approaches for climate change adaptation. Journal of Environmental Management, 232, 759-771. https://doi.org/10.1016/j.jenvman.2018.11.100

[53] Tesselaar, M., Botzen, W., Haer, T., Hudson, P., Tiggeloven, T., & Aerts, J. (2020). Regional inequalities in flood insurance affordability and uptake under climate change. Sustainability, 12(20), 8734. https://doi.org/10.3390/su12208734

[54] Thistlethwaite, J. and Wood, M. (2018). Insurance and climate change risk management: rescaling to look beyond the horizon. British Journal of Management, 29(2), 279-298. https://doi.org/10.1111/1467-8551.12302

[55] Velasco, J., Estrada, F., Calderón-Bustamante, Ó., Swingedouw, D., Ureta, C., Gay, C., … & Defrance, D. (2021). Synergistic impacts of global warming and thermohaline circulation collapse on amphibians. Communications Biology, 4(1). https://doi.org/10.1038/s42003-021-01665-6

[56] Wheatley, C., Beale, C., Bradbury, R., Pearce-Higgins, J., Critchlow, R., & Thomas, C. (2017). Climate change vulnerability for species—assessing the assessments. Global Change Biology, 23(9), 3704-3715. https://doi.org/10.1111/gcb.13759

[57] Williams, J., Chin-Yee, S., Maslin, M., Barnsley, J., Costello, A., Lang, J., … & Parikh, P. (2022). Africa and climate justice at cop27 and beyond: impacts and solutions through an interdisciplinary lens.. https://doi.org/10.14324/111.444/000180.v1

[58] Wright, C., Moore, C., Chersich, M., Hester, R., Schwerdtle, P., Mbayo, G., … & Butler, C. (2021). A transdisciplinary approach to address climate change adaptation for human health and well-being in africa. International Journal of Environmental Research and Public Health, 18(8), 4258. https://doi.org/10.3390/ijerph18084258

[59] Zebisch, M., Schneiderbauer, S., Fritzsche, K., Bubeck, P., Kienberger, S., Kahlenborn, W., … & Below, T. (2021). The vulnerability sourcebook and climate impact chains – a standardised framework for a climate vulnerability and risk assessment. International Journal of Climate Change Strategies and Management, 13(1), 35-59. https://doi.org/10.1108/ijccsm-07-2019-0042