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Mitigating climate change for food security

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Abstract

Climate change mitigation is critical for a sustainable food system. Agricultural productivity is affected by climate change due to increased temperature, altered rainfall patterns, as well as more frequent extreme weather conditions. These events endanger the structural stability of food production. This study examines the urgent need for climate-resilient agriculture infrastructure for food security. It addresses renewable energy technologies in agriculture with agrivoltaics as a promising option for resilience. It also incorporates the impacts of climate change on supply chains, advocating for comprehensive adaptation plans. The role of technology, policy and economic incentives, disaster preparedness, community engagement, and capacity building are emphasised. The study recommends integrated policy structures, funding technological innovation, adaptable extension services, public-private partnerships, regular research, and adaptive policy management to achieve climate-resilient food systems for sustainable food security and social equity

Keywords: Climate change; Food security; Renewable Energy Solutions; Sustainable Food Production; Agricultural Adaptation

1. Introduction

Reducing the effects of climate change on food security is an urgent global priority, particularly in regions prone to climate disruptions. Food production sustains the global economy and necessitates innovative strategies to strengthen climate resilience while ensuring sustainable food systems (Meah & Sharma, 2020). Agriculture, being both highly vulnerable to climate change and a significant contributor to environmental degradation, lies at the core of this challenge. Thus, devising collective solutions to mitigate climate change's impacts is essential.

Climate-smart agriculture presents a promising pathway; enabling farming systems to adopt innovative practices that enhance resilience and sustainability. Conservation of water supply and demand is critical; particularly in arid regions where agricultural production heavily depends on reliable water resources (Russo et al.; 2014). Renewable energy solutions further complement these efforts by reducing carbon emissions; minimizing reliance on fossil fuels; and improving energy efficiency. However; despite extensive research on climate-resilient agriculture; there remains a scarcity of qualitative studies addressing climate change's impact on food security and stakeholder responses; including those of farmers and policymakers.

This study adopts both quantitative and qualitative approaches to explore strategies for mitigating climate change risks to food security. The goal is to examine how diverse stakeholders respond to these challenges and to develop comprehensive; multifaceted approaches to ensure food security amid growing climate risks.

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1.1. Purpose of the Study

The purpose of this research is to review various methods of mitigating the impact of climate change on food security. In order to do this, it will review the literature and highlight the gaps in the current literature as well as analyse the contribution concerning climate-resilience approaches in agriculture.

1.2. Research Question

What are the fundamental approaches and strategies to reduce climate change on food security and how can they be enhanced to improve agricultural sustainability and boost food production?

1.3. Research Objectives

- To critically review existing literature on climate change mitigation strategies for food security.
- Identify the gaps and limitations of the studies for mitigating food security in the face of climate change to create the area of investigation and intervention.
- To investigate the efficacy of different interventions and regulations for food security during climate change.
- To recommend solutions to tackle the complex challenges of climate change on food security to ensure food sustainability.

2. Literature Review

2.1. Climate-Resilient Infrastructure for Agriculture

Climate-related risks pose great threats to agriculture and the need to strengthen the agricultural sector, especially in climate-vulnerable areas has been brought to the limelight. Meah and Sharma (2020) posit that building agricultural infrastructure is essential to maintaining food production amid climate change. The researchers highlight the important role of smallholder farmers, who contribute 60% – 75% of the food supply in most developing countries. This is supported by Gugissa et al. (2022) which focuses on the application of push-pull technology (PPT) in the maize-based farming systems of Ethiopia. The study results demonstrate the operational benefits of PPT in enhancing climate resilience; indicating the effectiveness of the smallholder farming systems integrated with the agro-ecological systems in the adaptation to climate change.

Meanwhile, Hellin et al (2020) argue against climate-smart agriculture (CSA) by pinpointing its potential risks of intensifying vulnerabilities and inequalities. They recommend a shift towards transformative adaptation. This is attributed to the fact that agricultural productivity and food security are influenced by socio-economics that can drive a region's exposure to climate change risks. Since agriculture is intertwined with the socio-economic structures, long-term sustainable climate change-resilient food systems will necessitate paradigm shifts towards more inclusive and equitable practices.

2.2. Sustainable Water Management in Agriculture

Managing water for sustainable agriculture is crucial for food security. According to Chartzoulakis & Bertaki (2015), water is vital for sustainable agricultural development, particularly in areas where the problem of water shortage is acute. They stress the importance of improving the efficiency of water use by pursuing better water management. These include water supply, irrigation methods, and soil, and plant care practices. Although these solutions may be useful in addressing agricultural challenges and food insecurity; there could be challenges with the implementation and management of such processes (Jafary and Bradley, 2018).

In addition, Russo et al. (2014) assert that water management should encompass economic, environmental and social objectives. They argue that the current water demand should be met without compromising its future use. At the same time, ecological integrity and societal objectives need to be achieved. Hence, sustainable water management and sustainable goals are crucial in addressing challenging water issues, especially in agricultural contexts (Ingrao et al., 2023).

2.3. Renewable Energy Solutions for Food Production

Renewable energy solutions play a key role in food production during climate change. Majeed et al., (2023) describe the usefulness of renewable energy for food production. The researchers state the advantages of solar energy, biomass energy, wind energy, and geothermal energy sources. However, implementing renewable energy on a large scale in agriculture can face many issues connected with technical obstacles, cost and policies. Further, the authors point out that there is a need to undertake holistic interventions to address system challenges, as well as to promote the learning and development of the various stakeholders within the agricultural sector.

Additionally, agrivoltaics, which refers to the combination of agricultural and solar power production on the same land area, provides a good way to improve land use efficiency and resilience of agricultural systems (Meah & Sharma, 2020).

2.4. Supply Chain Adaptation to Climate Change

Climate change significantly affects supply chain networks, influencing firm performance and resilience (Russo et al., 2014). However, reacting to disruptions caused by climate change remains one of the biggest challenges of food supply chains (Meah & Sharma, 2020). While the susceptibility of supply chains to extreme weather and climatic volatility is slowly gaining recognition, there is a lot of research and development that needs to be carried out to enhance the building up of food supply chain resilience.

Furthermore, as it concerns the implementation of the climate change effect towards food security, there are still a lot of questions organised by Yun and Ulku (2023) that offer a strategic and solution-oriented outlook known as CCR-SSCRM. Their study shows that the information regarding climate issues is relevant to supply chain risk management for enhanced adaptability and sustainability. This will assist the stakeholders trace assorted climate risks which may hamper the output of the product and coming up with a solution to the risks.

2.5. Innovative Agricultural Practices for Climate Mitigation

Technological applications should be employed to enhance food production to meet the food demand in the wake of climate change challenges. One of these is the climate-smart agriculture (CSA) practice. CSA stands for climate-smart agriculture which deals with an improved way of managing agriculture systems such as livestock, land crops, fisheries and forests with an aim of combating climate change and food insecurity. Innovative agricultural practices, including climate-smart agriculture (CSA), play a crucial role in mitigating climate change's impact on food systems (Meah & Sharma, 2020). These practices focus on sustainable land use, efficient water management, and technological innovations to boost resilience.

They further postulate that farmers must embrace digital agriculture innovations to overcome the challenges occasioned by climate change and food insecurity. However, Wakweya (2023) observes that the adoption of climate-smart agriculture faces challenges such as poor policies, lack of farmers' knowledge; institutional and financial constraints especially in developing countries.

2.6. Technological Innovations for Climate-Adaptive Food Systems

Christian et al. (2024) also discuss the recent advancements in climate-smart practices in the agri-food system. They underscore the need to embrace climate-sensitive intervention strategies and utilise precision agriculture techniques, sustainable farming technologies, and technology-enabled interfaces to enhance crop production, resilience, and earnings from agricultural operations. To effectively achieve this, the food sector needs to be fully ready and informed regarding new technologies for food security (Farooq et al., 2022).

Recent advancements in climate-smart practices in the agri-food system focus on integrating innovative technologies to enhance resilience and efficiency (Meah & Sharma, 2020). These include responsible technological innovation, poly-innovation, and micro-innovation. Firstly, responsible technological innovation holds that there could be positive and negative intentions from mega-technological tendencies, such as digital farming equipment or nanotechnologies, in agri-food systems. Secondly, poly-innovation stems from the polymedia whereby internetworking technologies create ties with organisational, social and business innovation. Lastly, micro innovation involves the process of modifying technologies, which are already in place, or inventing new ones through the normal processes of bricolage or small-scale tinker. Thus, commercialising these innovations through open design can enhance the adaptability of small-scale farming, especially in low-income countries (Charatsari et al., 2022).

2.7. Policy and Economic Incentives for Climate-Smart Agriculture

Policies and economic incentives are essential for climate-smart agricultural practices, especially in low-income countries. Policies encouraging the adoption of CSA practices are essential to scaling up sustainable agricultural solutions in low-income countries (Meah & Sharma, 2020), using data from China's Rural Revitalisation Survey. Their research findings highlight the importance of CSA for raising household income, average farm income, and income diversity. The study shows that intensifying farmers' adoption of climate-smart agricultural practices significantly increases the welfare of rural households. However, it does not address the policy impact of economic incentives for CSA practices. Concurrently, Branca et al. (2021) discuss the benefits of CSA in Southern Africa. These benefits include return on investment (ROI) and environmental improvement leading to climate-friendly farming. The research accentuates the need for well-designed policy incentives to promote clean agriculture and scale up CSA.

2.8. Disaster Preparedness and Emergency Response for Food Security

Natural disasters pose one of the most serious challenges to food security through disruption of agricultural activities. Tirivangasi (2018) reveals the effects of natural disasters and food insecurity and the losses people suffer in agriculture production, market access, and income generation. The author highlights the need for efficient risk management measures for climate change hazards. On the other hand, Culhane et al. (2018) claim that adopting a comprehensive agricultural emergency management system is necessary for business operations and food security.

Furthermore, Ainehvand et al. (2019) identify numerous barriers to food security after natural disasters in Iran. Through qualitative analysis, they categorise these barriers into structure challenges, process and resources management challenges, and organising and coordinating challenges. The findings suggest the need for these challenges to be overcome and ensure coordination among the stakeholders to devise an effective response to food security concerns during natural disasters. Therefore, this calls for more proactive disaster preparedness supported by an effective disaster response system.

2.9. Community Engagement and Capacity Building

Two of the important policies of commensal and capacity building aim to reduce the impacts of climate change on food security. In their paper on a Climate Smart Village, Sanogo et al. (2017), outlined a CSV approach that integrates Climate information, knowledge of better technologies, and development plans for the groundnut basin of Senegal. Focusing on this aspect, the above model addresses local communities as the key implementation actors. This is essential in conducting assessments of vulnerability and in the formulation of adaptive capacities that take into account the involvement of communities and people and proactive measures that enhance the management of resources, living conditions and well-being of vulnerable entities. However, although this model can be effective in several areas, it may not favour some regions due to a lack of participation from some stakeholders such as policymakers, farmers and community leaders among others.

In addition, Maka et al. (2019) emphasise the effect of climate change in the Gqumashe community within Eastern Cape Province in South Africa highlighting the function of agricultural extension. To achieve this the authors seek to establish the level of awareness that entails climate change effects on agriculture amongst the stakeholders. Thus, these stakeholders need to approach climate change in view of how they address the challenges attributable to climate change. However, successful community enhancement and participation in the fight against the impacts of climate change on food production is not just about having information about the problems affecting the community but also having sufficient knowledge about the issues, skills, and the ability to work together with different stakeholders. When the farmers and other stakeholders have adequate knowledge as well as sufficient skills in mitigating the effects of floods, they will be in a position to come up with better practices. This may include information sharing and capacity building to tackle climate change effects with the use of modern technologies.

2.10. Life Cycle Assessment of Food Production Systems

The life cycle assessment (LCA) is an important approach to examine the hypothetical environmental impacts of food production systems. Environmental degradation and climate change risks are affecting the global food industry thus leading to disruption of the food chain. Globalisation and higher standards of living have led to increased cases of various risks in the food chain hence the need to carry out an LCA. According to Cucurachi et al. (2019), it indicates that LCA is a tool that can yield information on the feed-forward and feedback loop analysis of environmental impacts on the food chain. Still, its measurement might be slightly more complicated in massive and complex systems that affect the environment on a vast scale.

While LCA outputs are often presented as environmental burdens per mass unit of the end product, the quality of the product also needs to be considered to ensure the actual value of the farming system has been accurately assessed (McAuliffe et al., 2018). McAuliffe et al. (2018) employ data from seven (7) livestock production systems including poultry, sheep, cattle, and pigs. Given the relevance of LCA in these products' production, the authors establish that there could be changes in the meat units which could affect the nutritional values due to various emission intensities. This is illustrated where the cattle system outperforms the pig and poultry systems due to its mass nature.

2.11. Optimisation of Food Processing and Packaging

Food preservation and processing are crucial in increasing food safety while minimising the environmental footprint. Amit et al. (2017) stress the role of food preservation techniques in promoting food quality, preserving nutritional benefits and minimising food waste. Even though many traditional methods like drying and heating are still used, modern technology has led to the use of highly advanced techniques such as irradiation and high-pressure technology. These techniques not only prolong the shelf life of the food but also reduce the chemical and microbial circulation, contributing to the sustainable food system.

Additionally, optimisation of food packaging processes provides a chance for enhanced process efficiency and lowered environmental burdens. García-Jiménez et al. (2023) examine bicriteria optimisation algorithms for double-layered multi-head weighing machines which aim at target weight optimisation with undelayed product waiting time in hoppers. The study shows the prospects to enhance the extraction processes and reduce the costs of extra products and rework through brute force optimisation factors. Besides, in the area of food processing and packaging, the Vanitha and Khan (2020) article within their submission proposed that pectin has multiple functions on this front. Pectin is widely used not only in food products and packing material because it has good characterization in terms of emulsifying and thickness properties and proactively protects foods from bacterial invasion and environmental changes.

3. Research Methodology

3.1. Research Design

Cross-sectional study design with both quantitative and qualitative data collection tools is used in the present study. The quantitative data collection tools will be questionnaires, through which the extent to which farmers have embraced issues to do with climate change and food security will be assessed. The data for the interviews will be in the form of natural language and content analysis of peer-reviewed articles, policy briefs and reports concerning climate-resilient approaches to food security.

3.2. Data Analysis

Data collected in this study will be qualitatively analysed using thematic analysis in order to identify the dominant or overriding themes and to compare and contrast the similarities and differences of the challenges and opportunities as presented in the various literatures of the field. In analysing numerical data, descriptive statistics will be used to establish the intensity of the impacts of climate change on food security and the conclusions that may be drawn.

3.3. Ethical Considerations

To address the ethical issues, the research will ensure the preservation of the interest of all the stakeholders like farmers, policymakers, and the communities involved in the research process. Participants' rights will also be protected as far as their participation will be voluntary and informed consent will be sought from them before the study. During the research, transparency and accountability will be kept to build trust and integrity of the findings.

4. Result

The key findings from the mixed methods evaluation of resilient farming systems through push-pull technology for maize farming systems in Ethiopia are presented below (Desalegn et al, 2022). PPT and non-PPT were examined to identify the socioeconomic characteristics and compound resilience scores. Table 1 shows the compound resilience scores of the two farming systems.

Table 1 SHARP and Modules Scores for PPT and Non-PPT (Desalegn et al, 2022)

SHARP+ Modules	PPT N = 156		Non-PPT N = 145		*t*-Test	
	Mean	Std. Dev.	Mean	Std. Dev.	Diff	*t*-Value
Household health	9.40	3.15	9.19	3.45	0.20	0.53
Ag activities	12.09	2.99	11.22	3.02	0.87 ***	2.51
Land access	12.65	2.28	12.12	2.36	0.52 **	1.95

Crop production	11.56	2.62	11.02	2.41	0.62 **	2.13
Maize production	11.09	2.77	10.17	2.62	0.76 ***	2.45
Weed management	14.48	2.18	14.30	2.15	0.07	0.29
Pest management	13.44	3.15	13.78	2.82	−0.03	−0.1
Livestock production	11.43	2.18	10.98	2.79	0.74 ***	2.48
Animal nutrition and health	12.15	2.99	11.80	3.29	0.71 **	1.92
Water Access	8.93	2.65	8.35	2.52	0.58 **	1.89
Soil quality	12.04	2.47	11.32	1.97	0.48 **	1.84
Land management	12.59	2.12	12.32	1.95	0.34 *	1.46
Trees	10.67	3.78	10.11	4.07	0.67 *	1.48
Shocks	10.64	3.20	10.09	3.57	0.54 *	1.42
Access info weather	10.64	4.82	9.59	5.38	1.05 **	1.79
Access to market	9.57	2.13	8.91	2.72	0.65 **	2.32
Income expenditure	11.92	2.64	10.97	2.87	0.81 ***	2.56
Productive assets	14.23	1.95	13.75	2.10	0.53 **	2.21
Community cooperation	15.07	2.20	14.82	2.63	0.36 *	1.29
Group membership	9.92	3.70	9.25	3.86	0.65 *	1.57
Nutrition	11.69	2.78	10.84	2.79	0.71 **	2.2
Decision-making	10.46	2.46	9.58	3.25	0.79 ***	2.39

Statistical significance: $* \rho < 0.01$ $** \rho < 0.05$ $*** \rho < 0.001$

The mean compound resilience scores of the 22 SHARP modules range from 8. 35 for the water access indicator to 15. 07 for the community cooperation indicator. Per SHARP's model of resilience, the targeted level is at the threshold The average scores for composite resilience for both the PPT farming system and non-PPT farming system would be in the low and high resilience categories. On the two farming systems, the PPT-based system surpassed the PPT non-adopters in 9 out of 22 composite resilience indicators, while the PPT non-adopters scored higher in only 6 indicators. In addition, it also exposed that 19 out of the 22 compound resilience scores indicated a significant difference between the PPT farming system and the non-PPT farming system. In each of the 19 indices, PPT agriculture was found to be a much more adaptation-resistant agricultural system.

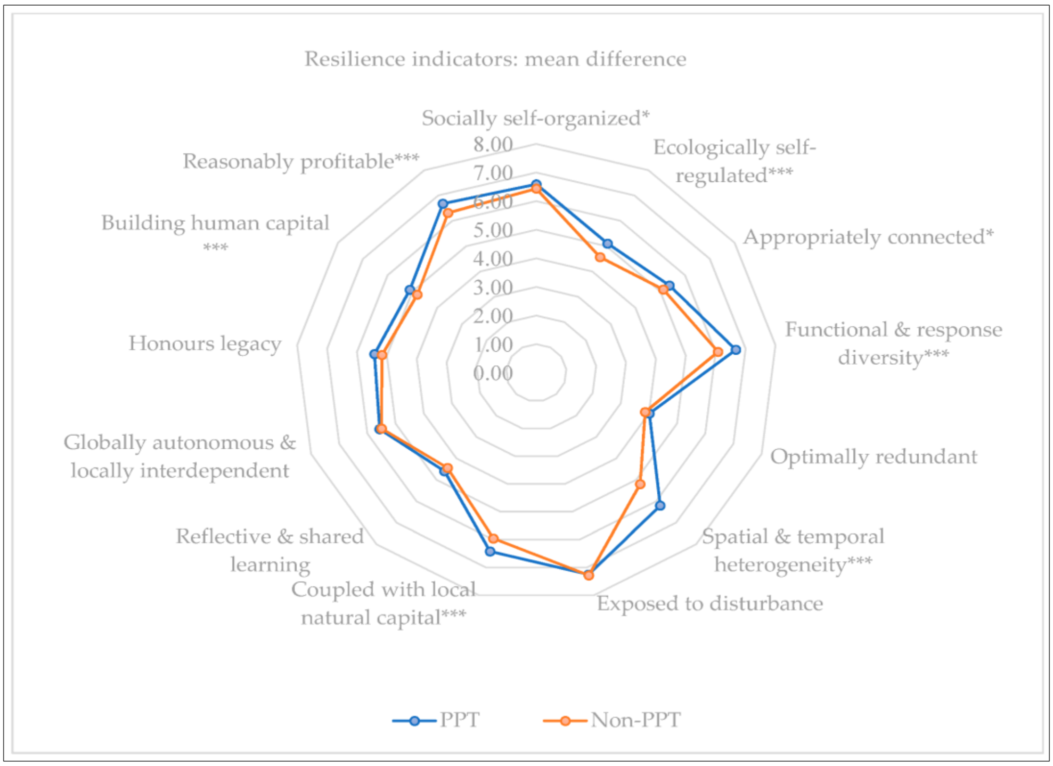

Figure 1 Mean scores for the 13 agroecosystem indicators for climate resilience of PPT and non-PPT farming systems (Desalegn et al, 2022)

Figure 1 presents the average scores of 13 climate resilience indicators for PPT and non-PPT farming systems. The average scores of 8 out of 13 agroecosystem indicators were notably greater for PPT farming systems.

Sector	**Challenges**	**Examples +**
Urban	• Demand management • Cost of adopting new technology	• Australia, USA, • *World*
Agriculture	• Over-allocation of water resources • Cost of new technology *vs.* low cost of water	• S Africa, USA
Ecosystem	• Development priorities	• *World*
Sector	**Solutions**	**Examples**
Urban	• Conservation education • Water reuse and recycling * • Stormwater management, green infrastructure *	• S Africa; Australia • *World*; UK • UK; Denmark
Agriculture	• Improve water allocation, irrigation management • Affordable precision agriculture methods *	• Greece; Spain • USA
Ecosystem	• Identification and protection of most valuable resources • Definition of a degradation tolerance level	• USA • *World*

Figure 2 Challenges and solutions for sustainable water management in urban, agricultural, and natural systems in developed countries (Tess et al., 2014)

Furthermore, qualitative evaluation of CSA adoption demonstrated the importance of innovative adaptation strategies characterised by equity and sustainability, requiring policymakers and practitioners to transition from technology solutions to more interactive and equitable ones. Moreover, sustainable water management practices emerged as the key pillars in dealing with the impacts of climate change on food security, emphasising the need for a comprehensive approach that encompasses socio-economic and institutional elements. Figures 2 and 3 highlighted the sustainable water management challenges and solutions for developed countries in urban, agricultural, and natural systems.

Sector	Challenges	Examples +
Urban	• Intermittent operation • Lost or stolen water • Rapid urban growth • Political conflict	• India, Ethiopia • Palestine • China • *Mid East*
Agriculture	• Irrigation infrastructure cost • Subsidies promoting irresponsible use • Low water use efficiency	• *Sub-Saharan Africa* • India • *N Africa*, China, Pakistan
Ecosystem	• Economic development priorities	• India
Sector	**Solutions**	**Examples**
Urban	• Institutional improvements • Low-tech water capture and treatment * • Graywater reuse * • Cooperation, sharing riparian rights • Stakeholder engagement	• Algeria; Palestine • Greece • Jordan • *Mid East*; *World* • Mexico; *World*
Agriculture	• Optimize water productivity * • Improve subsidy/pricing structure • Supplemental irrigation with rainwater harvesting	• *World* • India; *Mid East*; *World* • *Sub-Saharan Africa*, Burkina Fas; *Drylands*
Ecosystem	• Communication of ecosystem service value	• *Africa*, Ethiopia

Figure 3 Challenges and solutions for sustainable water management in urban, agricultural, and natural systems in developing countries (Tess et al., 2014)

Moreover, renewable energy integration also opened the prospects for lowering greenhouse gas emissions and advancing the sustainability of food production. Also, digital and policy interventions were essential to encourage climate-smart agricultural practices. Thus, overcoming technical feasibility, economic viability, and policy support was critical to realising the true potential of renewable energy in agriculture industries.

Disaster preparedness and emergency response measures emerge as the main determinants in enhancing the defence of food security against natural disasters, however, coordination and resource allocation gaps continue to present major challenges. Community involvement and capacity development are the key strategies in boosting food security and climate resilience, hence the need to provide tailored advisory services and strong local partnerships. Life cycle assessment is a useful tool to know the environmental impacts of food production systems, however, methodological limitations and data availability issues call for re-assessment.

5. Discussion

Climate change mitigation for global food security is a fundamental issue. The discourse explores the necessity of evolving climate-resilient farming methods to ensure food security during climate change. A quantitative approach (structured survey) was employed to obtain data on household and farm characteristics. The study depicts that farmers and policymakers are key stakeholders in the food industry and have a significant role in the food security crisis. Nevertheless, evidence-based cases on climate change-resistant agriculture illustrate the challenges of scaling mitigation strategies.

5.1. Innovations and Policies Integration

Innovations and policies are indeed sources of great hope in mitigating the agricultural impacts of climate change, but the adoption and efficiency of these will hinge on some factors.

Qualitative data revealed that technology-based solutions and policy interventions are crucially needed. However, they must be implemented properly. Hence, they increase productivity and net return, improve input use efficiency, production in emission, increase resilience, and increase gender and social inclusion. This implies that analysing power relations and structural injustices within the food system is fundamental to developing inclusive strategies that ensure equitable access to resources, decision-making processes and benefits.

Figure 6 presents an assessment of 12 projects (ECHORD PLUS PLUS, SWEEPER, VINEROBOT, FIGARO, SYMPHONY, AGROIT, FOODIE, AUDITOR, 4D4F, IoF 2020 except for the last one which is ongoing. The beneficiaries of the projects include the local communities, European farmers, breeders, and small and medium-sized enterprises that are engaged in the conservation of biodiversity and development of the territories using their labour.

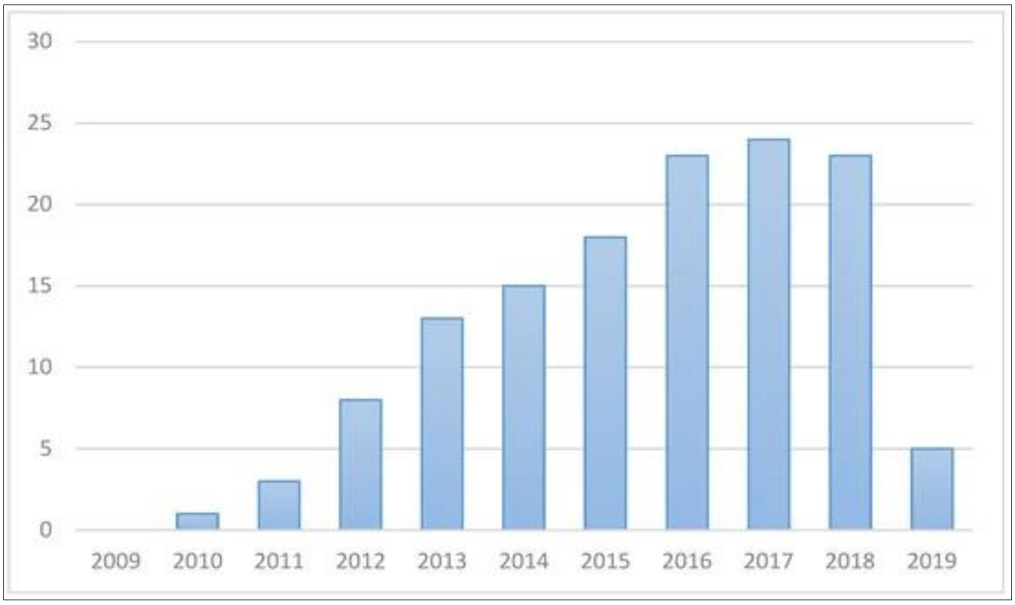

Figure 4 The number of financed European projects (2009–2017) (Fusco et al., 2020)

Figure 6 also shows an appreciable linear growth in the financing number of the projects from 2009 to 2017. Generally, the targets of these programmes are introduced using the latest technological innovations (robotics, sensors, big data, cloud computing) in every phase of the cultivation cycle from ploughing to harvesting. Only the RECAP and SMART AKIS projects deal with human capital support and especially, information exchange amongst the stakeholders to improve comprehension of regulations and policy.

5.2. Adaptive Governance for Climate-Resilience

Developing adaptive governance frameworks is paramount for tackling the complexities and uncertainties associated with CSA. Traditional top-down governance and management systems using old methods are not effective in handling dynamic environmental and community issues. However, instead of traditional governance structures, collaborative and adaptive management frameworks that consider innovation and flexibility should be in place. By implementing participatory decision-making, engagement of stakeholders and knowledge co-production into adaptive governance frameworks, organisations constantly learn from their environment and adjust to it.

5.3. Cross-Sectoral Findings and Policy Implications

The study demonstrates that climate-resilient agriculture, sustainable water resource utilisation, renewable energy integration, and supply chain adaptation play critical roles in climate change mitigation and food security. It emphasises the necessity to pursue comprehensive solutions, which can simultaneously tackle these overlapping challenges, recognising the synergistic possibilities in agricultural systems and supply chain development.

To develop integrated strategies, policymakers should pay attention to cross-sectoral collaboration and coordination building cohesion between agricultural, water, energy, and trade policies. Developing and implementing research and development programmes for scaling up climate-resilient agricultural practices, as well as sustainable water management technologies, renewable energy solutions and resilient supply chain systems is one of the key actions that should be prioritised.

6. Conclusion

The study has analysed the climate change threats and prospects concerning food security. While choosing the mitigation options of climate resilient strategy for food security, it uses a combination of research methodologies. The study illustrated that technology adoption in water resource management, renewable energy, supply chain and sustainable agriculture has the ability to enhance the sector. These are policy measures, technological choices, people's involvement, and ways of mitigating the effects of natural disasters. Moreover, the study points at cross-sectoral and knowledge exchange, which are important issues concerning climate change adaptation to complex systems as seen in the agri-food sector.

Recommendations

This calls for more of a multi-faceted approach to build resilience in the agriculture sector due to the growing threats of climate change. Any existing or new policy should thus be encouraged to adopt, support and implement sound climate-smart agriculture frameworks that shall embrace the different segments of the community. At the same time, it is crucial to embark on large-scale agricultural research as well as innovate on new digital technologies as key tools for enhancing both urban and rural agriculture. This technological advancement should be complemented with strong research and policy on capacity development and extension services which when done requires the allocation of funds to hiring extension agents and conducting farmer training on climate-smart agriculture practices, water management and disaster risk reduction techniques. Moreover, support for public-private partnerships is necessary because they create a synergy of knowledge, experience and technology for increasing climate resilience in agricultural work. Finally, it is always important to preventively analyses and update measures and strategies in order to prevent or address adverse climatic impacts that may harm agriculture productivity and efficiency in the future.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Ainehvand, S., Raeissi, P., Ravaghi, H. and Maleki, M. (2019) "Natural disasters and challenges toward achieving food security response in Iran.," PubMed, 8, p. 51. Available at: https://doi.org/10.4103/jehp.jehp_256_18.

[2] Amit, S.K., Uddin, Md.M., Rahman, R., Islam, S. and Khan, M.S. (2017) "A review on mechanisms and commercial aspects of food preservation and processing," Agriculture & Food Security, 6(1). Available at: https://doi.org/10.1186/s40066-017-0130-8.

[3] Balogun, A., Adebisi, N., Abubakar, I.R., Dano, U.L. and Tella, A. (2022) "Digitalization for transformative urbanisation, climate change adaptation, and sustainable farming in Africa: trend, opportunities, and challenges," Journal of Integrative Environmental Sciences, 19(1), pp. 17–37. Available at: https://doi.org/10.1080/1943815x.2022.2033791.

[4] Branca, G., Arslan, A., Paolantonio, A., Grewer, U., Cattaneo, A., Cavatassi, R., Lipper, L., Hillier, J. and Vetter, S. (2021) "Assessing the economic and mitigation benefits of climate-smart agriculture and its implications for political economy: A case study in Southern Africa," Journal of Cleaner Production, 285, p. 125161. Available at: https://doi.org/10.1016/j.jclepro.2020.125161.

[5] Charatsari, C., Lioutas, E.D., De Rosa, M. and Vecchio, Y. (2022) "Technological innovation and agrifood systems resilience: the potential and perils of three different strategies," Frontiers in Sustainable Food Systems, 6. Available at: https://doi.org/10.3389/fsufs.2022.872706.

[6] Chartzoulakis, K. and Bertaki, M. (2015) "Sustainable Water Management in Agriculture under Climate Change," Agriculture and Agricultural Science Procedia, 4, pp. 88–98. Available at: https://doi.org/10.1016/j.aaspro.2015.03.011.

[7] Cucurachi, S., Scherer, L., Guinée, J.B. and Tukker, A. (2019) "Life cycle assessment of food systems," One Earth, 1(3), pp. 292–297. Available at: https://doi.org/10.1016/j.oneear.2019.10.014.

[8] Culhane, M., Cardona, C.J., Goldsmith, T., St Charles, K., Suskovic, G., Thompson, B. and Starkey, M. (2018) "Building an all-hazards agricultural emergency response system to maintain business continuity and promote the sustainable supply of food and agricultural products," Cogent Food & Agriculture, 4(1), p. 1550907. Available at: https://doi.org/10.1080/23311932.2018.1550907.

[9] Farooq, M.S., Uzair, M., Raza, A., Habib, M., Xu, Y., Yousuf, M., Yang, S.H. and Khan, M.R. (2022) "Uncovering the research gaps to alleviate the negative impacts of climate change on food security: a review," Frontiers in Plant Science, 13. Available at: https://doi.org/10.3389/fpls.2022.927535.

[10] Fusco, G., Melgiovanni, M., Porrini, D. and Ricciardo, T.M. (2020) "How to Improve the Diffusion of Climate-Smart Agriculture: What the Literature Tells us," Sustainability, 12(12), p. 5168. Available at: https://doi.org/10.3390/su12125168.

[11] Gugissa, D.A., Abro, Z. and Tefera, T. (2022) "Achieving a Climate-Change Resilient Farming System through Push–Pull Technology: Evidence from Maize Farming Systems in Ethiopia," Sustainability, 14(5), p. 2648. Available at: https://doi.org/10.3390/su14052648.

[12] Jafary, F. and Bradley, C. (2018) "Groundwater Irrigation Management and the Existing Challenges from the Farmers' Perspective in Central Iran," Land, 7(1), p. 15. Available at: https://doi.org/10.3390/land7010015.

[13] Maka, L., Ighodaro, I.D. and Ngcobo-Ngotho, G.P.T. (2019) "Capacity development for scaling up Climate-Smart Agriculture (CSA) innovations: agricultural extension's role in mitigating climate change effects in Gqumashe community, Eastern Cape, South Africa," Suid-Afrikaanse Tydskrif Vir Landbouvoorligting/South African Journal of Agricultural Extension, 47(1). Available at: https://doi.org/10.17159/2413-3221/2019/v47n1a488.

[14] McAuliffe, G.A., Takahashi, T. and Lee, M.R.F. (2018) "Framework for life cycle assessment of livestock production systems to account for the nutritional quality of final products," Food and Energy Security, 7(3). Available at: https://doi.org/10.1002/fes3.143.

[15] Meah, N. and Sharma, S. (2020) "Climate-Resilient agricultural development in the global South," in Springer eBooks, pp. 1–24. Available at: https://doi.org/10.1007/978-3-030-32811-5_19-1.

[16] Russo, T. A., Alfredo, K. and Fisher, J. (2014) "Sustainable water management in urban, agricultural, and natural systems," Water, 6(12), pp. 3934–3956. Available at: https://doi.org/10.3390/w6123934.

[17] Russo, Tess A., Alfredo, K.A. and Fisher, J.D. (2014) "Sustainable water management in urban, agricultural, and natural systems," Water, 6(12), pp. 3934–3956. Available at: https://doi.org/10.3390/w6123934.

[18] Sanogo, D., Ndour, B.Y., Sall, M., Touré, K., Diop, M., Camara, B.A., Ndiaye, O. and Thiam, D. (2017) "Participatory diagnosis and development of climate change adaptive capacity in the groundnut basin of Senegal: building a climate-smart village model," Agriculture & Food Security, 6(1). Available at: https://doi.org/10.1186/s40066-017-0091-y.

[19] Tirivangasi, H.M. (2018) "Regional disaster risk management strategies for food security: Probing Southern African Development Community channels for influencing national policy," Jàmbá, 10(1). Available at: https://doi.org/10.4102/jamba.v10i1.468.

[20] Vanitha, T. and Khan, M. (2020) "Role of pectin in food processing and food packaging," in IntechOpen eBooks. Available at: https://doi.org/10.5772/intechopen.83677.