

CLIMATE-SMART AGRIBUSINESS STRATEGIES FOR SMALLHOLDER FARMERS IN EMERGING ECONOMIES

Lituhayu Supartiningrum

Department of Agricultural Industrial Technology, Faculty of Agricultural
Technology, University of Jember
Email: lituhayu@unej.ac.id

Abstract

This study aims to analyze various climate-smart agriculture-based agribusiness strategies that can be implemented by smallholder farmers to address the challenges of climate change in developing countries. The research method used was a literature review, examining various scientific articles, books, international reports, and previous research results relevant to the theme of climate-smart agribusiness. Data were analyzed descriptively and comparatively to identify effective strategies for increasing productivity, adaptation, and sustainability of farming businesses. The study results indicate that climate-smart agribusiness strategies include farm diversification, the use of digital agricultural technology, the implementation of water-efficient irrigation, the use of climate-resilient varieties, agroforestry, and strengthening market access and green financing. Furthermore, collaboration between governments, financial institutions, the private sector, and local communities is a crucial factor in supporting the successful implementation of these strategies. A climate-smart agribusiness approach can not only increase agricultural productivity but also strengthen the economic resilience of smallholder farmers to the risks of climate change. This study emphasizes that sustainability-based agribusiness transformation needs to be supported through inclusive policies, technological innovation, and farmer capacity building to create adaptive, resilient, and sustainable agricultural systems in developing countries.

Keywords: Climate-Smart Agriculture, Sustainable Agribusiness, Smallholder Farmers, Climate Change, Developing Countries, Food Security

INTRODUCTION

Climate change has become one of the most significant global challenges facing the modern agricultural sector, particularly for developing countries that remain heavily dependent on the agribusiness sector as a primary source of food security, employment, and economic growth. Rising global temperatures, changing rainfall patterns, prolonged droughts, floods, land degradation, and the increasing frequency of natural disasters have directly impacted agricultural productivity. In this context, smallholder farmers are the most vulnerable group

due to limited capital, access to technology, infrastructure, education, and adequate climate information (Olabanji & Chitakira, 2025a). Most smallholder farmers in developing countries still use traditional farming methods that are less adaptive to climate change, further threatening their ability to maintain productivity and income stability. This situation creates an urgent need for agribusiness strategies that not only focus on increasing production but also build environmental and economic resilience in a sustainable manner.

The concept of climate-smart agribusiness has emerged as a strategic approach that integrates the goals of increasing agricultural productivity, adapting to climate change, and reducing greenhouse gas emissions within a single framework for sustainable agricultural development. This approach emphasizes the importance of technological innovation, efficient use of resources, agricultural diversification, climate risk management, and strengthening a more resilient agribusiness value chain. Climate-smart agribusiness focuses not only on cultivation aspects but also encompasses distribution systems, marketing, financing, and agribusiness governance that support the sustainability of the agricultural sector (Waaswa et al., 2024a). In its implementation, this strategy can include the use of climate-resilient varieties, water-efficient irrigation, digital farming, agroforestry, the integration of agriculture and livestock, and the use of renewable energy in agricultural production processes. Thus, climate-smart agribusiness is seen as an innovative solution capable of addressing food security challenges while preserving the environment in developing countries.

Although the concept of climate-smart agribusiness is increasingly being introduced into global agricultural policies, its implementation at the smallholder farmer level still faces various structural barriers. Many smallholder farmers lack adequate access to modern agricultural technology, extension services, green financing, or market information that support climate-based agribusiness transformation. Furthermore, low digital literacy and limited farmer managerial capacity are also inhibiting factors in implementing adaptive and innovative agribusiness strategies. Furthermore, institutional and policy support in several developing countries is still unable to fully create an agribusiness ecosystem conducive to the implementation of climate-smart agricultural practices (Noutchie, 2025). As a result, most smallholder farmers still struggle to increase productivity while maintaining the sustainability of their farming businesses amidst the increasingly complex pressures of climate change.

From a development economics perspective, strengthening climate-smart agribusiness strategies plays a crucial role in improving the welfare of smallholder farmers and reducing poverty in rural areas (Yamoah & Kaba, 2024a). Smallholder farmers are key actors in global food production because they contribute a significant portion of food needs in developing countries (Noutchie, 2025). Therefore, enhancing the capacity of smallholder farmers through a climate-smart agribusiness approach can have a broad impact on national food security, economic stability, and environmental sustainability. This strategy also has the potential to create new economic opportunities through the development of sustainable agricultural products, access to green markets, and increased added value of agricultural products (Ewulo et al., 2025). By integrating technological innovation and strengthening the socioeconomic capacity of farmers, climate-smart agribusiness can be a crucial instrument in driving the transformation of the agricultural sector toward a more inclusive and climate-resilient food system.

Various previous studies have shown that implementing climate-smart agricultural strategies can increase production efficiency, reduce the risk of crop failure, and strengthen the economic resilience of farming households. However, most research focuses on the technical aspects of agricultural cultivation and has not addressed the comprehensive integration of agribusiness strategies within the context of smallholder farmers in developing countries. However, the success of climate-smart agribusiness implementation is significantly influenced by the interconnectedness of production, marketing, access to financing, technology use, and policy support. Furthermore, socioeconomic conditions and regional characteristics differ across developing countries, impacting the effectiveness of these strategies.

This research is important because it can provide theoretical and practical contributions to the development of agribusiness models that are adaptive to climate change while supporting sustainable agricultural development. Theoretically, this research is expected to enrich the literature on integrating climate-smart agriculture concepts with modern agribusiness approaches in developing countries. Practically, the research findings can serve as a reference for governments, development institutions, agribusinesses, and farmer organizations in formulating more effective policies and programs for empowering smallholder farmers. By understanding the opportunities, challenges, and implementation strategies for climate-smart agribusiness, it is hoped that the agricultural sector in developing countries will become more

resilient, productive, and sustainable in the face of the dynamics of global climate change.

RESEARCH METHOD

This research uses a literature review method to analyze various climate-smart agribusiness strategies implemented by smallholder farmers in developing countries. This method was chosen because it provides a comprehensive understanding of the concepts, approaches, challenges, and effectiveness of climate change adaptation and mitigation strategies in the agribusiness sector. Research data was obtained from various scientific sources, such as reputable international journals, national articles, international organization reports, conference proceedings, and policy documents relevant to the themes of sustainable agriculture, food security, and climate change. The literature used focused on publications within the last ten years to ensure the data and discussions remain relevant to current global developments.

The analysis phase involved identification, selection, evaluation, and synthesis of the various collected literature sources. This study uses a qualitative descriptive approach to interpret the results of previous research on the implementation of climate-based agribusiness strategies, including agricultural technology innovation, farm diversification, resource efficiency, supply chain strengthening, and the use of digital technology to support smallholder farmer productivity. Furthermore, various findings from the literature are analyzed to identify patterns, relationships, and research gaps that require further development. Through this literature review method, the research is expected to produce a deeper understanding of effective, adaptive, and sustainable agribusiness strategies to improve the economic and environmental resilience of smallholder farmers in developing countries.

RESULT AND DISCUSSION

Farming Business Diversification Strategy as an Effort to Reduce Climate Risk

Farming business diversification strategy is a crucial approach to addressing the risks of climate change, which are increasingly impacting the agricultural sector in various developing countries. Changing rainfall patterns, rising temperatures, prolonged droughts, floods, and the emergence of pests and plant diseases due to ecosystem changes have led to uncertainty in agricultural production (Miari, 2023). These conditions make smallholder farmers the most vulnerable group due to their dependence on a single commodity and limited access to technology, capital, and climate information.

In this context, farming business diversification is an adaptation strategy that can increase economic resilience while maintaining the sustainability of agricultural production. Farming business diversification is not only understood as growing more than one type of crop, but also includes the integration of various agricultural activities such as livestock, fisheries, agroforestry, and agricultural processing, which can create alternative sources of income for farmers in the event of crop failure due to climate factors.

Farming business diversification plays a crucial role in reducing farmers' dependence on a single source of income (Rajnović et al., 2025). When farmers rely solely on a single commodity, the risk of loss is very high if that commodity experiences a decline in productivity due to drought, flooding, or attacks by plant pests. Conversely, through diversification, farmers can spread risk across multiple businesses, so that losses in one sector can be offset by profits from others (Miaris et al., 2025). For example, farmers who combine rice cultivation with horticulture and poultry farming have more stable income opportunities than monoculture farmers. When rice production declines due to erratic rainfall, the proceeds from horticulture or livestock farming can still support household economic needs. Thus, diversified farming creates a more flexible and resilient agricultural system to climate stress.

In addition to reducing economic risk, diversified farming also contributes to improving the health of agricultural ecosystems (Chao, 2024). Long-term monoculture farming systems often lead to soil degradation, decreased fertility, and increased vulnerability to pest attacks. Conversely, diversified farming systems can improve ecological balance by utilizing a variety of crops that perform different functions in maintaining soil structure and nutrient cycling. The implementation of crop rotation, intercropping, and the integration of food crops with perennial crops can help maintain soil moisture and reduce erosion (Usman et al., 2023). Crop diversity can also suppress the development of certain pests because agricultural environments are becoming more complex and do not support the dominance of a single pest species. In the context of climate change, healthy ecosystems are crucial for maintaining long-term agricultural production stability.

Farming diversification strategies can also be implemented through the development of commodities with greater tolerance to extreme climate conditions. Climate change requires farmers to be more adaptive in selecting crop types and cultivation patterns that suit constantly changing environmental conditions. The use of drought-resistant varieties, short-lived crops, and commodities that require less water are part of relevant diversification

strategies. In some regions, farmers have begun developing alternative crops such as sorghum, cassava, legumes, and horticultural crops that are more tolerant of high temperatures than conventional food crops (Madaki et al., 2023a). This commodity diversification not only helps maintain production continuity but also opens up new market opportunities that can increase farmers' incomes.

Integrating the agricultural sector with livestock farming is a form of diversification widely implemented to increase the efficiency and resilience of farming businesses. This integrated crop and livestock system allows for more optimal resource utilization because waste from one activity can be used as input for another. Rice straw, for example, can be used as animal feed, while livestock manure can be processed into organic fertilizer to improve soil fertility. This integration pattern helps farmers reduce their dependence on chemical fertilizers, which tend to increase in price and are vulnerable to distribution disruptions. Furthermore, livestock provides an economic asset that can be sold at any time when farmers experience economic pressure due to crop failure. Thus, the integration of agriculture and livestock farming not only increases production efficiency but also strengthens the economic resilience of farming households to climate risks.

Agroforestry development is also an effective farming diversification strategy in addressing climate change. Agroforestry is a land-use system that combines agricultural crops with trees in a single area. The presence of trees in agricultural land has numerous ecological benefits, such as increasing carbon sequestration, maintaining soil moisture, reducing erosion, and creating a more stable microclimate (Blesh et al., 2023). In extreme weather conditions, trees can protect food crops from strong winds and excessively high temperatures. In addition to ecological benefits, agroforestry also provides economic benefits because farmers can obtain additional yields from fruits, timber, or plantation crops planted alongside food crops. This system creates short-term and long-term income sources, thereby mitigating the economic risks of climate fluctuations.

Farming diversification is also closely related to developing added value for agricultural products. Climate risks affect not only production but also market prices for agricultural products. During peak harvests in certain seasons, commodity prices can drop drastically, making farmers' incomes unstable (Madaki et al., 2023b). Therefore, processing agricultural products into value-added products can be an effective diversification strategy. Farmers can develop food processing businesses, such as making chips, flour, dairy

products, or other local food products. Diversifying into the processing sector allows farmers to generate greater profits than simply selling raw crops. Furthermore, processed products have a longer shelf life, reducing the risk of losses due to crop damage.

The role of agricultural extension is crucial in promoting successful agricultural diversification (Poncet et al., 2024). Extension workers can help farmers understand climate change patterns, select commodities suited to local conditions, and develop more adaptive cultivation techniques. Furthermore, extension services can improve business management skills and improve farmers' access to market information. Sustainable training programs enable farmers to be better prepared for environmental changes and more confident in developing new businesses. Government policy support in the form of input subsidies, access to financing, agricultural insurance, and market infrastructure development are also important factors in accelerating the adoption of agricultural diversification at the community level.

In the long term, agricultural diversification strategies not only serve as an adaptation to climate change but also serve as a foundation for sustainable agricultural development. Diverse agricultural systems tend to be more stable, efficient, and environmentally friendly than monoculture systems that rely heavily on external inputs. Diversification creates a balance between economic, social, and ecological aspects of agricultural activities. Through diversification, farmers not only have the opportunity to increase income but also maintain family food security and the sustainability of natural resources. Therefore, diversification of agricultural businesses needs to be seen as a primary strategy in building an agribusiness system that is resilient to climate risks and capable of supporting the welfare of farmers in a sustainable manner.

Climate Change Challenges to Smallholder Farmer Productivity in Emerging Economies

Climate change poses a serious challenge to the agricultural sector in various developing and emerging economies, particularly for smallholder farmers who are heavily dependent on natural conditions for their farming activities. Weather instability, changing seasonal patterns, rising global temperatures, and the increasing frequency of natural disasters have significantly impacted agricultural productivity (Hilmi et al., 2024). In many developing countries, smallholder farmers play a crucial role in maintaining food security and providing for the population. However, limited capital, technology, and access to information make this group of farmers most

vulnerable to the impacts of climate change. When weather conditions are unpredictable, farmers struggle to determine the appropriate planting time, increasing the risk of crop failure. This situation not only impacts agricultural production but also impacts the economic conditions and well-being of farming households.

One of the main impacts of climate change on smallholder farmer productivity is changes in rainfall patterns (Guja & Bedeke, 2025). In many emerging economies, the rainy and dry seasons are now more erratic than in previous years. This makes it difficult for farmers to adjust planting and harvesting schedules. When the rainy season arrives late, plants experience water shortages in the early stages of growth, resulting in decreased yields. Conversely, excessive rainfall can cause flooding and waterlogging, damaging crops and reducing soil fertility. This weather uncertainty makes traditional farming systems used by farmers less effective. Many smallholder farmers still rely on inherited experience to predict the seasons, making it difficult to adapt to increasingly unstable climate change.

In addition to changes in rainfall, rising air temperatures are also a factor that reduces agricultural productivity. Higher temperatures cause water evaporation to occur more rapidly, reducing soil moisture. Food crops such as rice, corn, and wheat have a specific temperature tolerance limit for optimal growth (Wahab et al., 2024). When temperatures exceed this limit, plant growth is disrupted and yields are lower. High temperatures also increase the risk of pest and disease attacks. Many pests thrive in warmer conditions, requiring farmers to incur additional costs for pest control. For smallholder farmers with limited capital, this situation poses a significant economic burden, as production costs increase while yields decline.

Climate change also increases the frequency of natural disasters such as droughts, floods, and storms, which directly impact agricultural activities. Prolonged droughts cause agricultural land to lose its water supply, resulting in poor crop growth. On the other hand, floods can destroy agricultural areas quickly and cause significant losses for farmers. Agricultural infrastructure in developing countries is generally limited, thus limiting the ability of smallholder farmers to cope with disasters. Many farmers lack adequate irrigation systems or access to agricultural insurance to protect their businesses from the risks of extreme weather (Zenda, 2024). Consequently, when disasters occur, smallholder farmers often experience significant losses, impacting the sustainability of their farming operations.

The impact of climate change on smallholder farmer productivity is also exacerbated by limited access to modern agricultural technology. Most smallholder farmers in emerging economies still use traditional farming methods with low levels of mechanization. The use of drought-resistant seeds, water-saving irrigation technologies, and climate-based farming systems remains difficult to achieve due to financial constraints and a lack of infrastructure support (Ndhlovu & Mhlanga, 2023). Furthermore, access to weather information and adaptive agriculture training is also unevenly distributed in rural areas. Accurate climate information is crucial to help farmers determine cultivation strategies appropriate to changing environmental conditions. Low levels of education and technological literacy among smallholder farmers also hinder the implementation of more sustainable agricultural innovations.

From an economic perspective, climate change is causing the incomes of smallholder farmers to become increasingly unstable. Declining crop yields due to extreme weather make it difficult for farmers to meet their daily needs. In many cases, farmers must borrow capital to purchase seeds, fertilizers, and other production needs. When harvests do not meet expectations, farmers risk being trapped in prolonged debt (Ndimbo et al., 2025). This situation increases poverty levels in rural areas and weakens community food security. Furthermore, rising production costs due to the need to adapt to climate change reduce farmers' profits. This economic uncertainty has also led to a decline in interest among young people in working in the agricultural sector, as it is perceived as unable to provide a stable income.

Nevertheless, various adaptation efforts can be implemented to mitigate the impact of climate change on smallholder farmer productivity. The implementation of climate-smart agriculture, diversification of farming operations, the use of extreme weather-resistant crop varieties, and more efficient water resource management are crucial steps in increasing the resilience of the agricultural sector. Support from the government and relevant institutions is essential in providing access to technology, financing, training, and climate information for smallholder farmers. With strong cooperation between the government, communities, and the private sector, small farmers in emerging economies can increase their ability to adapt to climate change so that agricultural productivity is maintained and food security can be maintained sustainably.

The Role of Local Institutions and Farmer Groups in the Implementation of Climate-Smart Agribusiness

Climate change has had a significant impact on the agricultural sector, particularly for smallholder farmers in developing countries who are highly dependent on natural conditions. Uncertain planting seasons, rising temperatures, droughts, floods, and increased pest and disease outbreaks pose challenges that impact the productivity and sustainability of farming businesses. To address these challenges, the concept of climate-smart agribusiness has developed as an approach that integrates increased agricultural productivity, adaptation to climate change, and environmental sustainability simultaneously. However, the success of climate-smart agribusiness implementation is not solely determined by agricultural technology or government policy support; it is also greatly influenced by the existence of local institutions and farmer groups as key drivers at the community level (Olabanji & Chitakira, 2025b).

Local institutions play a crucial role in building the capacity of rural communities to collectively address the impacts of climate change. Local institutions encompass various forms of social organization, community norms, cooperative networks, and the mutual assistance system that develops within farming communities (Waaswa et al., 2024b). In the implementation of climate-smart agribusiness, local institutions serve as a coordinating platform between farmers, the government, agricultural extension workers, and other parties involved in sustainable agricultural development. Through local institutions, information on climate change, environmentally friendly agricultural technologies, and adaptation strategies can be disseminated more effectively to the community. Furthermore, local institutions help build trust and social solidarity, which are essential for sustainable agricultural resource management.

Farmer groups, as part of local institutions, play a strategic role in supporting the implementation of climate-smart agribusiness practices at the field level. Farmer groups serve as a platform for collective learning for farmers to understand cultivation techniques that are more adaptive to climate change. Through discussions, training, and mentoring, farmers can gain knowledge on the use of climate-resistant seeds, water-efficient irrigation systems, the use of organic fertilizers, crop diversification, and soil and water conservation techniques (Jumiyati, 2024). The group learning process facilitates the transfer of knowledge because it is tailored to the experiences and local conditions of

the community. This is crucial given that many smallholder farmers still face limited access to modern agricultural education, technology, and information.

In addition to serving as a learning medium, farmer groups also play a role in strengthening farmers' economic capacity to address the risks of climate change. In modern agribusiness systems, smallholder farmers often face difficulties in obtaining capital, production inputs, and market access (Nachibi et al., 2024). Through farmer groups, farmers can collaborate in procuring seeds, fertilizers, and agricultural equipment, as well as collectively marketing their harvests. This collaboration can reduce production costs and improve farmers' bargaining power in the market. Thus, farmer groups help create a more efficient and competitive agribusiness system. The existence of farmer groups also facilitates the distribution of government assistance and agricultural empowerment programs because farmers are organized under a single, clear framework.

In the context of climate change, farmer groups also play a crucial role in building environmental awareness among rural communities. The implementation of climate-smart agribusiness requires a shift in farmer behavior from conventional agricultural practices to more environmentally friendly and sustainable ones. Farmer groups serve as an effective social space for instilling an understanding of the importance of maintaining soil fertility, reducing excessive chemical use, and utilizing natural resources wisely. This collective awareness is important to ensure that agricultural activities are not only oriented towards short-term economic profits, but also consider environmental sustainability and future food security (Yamoah & Kaba, 2024b).

However, the role of local institutions and farmer groups in implementing climate-smart agribusiness still faces various challenges. Many farmer groups lack adequate organizational and management capacity, thus hindering their empowerment function. Low levels of farmer education, limited access to technology, and minimal mentoring support hinder the adoption of climate-smart agricultural innovations. Furthermore, coordination between the government, agricultural extension workers, and farmer organizations is often ineffective, resulting in less sustainable programs (Ma & Rahut, 2024). Therefore, strengthening institutional capacity through training, mentoring, access to financing, and the development of broader collaborative networks is necessary.

CONCLUSION

Research on Climate-Smart Agribusiness Strategies for Smallholder Farmers in Emerging Economies shows that implementing climate-smart agribusiness strategies plays a crucial role in increasing the resilience of the agricultural sector to climate change while strengthening the well-being of smallholder farmers. Various strategies, such as farm diversification, the use of environmentally friendly agricultural technologies, efficient water resource management, and the use of digital innovation, have been proven to help farmers increase productivity and reduce the risk of losses due to extreme weather events. In addition to increasing agricultural yields, this approach also encourages the creation of a more adaptive and sustainable agribusiness system, one that maintains a balance between economic, social, and environmental needs in developing countries.

The study also confirms that the successful implementation of climate-smart agribusiness strategies is heavily influenced by government policy support, access to financing, farmer education and training, and collaboration between the public and private sectors. Limited capital, limited access to technology, and limited climate information remain key challenges faced by smallholder farmers in implementing sustainable agricultural innovations. Therefore, it is necessary to strengthen institutions, increase agricultural technology literacy, and develop a sustainable mentoring system so that the transformation towards climate-smart agribusiness can run effectively and provide long-term benefits for food security and economic development in developing countries.

REFERENCES

- Blesh, J., Mehrabi, Z., Wittman, H., Kerr, R. B., James, D., Madsen, S., Smith, O. M., Snapp, S., Stratton, A. E., Bakarr, M., Bicksler, A. J., Galt, R., Garibaldi, L. A., Gemmill-Herren, B., Grass, I., Isaac, M. E., John, I., Jones, S. K., Kennedy, C. M., ... Kremen, C. (2023). Against the odds: Network and institutional pathways enabling agricultural diversification. *One Earth*, 6(5), 479–491. <https://doi.org/10.1016/j.oneear.2023.03.004>
- Chao, K. (2024). Family farming in climate change: Strategies for resilient and sustainable food systems. *Heliyon*, 10(7). <https://doi.org/10.1016/j.heliyon.2024.e28599>
- Ewulo, T. A., Akinseye, F. M., Teme, N., Agele, S. O., Yessoufou, N., & Kumar, S. (2025). Factors driving Climate-Smart Agriculture adoption: A study of smallholder farmers in Koumpentum, Senegal. *Frontiers in Agronomy*, 7. <https://doi.org/10.3389/fagro.2025.1552720>

- Guja, M. M., & Bedeke, S. B. (2025). Smallholders' climate change adaptation strategies: Exploring effectiveness and opportunities to be capitalized. *Environment, Development and Sustainability*, 27(8), 17927–17956. <https://doi.org/10.1007/s10668-024-04750-y>
- Hilmi, Y. S., Tóth, J., Gabnai, Z., Király, G., & Temesi, Á. (2024). Farmers' resilience to climate change through the circular economy and sustainable agriculture: A review from developed and developing countries. *Renewable Agriculture and Food Systems*, 39, e15. <https://doi.org/10.1017/S1742170524000097>
- Jumiyati, S. (2024). Development of climate smart agriculture based on empowering farmers around forests through triple-helix collaboration. *Interaction, Community Engagement, and Social Environment*, 2(1), 75–91. <https://doi.org/10.61511/icese.v2i1.2024.990>
- Ma, W., & Rahut, D. B. (2024). Climate-smart agriculture: Adoption, impacts, and implications for sustainable development. *Mitigation and Adaptation Strategies for Global Change*, 29(5), 44. <https://doi.org/10.1007/s11027-024-10139-z>
- Madaki, M. Y., Kaechele, H., & Bavorova, M. (2023a). 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>
- Madaki, M. Y., Kaechele, H., & Bavorova, M. (2023b). 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>
- Miaris, G. (2023). Farm business development: The motives and effects of diversification strategies. *Acta Universitatis Agriculturae Sueciae*, (2023:39). <https://doi.org/10.54612/a.3h65imn1e9>
- Miaris, G., Manevska-Tasevska, G., & Hansson, H. (2025). Farm diversification strategies and their relations to farm financial performance: Evidence from Swedish agriculture. *Agricultural Finance Review*, 85(1), 113–128. <https://doi.org/10.1108/AFR-04-2023-0051>
- Nachibi, S. U., Arimiyaw, A. W., Ganee, E. M., & Morgan, A. K. (2024). Dissemination of climate-smart agriculture practices in the Upper West Region of Ghana: Insights from local stakeholders and institutions. *International Journal of Agricultural Sustainability*, 22(1), 2421069. <https://doi.org/10.1080/14735903.2024.2421069>
- Ndhlovu, E., & Mhlanga, D. (2023). Smart Technologies, Climate Change, and Smallholder Farmer Production in Zimbabwe. In D. Mhlanga & E. Ndhlovu (Eds.), *The Fourth Industrial Revolution in Africa: Exploring the Development Implications of Smart Technologies in Africa* (pp. 293–309). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-28686-5_15

- Ndimbo, G. K., Yu, L., & Ndi Buma, A. A. (2025). ICTs, smallholder agriculture and farmers' livelihood improvement in developing countries: Evidence from Tanzania. *Information Development*, 41(2), 368–387. <https://doi.org/10.1177/02666669231165272>
- Noutchie, S. C. O. (2025). Advancing climate resilience in African agribusiness: Strategies, innovations, and pathways for sustainable transformation. *International Journal of Business Ecosystem & Strategy* (2687-2293), 7(4), 323–329. <https://doi.org/10.36096/ijbes.v7i4.865>
- Olabanji, M. F., & Chitakira, M. (2025a). The Adoption and Scaling of Climate-Smart Agriculture Innovation by Smallholder Farmers in South Africa: A Review of Institutional Mechanisms, Policy Frameworks and Market Dynamics. *World*, 6(2), 51. <https://doi.org/10.3390/world6020051>
- Olabanji, M. F., & Chitakira, M. (2025b). The Adoption and Scaling of Climate-Smart Agriculture Innovation by Smallholder Farmers in South Africa: A Review of Institutional Mechanisms, Policy Frameworks and Market Dynamics. *World*, 6(2), 51. <https://doi.org/10.3390/world6020051>
- Poncet, V., van Asten, P., Millet, C. P., Vaast, P., & Allinne, C. (2024). Which diversification trajectories make coffee farming more sustainable? *Current Opinion in Environmental Sustainability*, 68, 101432. <https://doi.org/10.1016/j.cosust.2024.101432>
- Rajnović, L. D., Borojević, N., & Eremic, J. (2025). ANALYSIS OF RISK AVOIDANCE THROUGH DIVERSIFICATION, WITH REFERENCE TO AGRICULTURAL FARMS. *Economic of Agriculture*, 72(2), 563–576. <https://doi.org/10.59267/ekoPolj2502563R>
- Usman, M., Ali, A., Bashir, M. K., Radulescu, M., Mushtaq, K., Wudil, A. H., Baig, S. A., & Akram, R. (2023). Do farmers' risk perception, adaptation strategies, and their determinants benefit towards climate change? Implications for agriculture sector of Punjab, Pakistan. *Environmental Science and Pollution Research*, 30(33), 79861–79882. <https://doi.org/10.1007/s11356-023-27759-8>
- Waaswa, A., Oywaya Nkurumwa, A., Mwangi Kibe, A., & Ng'eno Kipkemoi, J. (2024a). Adapting agriculture to climate change: Institutional determinants of adoption of climate-smart agriculture among smallholder farmers in Kenya. *Cogent Food & Agriculture*, 10(1), 2294547. <https://doi.org/10.1080/23311932.2023.2294547>
- Waaswa, A., Oywaya Nkurumwa, A., Mwangi Kibe, A., & Ng'eno Kipkemoi, J. (2024b). Adapting agriculture to climate change: Institutional determinants of adoption of climate-smart agriculture among smallholder farmers in Kenya. *Cogent Food & Agriculture*, 10(1), 2294547. <https://doi.org/10.1080/23311932.2023.2294547>
- Wahab, F., Khan, M. J., Khan, M. Y., & Mushtaq, R. (2024). The impact of climate change on agricultural productivity and agricultural loan recovery; evidence from a developing economy. *Environment, Development and*

- Sustainability*, 26(10), 24777–24790. <https://doi.org/10.1007/s10668-023-03652-9>
- Yamoah, F. A., & Kaba, J. S. (2024a). Integrating climate-smart agri-innovative technology adoption and agribusiness management skills to improve the livelihoods of smallholder female cocoa farmers in Ghana. *Climate and Development*, 16(3), 169–175. <https://doi.org/10.1080/17565529.2021.2024125>
- Yamoah, F. A., & Kaba, J. S. (2024b). Integrating climate-smart agri-innovative technology adoption and agribusiness management skills to improve the livelihoods of smallholder female cocoa farmers in Ghana. *Climate and Development*, 16(3), 169–175. <https://doi.org/10.1080/17565529.2021.2024125>
- Zenda, M. (2024). A systematic literature review on the impact of climate change on the livelihoods of smallholder farmers in South Africa. *Heliyon*, 10(18). <https://doi.org/10.1016/j.heliyon.2024.e38162>