



ADVANCED INTERNATIONAL JOURNAL
OF BUSINESS, ENTREPRENEURSHIP
AND SMES
(AIJBES)

www.gaexcellence.com/aijbess



CLIMATE CHANGE AND FOOD SECURITY NEXUS IN VULNERABLE REGIONS: A NARRATIVE REVIEW OF IMPACTS, ADAPTATION, AND POLICY RESPONSES

Irlisuhayu Mohd Ramli^{1*}, Zulkhairi Nisa², Siti Muliana Samsi³

¹Department of Economics, Faculty of Business and Management, Universiti Teknologi MARA Cawangan Kedah, Malaysia

 irlisuhayu@uitm.edu.my

 <https://orcid.org/0009-0004-0465-8595>

²Department of Economics, Faculty of Business and Management, Universiti Teknologi MARA Cawangan Kedah, Malaysia

 zulkhairinisa@uitm.edu.my

 <https://orcid.org/0009-0002-5807-3985>

³Department of Economics, Faculty of Business and Management, Universiti Teknologi MARA Cawangan Kedah, Malaysia

 drsitimuliana@uitm.edu.my

 <https://orcid.org/0000-0003-2914-8204>

*Corresponding Author

Article Info:

Article history:

Received date: 27.07.2026

Revised date: 24.08.2026

Accepted date: 09.09.2026

Published date: 24.09.2026

To cite this document:

Ramli, I. M., Nisa, Z., & Samsi, S. M. (2026). Climate Change and Food Security Nexus In Vulnerable Regions: A Narrative Review of Impacts, Adaptation, And Policy Responses. *Advanced International Journal of Business Entrepreneurship and SMEs*, 8 (29), 1739-1759.

Abstract:

In climate-sensitive areas, such as Sub-Saharan Africa, South Asia, the Middle East and North Africa, and Small Island Developing States, where climatic exposure interacts with socioeconomic inequality and limited adaptive capacity, climate change has become a serious threat to food security. The lack of a framework that explains how climatic hazards are communicated through all four dimensions of food security and how adaptation outcomes are conditioned by governance is the unique conceptual gap, notwithstanding the expansion of research. The evidence on climate consequences, adaptation tactics, and policy responses is critically synthesised in this narrative review. Predefined Boolean search phrases were used to find peer-reviewed English language journal articles published between 2015 and 2025 that were indexed in Scopus. Full texts were evaluated as needed after titles and abstracts were checked; non-journal publications and research unrelated to the relationship between food security and climate change were not included. The literature was categorised into four interrelated themes: policy, governance, and implementation; access, nutrition, and uneven vulnerability; adaptation and resilience; and disruptions to availability and stability. The synthesis shows that through interacting biophysical, market, nutritional, and institutional processes, climate change impacts all four aspects of food security: availability, access, utilisation, and

stability. Finance, information and extension services, inclusive involvement, institutional capacity, and cogent cross-sectoral policy all contribute to the effectiveness of climate-smart agriculture, livelihood diversification, and resilient infrastructure. The review offers an integrated paradigm for climate change, food security, adaptation, and governance that connects structural vulnerability and hazards to distinct food security outcomes and positions adaptation and governance as interdependent mediators. This approach offers a foundation for context-sensitive research and policy and explains why technically comparable interventions provide varied results in different circumstances. Relying just on Scopus may leave out grey literature and pertinent studies that are indexed elsewhere.

DOI: 10.35631/AIJBS.829100 **Keyword:**

Adaptation; Climate Change; Climate-Smart Agriculture; Food Security; Food Systems; Narrative Review; Policy Responses; Resilience; Sustainable; Vulnerable Regions.



© The authors (2026). This is an Open Access article distributed under the terms of the Creative Commons Attribution (CC BY NC) (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact aijb@gaexcellence.com.

Introduction

As its consequences on agricultural systems, food supply chains, and human lifestyles become more apparent, climate change has become one of the biggest risks to global food security. Global food production systems are changing as a result of rising temperatures, changing precipitation patterns, extended droughts, floods, and an increase in the frequency of extreme weather events, especially in areas with low ability for adaptation (El Bilali et al., 2020; Hang et al., 2025). All nations are impacted by climate change, but its effects are more severe in vulnerable areas, such as Sub-Saharan Africa, South Asia, the Middle East and North Africa (MENA), and portions of Latin America, where food insecurity is made worse by a reliance on rain-fed agriculture, pervasive poverty, inadequate institutional capacity, and resource limitations (Anshida et al., 2024; Elkhalfi et al., 2025). Sustainable development and the accomplishment of the Sustainable Development Goals (SDGs), especially SDG 2 (Zero Hunger) and SDG 13 (Climate Action), are threatened by these interrelated challenges, which also jeopardise agricultural productivity and the overall operation of food systems.

The four internationally recognised dimensions of food security food availability, food access, food utilisation, and food stability are all impacted by climate change and go beyond agricultural output (El Bilali et al., 2020; Firdaus et al., 2019). While disruptions to markets and food supply chains increase price volatility and limit family access to nutrient-dense food, climate-induced losses in agricultural yields, animal productivity, fisheries, and water resources reduce food availability (Tóth et al., 2008; Ziervogel & Ericksen, 2010). Concurrently, declining food quality, increasing malnutrition, and micronutrient deficiencies underscore how

climate change affects food consumption, especially for women, children, and marginalised groups (Aberman & Tirado, 2014; Karimdjanoj et al., 2025). By making food systems more susceptible to frequent climatic shocks and socioeconomic disturbances, the cumulative consequences of these changes further jeopardise their long-term stability (El Bilali, 2021; Richardson et al., 2018). Therefore, addressing food security in the context of climate change necessitates an integrated systems approach that takes into account institutional, social, economic, and environmental aspects concurrently rather than separately.

Even though research on food security and climate change is expanding quickly, there are still many significant gaps in the body of current work. According to Anshida et al. (2024) and El Bilali et al. (2020), studies often look at agricultural production, nutrition, climate adaptation, or food policy separately rather than as interrelated parts of food systems, indicating a lack of conceptual integration across disciplines. Second, empirical data is still geographically unequal, with significant focus on certain nations or areas and little comparative understanding across susceptible locations (Alemu & Mengistu, 2019; Elkhalfi et al., 2025). Third, the development of cohesive theoretical frameworks is hampered by inconsistent terminology, including the use of concepts like vulnerability, resilience, adaptation, climate-smart agriculture, and food system resilience (Hang et al., 2025; Ziervogel & Ericksen, 2010). Lastly, it is challenging to find transferable policy lessons or best practices capable of enhancing food security under changing climatic conditions because implementation models for climate adaptation differ significantly across institutional, socioeconomic, and governance contexts (Ferranti, 2023; Purbawan et al., 2026). Together, these restrictions limit the synthesis of evidence and make it more difficult for scholars and decision-makers to develop comprehensive, context-sensitive solutions.

In light of these difficulties, a thorough narrative review is both important and relevant in order to identify rising research priorities, critically analyse existing evidence, and consolidate current understanding. A narrative review offers more flexibility for combining various conceptual viewpoints, theoretical advancements, local experiences, and policy approaches from multidisciplinary literature than systematic reviews, which mainly focus on methodological aggregation. With evidence from environmental science, agriculture, economics, nutrition, public policy, and development studies, this method is especially suitable for analysing the complex relationships between climate change and food security. Additionally, by combining policy responses with adaptation techniques, it is possible to find common themes, implementation gaps, and potential for enhancing resilience in susceptible areas. This information may be used to influence future research and evidence-based policymaking.

Therefore, by analysing the main effects of climate change on food security, assessing adaptation strategies used in various contexts, and evaluating policy responses intended to improve food system resilience, this narrative review seeks to critically synthesise the body of research on the relationship between climate change and food security in vulnerable regions. This is how the rest of the paper is structured. The methodology used for the narrative review is described in the next section. The effects of climate change on the four aspects of food security are then summarised, adaption options used in sensitive areas are reviewed, and current policy responses are examined. In order to enhance resilient and sustainable food systems, the paper's conclusion identifies research gaps, discusses policy implications, and suggests future study topics.

Literature Review

In order to compile and assess the corpus of research on the relationship between food security in vulnerable areas and climate change, this study used a narrative review methodology. Narrative reviews offer more flexibility for integrating findings from multidisciplinary literature, identifying conceptual developments, comparing theoretical perspectives, and highlighting emerging research gaps than systematic reviews, which are intended to address specific research questions through thorough evidence aggregation (Ferrari, 2015; Green et al., 2006). A narrative review was thought to be the best method for creating a thorough and interpretive synthesis of the available data because of the complexity of climate change, food security, adaptation, and policy responses across various geographic and socioeconomic situations.

Because of its broad coverage of excellent peer-reviewed publications in the fields of environmental science, agriculture, economics, public policy, sustainability, and interdisciplinary research, the Scopus database was the only one used for the literature search. Because of its thorough bibliographic coverage and strict indexing criteria, Scopus is widely regarded as one of the biggest abstract and citation databases and is often suggested for evidence synthesis (Elsevier, 2024). The search strategy was created utilising Boolean operators and several synonymous terms that represented the main ideas of the review in order to guarantee transparency and reproducibility. The Scopus database was searched using the following string:

("climate change" OR "global warming" OR "climatic shifts" OR "environmental change") AND ("food security" OR "food safety" OR "nutrition" OR "food access") AND ("vulnerable" OR "at-risk" OR "marginalized" OR "disadvantaged") AND ("regions" OR "areas" OR "communities" OR "populations") AND ("impact" OR "effect" OR "influence" OR "consequence") AND ("adaptation" OR "resilience" OR "mitigation" OR "strategies")

Only peer-reviewed journal articles written in English and published between 2015 and 2025 were included in the search. In order to ensure that the evaluation included current knowledge pertinent to current global climate and food security concerns, this timeline was chosen to incorporate recent advancements in climate science, food systems research, and adaptation policy. Examining article titles, abstracts, and, if needed, full texts to ascertain their applicability to the review's goals constituted additional screening.

The procedure of choosing articles was transparent but interpretive, in line with the methodology of narrative reviews. Studies that addressed the connections between food security and climate change, looked into the effects on populations or regions that are at risk, assessed adaptation or resilience tactics, or talked about policy solutions that are pertinent to food systems were included. Excluded were articles that only addressed unrelated environmental issues, conference papers, editorials, book reviews, solely technical agricultural breakthroughs with little bearing on food security, and publications with insufficient conceptual or methodological importance. In order to find recurrent patterns, conceptual connections, policy implications, and areas where the literature is still fragmented, the chosen studies were thematically synthesised rather than statistically aggregated. This method preserved the contextual diversity typical of research on food security and climate change while facilitating the integration of evidence across disciplines (Ferrari, 2015). In order to extract literature exploring the synergy between food security and climate change, the search method

included a customised combination of Boolean operators and particular term clusters, the specifics of which are recorded in Table 1.

Table 1: Search Strategy

Component	Description
Database	Scopus
Search String	("climate change" OR "global warming" OR "climatic shifts" OR "environmental change") AND ("food security" OR "food safety" OR "nutrition" OR "food access") AND ("vulnerable" OR "at-risk" OR "marginalized" OR "disadvantaged") AND ("regions" OR "areas" OR "communities" OR "populations") AND ("impact" OR "effect" OR "influence" OR "consequence") AND ("adaptation" OR "resilience" OR "mitigation" OR "strategies")
Publication Timeframe	2015–2025
Language	English
Document Type	Peer-reviewed journal articles
Inclusion Criteria	Studies addressing climate change and food security; impacts on vulnerable regions or populations; adaptation, resilience, mitigation, or policy responses; relevant conceptual or empirical research.
Exclusion Criteria	Conference papers, editorials, book reviews, non-English publications, studies unrelated to food security, articles lacking sufficient relevance to the review objectives, and duplicate records.
Selection Approach	Titles and abstracts were initially screened, followed by full-text assessment where necessary. Eligible studies were synthesized thematically using a narrative review approach to identify conceptual trends, evidence gaps, adaptation strategies, and policy responses.
Search Strings	(Predictive Analytics OR Machine Learning) AND (Lean Management OR Lean 4.0)
Publication Years	2015 – 2025
Inclusion Criteria	Peer-reviewed articles; English language; focus on predictive-Lean integration

Component	Description
Exclusion Criteria	Non-peer-reviewed white papers; studies of traditional Lean without digital context

Conceptual Background

Definitions

Long-term changes in the Earth's climate system brought about by both natural variability and human activity specifically, the rise in greenhouse gas concentrations in the atmosphere are referred to as climate change. The defining signs of modern climate change, according to the Intergovernmental Panel on Climate Change (IPCC), are rising global temperatures, altered precipitation patterns, rising sea levels, and an increase in the frequency and severity of extreme weather events (IPCC, 2023). With disproportionate effects on developing nations and climate-sensitive industries like agriculture, these climate shifts have significant ramifications for ecosystem functioning, agricultural production, environmental sustainability, and human well-being (Hang et al., 2025).

The Food and Agriculture Organization (FAO) framework is widely used to define food security. According to FAO (2009), food security is the state in which all people, at all times, have physical, social, and economic access to enough safe, nutritious food that satisfies their dietary needs and food preferences for an active and healthy life. The four interconnected pillars of this multifaceted idea are food availability, food access, food utilisation, and food stability. By lowering agricultural production, upsetting food supply chains, raising food price volatility, and jeopardising nutritional quality and dietary diversity, climate change affects each of these dimensions (Aberman & Tirado, 2014; El Bilali et al., 2020; Firdaus et al., 2019). As a result, food security should be viewed as a multifaceted result influenced by institutional, social, economic, and environmental issues rather than only an agricultural problem.

The relationship between food security and climate change requires an awareness of vulnerability. According to the IPCC, vulnerability is the tendency or inclination of people, groups, or systems to suffer negative consequences from climate-related risks, as defined by exposure, sensitivity, and adaptation capacity (IPCC, 2023). When it comes to food security, vulnerable areas are defined by a high reliance on livelihoods that are susceptible to climate change, pervasive poverty, poor governance, poor infrastructure, and restricted access to financial and technological resources. Particularly in Sub-Saharan Africa, South Asia, Small Island Developing States (SIDS), and portions of the Middle East and North Africa, these circumstances intensify the negative effects of climate shocks on agricultural production and household food security (Anshida et al., 2024; Elkhalfi et al., 2025).

The ideas of resilience and adaptation are closely linked to vulnerability. In reaction to real or anticipated climatic stressors, adaptation refers to changes in human or environmental systems that lessen possible harm or allow civilisations to take advantage of new opportunities (IPCC, 2023). Climate-smart agriculture, better irrigation systems, livelihood diversification, sustainable land management, and institutional reforms are some examples of adaptation strategies (Anshida et al., 2024). In contrast, resilience refers to the ability of communities,

institutions, and food systems to foresee, absorb, recover from, and adapt to climate perturbations while preserving vital functions (Purbawan et al., 2026). Strategies for enhancing food security under shifting climatic conditions are based on the complimentary ideas of adaptation and resilience.

Key Theories or Frameworks

The FAO's Four Pillars of Food Security Framework serves as the main theoretical foundation for the connection between climate change and food security. This framework offers a thorough lens through which to view how the availability, accessibility, utilisation, and stability of food are all impacted by climate change (FAO, 2009). The paradigm acknowledges that socioeconomic factors, market accessibility, nutrition, public health, and institutional governance all interact together to establish food security results rather than focusing only on agricultural productivity. This methodology is regularly used in current research to assess the multifaceted effects of climate variability and extreme weather events on vulnerable populations (El Bilali et al., 2020; Firdaus et al., 2019).

The IPCC's Vulnerability Framework, which defines climate risk as the interplay between climate hazards, exposure, vulnerability, and adaptive capacity, is a second significant conceptual viewpoint (IPCC, 2023). According to this concept, food insecurity results from both the incidence of climatic hazards and the socioeconomic factors that influence how communities react to those hazards. According to Anshida et al. (2024) and Richardson et al. (2018), smallholder farmers, marginalised communities, and areas that rely significantly on rain-fed agriculture are more susceptible to food insecurity due to their increased exposure and susceptibility as well as their low potential for adaptation. This viewpoint clarifies why comparable meteorological events may result in noticeably different food security outcomes in various geographical areas.

By acknowledging that interrelated systems encompassing production, processing, distribution, marketing, consumption, and government provide food security, the Food Systems Framework expands the analysis. Multiple stages of these food systems are simultaneously disrupted by climate change, which affects consumer access, market functioning, transportation networks, agricultural output, and nutritional consequences (El Bilali et al., 2020; Tóth et al., 2008). Because it emphasises the relationships between environmental change, economic development, institutional capacity, and public policy rather than concentrating solely on agricultural production, this systems perspective has grown in popularity.

Finally, Climate-Smart Agriculture (CSA) offers an operational paradigm that links resilience, adaptation, and sustainable agricultural production. The FAO created CSA with the intention of boosting agricultural productivity in a sustainable way, lowering greenhouse gas emissions where feasible, and enhancing resilience and adaptability (FAO, 2013). It includes sustainable soil management, integrated pest control, drought-tolerant crops, efficient irrigation, and a variety of agricultural techniques (Anshida et al., 2024; Hang et al., 2025). This review connects CSA with the Four Pillars, IPCC Vulnerability, and Food Systems frameworks to offer an integrated paradigm for climate, food security, adaptation, and governance. Climate hazards enter through biophysical, market, nutritional, and institutional pathways; exposure, sensitivity, and adaptive capacity explain differentiated vulnerability; adaptation and governance mediate whether disruptions result in persistent food poverty. The framework thus

explains why the effectiveness of an intervention depends not just on its technical features but also on funding, information, infrastructure, involvement, institutional competency, and policy coherence.

Thematic Review of Literature

Instead of a series of reviews of individual studies, this review synthesises the information into four analytically linked themes that cover the main aspects of the climate change food security nexus in vulnerable countries. Theme 1 studies the impacts of climate change on food supply and system stability and theme 2 examines food access, nutrition and unequal socio-economic vulnerability. Theme 3 focuses on adaptation techniques and the shift from short term coping to longer term resilience; Theme 4 assesses policy integration, governance and persistent implementation gaps. Thematic structure helps to synthesise recurrent patterns, points of dispute, conceptual constraints and policy relevant insights from the diverse literature in a more comprehensible manner.

Theme 1: Climate-Driven Disruptions to Food Availability and System Stability

The most direct impact of climate change on food security is through its disruption of agricultural productivity and the ecological resources on which food systems depend. They include higher temperatures, altered rainfall patterns, recurring droughts, flooding, heatwaves, soil degradation, water shortages, and shifting pest and disease threats, which impair agricultural and livestock productivity. These implications are particularly significant in countries where agricultural production is mostly rain-fed and where irrigation, storage, crop insurance and agricultural extension services are still restricted. The attendant losses are not confined to particular harvests, as climatic shocks can affect growing seasons, reduce land productivity and increase interannual unpredictability in food supplies. Thus, food availability and stability are strongly related: lower average output decreases the amount of food given, while increased climate variability renders that supply less predictable over time (El Bilali et al., 2020; Firdaus et al., 2019; Tóth et al., 2008).

There is widespread agreement in the literature that agricultural productivity is negatively affected by extreme weather events and gradual climate transitions, although research dispute on the main transmission mechanism. Production-oriented analyses tend to focus on biophysical effects on yields, soils, water resources and crop suitability, while food-systems perspectives pay more attention to the interaction between production losses, storage constraints, transportation failures, market disruptions and price instability. Geographical scale of analysis also differs. Studies at the regional and country level often point to site-specific combinations of rainfall dependence, land degradation and institutional weakness, while more general assessments stress that climate shocks can be transmitted through interlinked markets and supply chains even to areas not directly hit by an extreme event. Hence, the direction of the relationship is generally similar but the magnitude of the estimated magnitude and the dominant pathway differ depending on commodity, location, climate exposure, baseline productivity, and the adaptive capacity embedded in the food system (El Bilali et al., 2020; Firdaus et al., 2019; Tóth et al., 2008).

An important drawback of this research continues to be its focus on agricultural production as the major measure of food security. While yield loss is an important measure, it does not fully represent the effects of climatic shocks on storage, distribution, household purchasing power,

diet quality, or the ability to maintain food access. Furthermore, many studies are limited to single hazards rather than compound or sequential events such as drought and subsequent price inflation, flooding and subsequent disease outbreaks, or heat stress paired with water scarcity. Evidence is also unequal among crops, livestock systems, fisheries and postharvest stages, thereby limiting cross-sectoral comparison. This analysis thus sees production disruption as one piece of a larger food system process and assesses how variations in availability interact with access, utilisation, susceptibility, adaptation and policy responses across climate-sensitive locations.

Theme 2: Food Access, Nutrition, and Unequal Socioeconomic Vulnerability

Climate change impacts on food security are not only related to the physical quantity of food produced but also to the economic and social ability of households to access and utilise adequate meals. Production deficits, damage to transport infrastructure, market interruptions and increased expenses of storage and delivery can raise food prices and make basic and nutrient-rich foods less affordable. Poor households are particularly vulnerable since food is a very substantial part of their spending, allowing little room to absorb higher prices or income losses. Climate sensitive disease, contaminated water, poor sanitation and low dietary diversity can further constrain food utilisation by decreasing the body's ability to extract nutritional advantages from the food consumed. Climate change affects not just hunger and caloric adequacy but also malnutrition, nutritional deficiencies, food safety and health consequences in general (Aberman & Tirado, 2014; El Bilali et al., 2020; Firdaus et al., 2019).

The literature generally agrees that smallholder farmers, low-income households, women, children, pastoralists and communities whose livelihoods are susceptible to climate change are disproportionately vulnerable, although there are differences in theories as to why these groups experience higher levels of food insecurity. Some stories focus on direct exposure to droughts, floods and temperature stress; others point to structural issues such as poverty, unequal access to land and credit, poor market integration, limited public services and lack of social safety. The literature also varies in terms of conceiving vulnerability as a geographically concentrated condition or socially differentiated process. Although regional analyses tend to highlight Sub-Saharan Africa, South Asia, the Middle East and North Africa, and Small Island Developing States as climate hotspots, studies at the household level indicate that there can be significant variations within the same locality by income, gender, asset ownership, livelihood structure and access to institutions (Richardson et al., 2018; Wouterse et al., 2022).

These results imply that food insecurity driven by climate cannot be attributed to climatic exposure alone. Vulnerability arises from the interplay of hazards and pre-existing socio-economic imbalances, institutional shortcomings and limits on adaptive capability. However, most of the work relies on national averages or broad geographic categories that may mask subnational discrepancies and intrahousehold inequities. Nutrition and food utilisation likewise receive less attention than production and availability, despite their relevance for comprehending the long-term implications for human development. More attention to distributional results: who bears the costs of adaptation, who has access to new technology, and whose knowledge and priorities determine food-security actions. Thus, this analysis uses an equity-sensitive reading of vulnerable regions that includes the geographical exposure and social circumstances that shape differentials in food-security outcomes.

Theme 3: Adaptation Strategies and the Transition from Coping to Resilience

The adaptation solutions mentioned in the literature include a range of farm-level technology, livelihood changes, postharvest enhancements, community-based efforts and broader investments in food-system resilience. Agricultural strategies frequently mentioned are drought-tolerant and heat-resilient crop types, enhanced irrigation, water harvesting, soil conservation, altered planting schedules, integrated pest management, crop diversification and sustainable land management. Outside the farm, livelihood diversification, increased food storage and processing, enhanced transport systems, climate information services, education, extension support and access to finance can lessen sensitivity to climatic shocks. These measures are intended to not only restore output after an unfavourable event, but also to strengthen the capacity of families and institutions to foresee, absorb, reorganise and recover from future disruptions (Purbawan et al., 2026; Wouterse et al., 2022; Ziervogel & Ericksen, 2010).

Agreement exists that adaptation is required, but the literature differs in its appraisal of the most successful techniques and the conditions under which they provide lasting food-security gains. While technological initiatives focus on enhanced seed types, irrigation efficiency and climate-smart production practices, socioeconomic approaches emphasise diversification of livelihoods, market access, social protection, institutional support and collective action. Evidence from smallholders shows that the ability to take on adaptation strategies is based on asset ownership, access to finance, perception of risk, information, and local institutions, not just on technical effectiveness. Some studies view adaptation as essentially incremental adjustment within current farming systems, whereas resilience-oriented research focuses on more transformative changes in livelihood structures, value chains, governance arrangements and resource management. This distinction is essential since actions that stabilise short-term output may not always diminish long-term vulnerability or improve all dimensions of food security (Purbawan et al., 2026; Wouterse et al., 2022; Ziervogel & Ericksen, 2010).

However, there are also limitations in the adaptation literature, such as limited longitudinal examination, inconsistent definitions and lack of comparable indicators. Many studies discover or suggest adaption possibilities, but do not establish whether they lead to lasting improvements in the availability, access, utilisation and stability of food. The terms adaptation, coping, climate-smart agriculture, resilience and transformation are frequently employed inconsistently, which leads to conceptual ambiguity and makes cross-study comparability challenging. Moreover, maladaptation, costs of adoption, maintenance needs, trade-offs between policy objectives and the potential for interventions to assist relatively well-resourced farmers but exclude the most disadvantaged are typically inadequately considered. Thus, the evaluation distinguishes between short-term coping and adaptive capability and longer-term resilience and evaluates adaptation solutions in terms of feasibility, inclusiveness, scalability and contribution to multidimensional food-security goals.

Theme 4: Policy Integration, Governance, and Implementation Gaps

Policy solutions to the climate change and food security nexus need to be coordinated across sectors such as agriculture, water, nutrition, health, trade, infrastructure, disaster risk management, environmental protection and social welfare. The literature reviewed supports integrated policy frameworks that deal with all four elements of food security, rather than

equating food security policy to increased agricultural output only. Relevant measures include public investment in climate resilient infrastructure, agricultural research and extension, early warning systems, strategic food reserves, social safety nets, food assistance, risk financing, regional trade cooperation and targeted support to populations exposed to climate risks. Vulnerability assessment frameworks can help policymakers to translate climate hazards, sensitivity, and adaptive capacity into policy relevant priorities, while regional cooperation can help to mitigate the impacts of resource scarcity and supply disruption across national borders (El Bilali et al., 2020; Richardson et al., 2018; Ziervogel & Ericksen, 2010).

There is general agreement on the need to integrate food security and climate policies, although the relative importance of adaptation, mitigation, market mechanisms, governmental involvement and community led governance differs between studies. Some approaches focus on agricultural modernisation and climate smart technologies, while others focus on social protection, agroecological practices, local knowledge and distributive justice. Similarly, trade and regional cooperation can increase food availability by shifting supplies between locations, but reliance on external markets can also make vulnerable countries more susceptible to international price volatility and climate-induced output shocks in other parts of the world. Further scenario-based evidence suggests that adaptation could compensate for some of the projected increase in food insecurity, but adaptation alone may be inadequate under high emissions pathways. Strong mitigation and substantial investment in adaptation are likely to be complementary rather than substitutable responses (Richardson et al., 2018; Ziervogel & Ericksen, 2010).

The main policy gap is not so much the absence of suggested measures but ineffective execution, fragmented governance, inadequate financing and limited evaluation of policy impacts. Climate policies and food security plans are often developed by different administrative systems, resulting in overlapping mandates, misaligned objectives, and insufficient cooperation across levels of government. Equally, the models for implementation differ significantly among nations, making policy transfer problematic without consideration of institutional capability, political economics, local participation and resource restrictions. Moreover, vulnerability evaluations at the national level may be too aggregated to identify marginalised groups or to measure the extent to which interventions diminish inequality. Thus, the broader aim of this study is to combine research on impacts, adaptation, and policy implementation, and to clarify how integrated governance may transform information on climate risk into equitable and context sensitive gains in resilience in food systems.

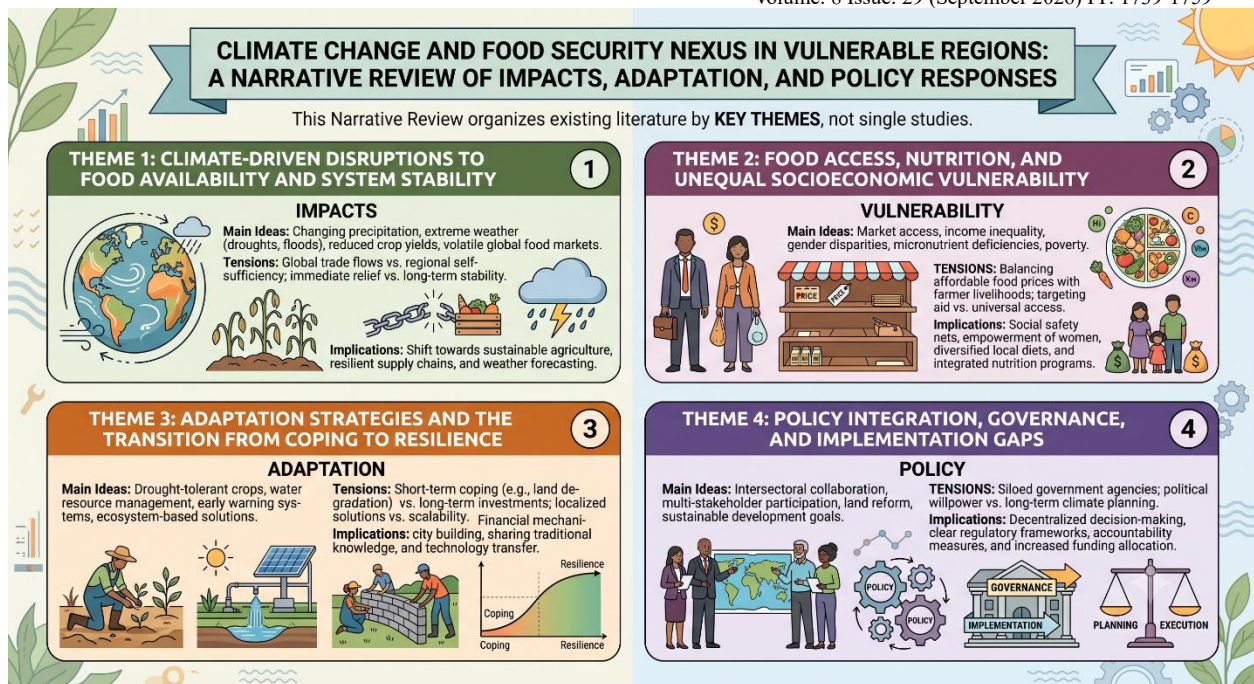


Figure 1: Thematic Review of Literature

Critical Discussion

The last thematic assessment collated the present state of knowledge on the climate change food security nexus in vulnerable regions. Building on this synthesis, the present debate goes beyond descriptive reporting to critically review the literature along four analytical dimensions: regions of agreement, areas of disagreement, areas of knowledge lacunae, and broader theoretical, policy and practical consequences. This analytical approach contributes to a better understanding of the strengths and limits of the existing knowledge, identifies priorities for future research and informs more integrated and context sensitive solutions to enhance food security in a changing environment.

Agreements in the Literature

The literature examined reveals a broad consensus that climate change is a multidimensional driver of food insecurity, particularly in areas with high climatic vulnerability, socioeconomic deprivation and low adaptive capacity. Evidence from various geographical contexts consistently shows that increasing temperatures, shifting precipitation patterns, extreme weather events and environmental degradation negatively affect agricultural productivity, disrupt food supply chains and undermine the four dimensions of food security: availability, access, utilisation and stability (El Bilali et al., 2020; Firdaus et al., 2019; Richardson et al., 2018). There is also broad consensus that vulnerable groups such as smallholder farmers, low-income households, women and children are disproportionately impacted as climatic hazards intersect with existing structural inequities. Additionally, the literature has consistently pointed to adaptation and resilience-building as key elements of sustainable food systems, highlighting that climate related food insecurity cannot be addressed through production-oriented interventions alone (Anshida et al., 2024; Ziervogel & Ericksen, 2010).

Beyond these substantive conclusions, an essential convergence is the idea that food security should be conceptualised as an integrated systems issue, not as a merely agricultural outcome. Most of the recent studies argue for multiple policy responses, including technical innovation, institutional strengthening, social protection and reforms in governance. This consensus marks a significant theoretical transition from linear climate crop correlations to systems-oriented viewpoints that acknowledge the interconnection of environmental, economic, social and political phenomena. However, there is increasing consensus on the complexity of the climate change food security nexus. But corresponding advances in integrated empirical frameworks are comparatively limited, suggesting that conceptual consensus has outpaced methodological integration.

Disagreements

There is general consensus that climate change has negative implications, but the interpretation of the processes via which these impacts affect food security varies widely in the literature. Studies focusing on production mainly emphasise reductions in agricultural output due to climatic stressors, while research on food systems emphasise market disruptions, food affordability, nutritional outcomes, and institutional capacity (El Bilali et al., 2020; Toth et al., 2008). The same disparity is apparent in the investigation of adaptation. Some studies focus on technological innovations such as climate-smart agriculture, improved irrigation and drought-resistant crops while others argue that social protection, livelihood diversification, governance reform and community participation are equally important determinants of resilience (Purbawan et al., 2026; Ziervogel & Ericksen, 2010). Thus, there are many, sometimes conflicting, opinions in the literature about where adaptation investments should be prioritised.

The conflicts are mostly around variations in academic orientation, analytical scale, and contextual assumptions, not opposing factual findings. In agricultural and environmental science, adaptation is often considered in terms of productivity and resource efficiency; in development, economics, and public policy studies, adaptation is often considered in terms of vulnerability, equity, and institutional efficacy. In addition, studies at the household, regional and global level generally highlight distinct priorities because they analyse different components of the food system. These differences illustrate that no single conceptual framework can effectively reflect the complexity of climate related food insecurity, highlighting the necessity of interdisciplinary methods that integrate environmental processes with socioeconomic and governance aspects.

Gaps

Research on climate change and food security has increased significantly but many important information gaps remain. First, empirical information is geographically uneven, with studies concentrated in selected nations and regions and few comparative cross regional studies (Anshida et al., 2024; Elkhalfi et al., 2025). Second, there is a major part of the literature that is still focused on agricultural output, and very little studies focus on food utilisation, nutrition, food system governance and long-term stability using integrated analytical frameworks (Aberman & Tirado, 2014; Firdaus et al., 2019). Third, the use of inconsistent terminology for concepts like vulnerability, resilience, adaptive capacity, climate-smart agriculture, and transformation inhibits comparison between studies and impedes cumulative theoretical growth.

Another crucial methodological limitation is the design. Most existing research is cross-sectional, context specific or descriptive and provides little information on the longer-term effectiveness, scalability and equality implications of adaption tactics. In particular, comparative analyses of policy implementation, institutional performance and governance effectiveness are relatively rare, but they are relevant for the conversion of scientific information into practical consequences. Furthermore, interactions between climate hazards, economic shocks, political instability and food system disruptions are rarely studied together and future research should aim to use systems-based, inter disciplinary and longitudinal approaches that can better capture the changing nature of climate related food insecurity.

Implications

The conclusions presented in this paper have several theoretical, research, and policy ramifications. Theoretically, they advocate for a shift away from production centric models and toward integrated food systems frameworks that clearly acknowledge the interplay of institutional, governance, climatic, environmental, and socioeconomic elements. Rather than analysing vulnerability, resilience, adaptive capacity, and food system dynamics separately, future conceptual improvements should integrate them into cohesive analytical models. In addition to facilitating comparative study across vulnerable locations and bolstering interdisciplinary collaboration, such integration would enhance theoretical consistency (El Bilali et al., 2020; Richardson et al., 2018).

Practically speaking, the research indicates that coordinated efforts that go beyond agricultural productivity are necessary to improve food security under climate change. Investments in climate-smart agriculture should be paired with increased social protection, policies that are attentive to nutrition, robust infrastructure, market expansion, early warning systems, and inclusive governance. Developing context specific adaptation measures that take into account regional variations in institutional capacity, socioeconomic situations, and climate exposure is equally crucial. Therefore, longitudinal evaluation of adaptation outcomes, comparative policy analysis, and integrated assessment frameworks that may support equitable and resilient food systems in vulnerable regions while guiding evidence-based decision making should be given top priority in future research.

Recommendations and Future Directions

Recommendations for Practice

The results of this narrative review imply that practitioners should use an integrated, climate resilient approach that addresses all four elements of food security, not just agricultural productivity. Farmers, agricultural extension services, development practitioners and local organisations should promote climate-smart agricultural methods such as drought-tolerant crop varieties, efficient irrigation systems, sustainable soil management, integrated pest management and crop diversification. These approaches should be reinforced by livelihood diversification, improved postharvest management and enhanced access to climate information services to strengthen adaptive capacity and reduce vulnerability to recurrent climatic shocks (Anshida et al., 2024; Purbawan et al., 2026). Equally crucial is the integration of nutrition-sensitive strategies so that adaptation efforts not only increase food production but also enhance dietary quality and household nutritional outcomes (Aberman & Tirado, 2014).

Continuous education, technical training and community participation are also required to enhance local capacities for effective implementation. Practitioners should design adaption techniques that are contextually relevant and that incorporate indigenous knowledge with scientific information and take into consideration regional environmental circumstances and socio-economic realities. Regular monitoring and evaluation of adaptation activities are required to measure their success in terms of food availability, access, utilisation and stability. Such evidence-based practice would boost continuous learning, increase resource allocation and build the long-term resilience of vulnerable communities (Ziervogel & Ericksen, 2010).

Recommendations for Policy or Organizational Use

Governments, international development agencies, and regional bodies should improve policy integration by mainstreaming climate adaptation into the overarching policies for food security, agricultural development, nutrition, the environment, and disaster-risk management. Policy interventions need to go beyond agricultural output and address structural vulnerabilities impacting food affordability, market access, social protection, infrastructure and institutional capacity. Investing in climate-resilient infrastructure, early-warning systems, agricultural research and extension, digital climate information services, and sustainable water management should be prioritised to reduce the long-term vulnerability of food systems (El Bilali et al., 2020; Richardson et al., 2018). Vulnerable groups like smallholder farmers, women, children and marginalised rural communities should receive special attention through targeted financial support, insurance and inclusive adaptation programs.

At the organisational level, the efficient implementation demands more collaboration across government agencies, research institutes, civil society organisations and the commercial sector. Organisations should set up cross-sectoral governance systems that allow information exchange, joint planning and coordinated resource mobilisation across agricultural, health, trade and environmental sectors. Moreover, standardised vulnerability assessment frameworks and performance indicators need to be created to evaluate the effectiveness of policies and support adaptive decision-making. Strengthening institutional accountability and evidence-based governance will facilitate the translation of scientific information into practical initiatives that can increase food security under changing climate conditions (Ferranti, 2023; Ziervogel & Ericksen, 2010).

Future Research Directions

Future research must adopt interdisciplinary techniques that incorporate environmental science, agricultural economics, nutrition, public health, governance and climate policy into comprehensive food-system frameworks. Longitudinal studies are particularly essential to assess the long-term effectiveness, sustainability and scalability of adaption measures under varying climatic and socio-economic situations. To enhance understanding on the role of institutional capacity, quality of governance and socioeconomic variables in shaping adaptation results across susceptible regions, comparative cross-regional analyses should also be broadened. Such study would increase the external validity of present findings and contribute to the creation of more transferable policy recommendations (Anshida et al., 2024; Richardson et al., 2018).

Further research is necessary to address the conceptual and methodological constraints noted across the literature. Future research needs to provide standardised definitions and measurement methods for key topics such as vulnerability, resilience, adaptive capacity, and food system change to promote comparability across studies. Agricultural production is comparatively better investigated than food utilisation, nutrition, postharvest systems, supply chain resilience and governance and deserves more attention. Finally, researchers should apply systems-based approaches that explore the linkages among climatic hazards, economic shocks, institutional responses, and social inequities to generate more comprehensive data to inform integrated adaptation strategies and policy creation. Progressing these research goals will help build a more cohesive theoretical framework and promote evidence-based decision-making for climate-resilient food systems (El Bilali et al., 2020; Firdaus et al., 2019).

Conclusion

This narrative review synthesised multidisciplinary literature on the nexus between climate change and food security in vulnerable regions by examining four interrelated dimensions: climate-driven disruptions to food availability and system stability; food access and socioeconomic vulnerability; adaptation strategies that strengthen resilience; and policy integration for sustainable food systems. The weight of evidence reviewed demonstrates in no uncertain terms that climate change is not only an environmental problem, but a systemic risk that impacts all dimensions of food security through complex interactions between climatic hazards, agricultural production, market dynamics, nutritional outcomes, institutional capacity and socioeconomic inequality. The severity of impacts differs among geographical contexts, yet the literature shows that the most vulnerable regions are disproportionately impacted as climatic risks are intensified by poverty, weak governance, poor infrastructure, and limited adaptive capacity (El Bilali et al., 2020; Richardson et al., 2018).

Besides summarising the state of the art, this study advances the literature by synthesising disparate information into an integrated theme framework, rather than addressing agricultural, nutritional, socioeconomic and governance challenges as distinct research fields. The review indicates that multifaceted adaptation solutions backed by integrated policies, inclusive governance and resilient food systems are needed for effective responses to climate-related food insecurity. It additionally emphasises the continuing conceptual fragmentation, methodological inconsistency and uneven geographical coverage that continue to hamper theoretical growth and evidence-based policymaking. The review highlights key areas of convergence and divergence, providing a clearer conceptual basis for future multidisciplinary research and more cohesive policy planning for vulnerable regions.

In the end, the capacity of governments, researchers, development organisations and local people to integrate scientific data with context-specific adaptation and governance measures will be critical to increasing food security in a changing climate. As climate risks continue to grow, future initiatives should move beyond reactive reactions to proactive, inclusive and resilient food-system reform that simultaneously addresses environmental sustainability, social equality and long-term human wellbeing.

Limitations

Several limitations should be considered when interpreting the findings of this narrative review. First, the literature search was restricted to the Scopus database, which, although

comprehensive and widely recognized for indexing high-quality peer-reviewed publications, may not capture all relevant studies available in other databases such as Web of Science, PubMed, CAB Abstracts, or regional indexing platforms. Consequently, some potentially relevant evidence, particularly grey literature, government reports, policy documents, and publications in non-indexed journals, may not have been included. Second, the review focused on studies published within the predefined timeframe used for article selection. While this approach ensured the inclusion of contemporary evidence, it may have excluded earlier foundational studies that continue to influence current theoretical and policy discussions.

Another limitation concerns the uneven distribution of research across sectors and geographical regions. Much of the existing literature continues to emphasize agricultural production and climate impacts in selected regions, particularly Sub-Saharan Africa and South Asia, whereas comparatively fewer studies investigate food utilization, nutrition, governance, postharvest systems, fisheries, or urban food security. Furthermore, conceptual overlap among terms such as *vulnerability*, *resilience*, *adaptive capacity*, *climate-smart agriculture*, and *food-system resilience* complicates direct comparison across studies because definitions and measurement approaches vary considerably. These inconsistencies reflect broader conceptual fragmentation within the field and highlight the need for greater standardization in future research (El Bilali et al., 2020; Firdaus et al., 2019).

Finally, the interpretive nature of narrative review methodology should be acknowledged. Unlike systematic reviews or meta-analyses that employ quantitative synthesis and formal quality appraisal procedures, narrative reviews emphasize conceptual integration, critical interpretation, and thematic synthesis (Ferrari, 2015; Green et al., 2006). Consequently, the organization of themes, interpretation of evidence, and identification of research priorities inevitably involve scholarly judgment. Nevertheless, transparent search procedures, clearly defined selection criteria, and thematic analysis were employed to enhance the credibility, coherence, and reproducibility of the review. These limitations do not diminish the value of the review but instead define the scope within which its findings should be interpreted and applied.

-
- Acknowledgements:** The authors would like to express their sincere gratitude to Kedah State Research Committee, UiTM Kedah Branch for providing the necessary resources and support throughout the course of this research. Special appreciation is extended to colleagues and peers who contributed valuable insights and constructive feedback, which greatly enhanced the quality of this paper.
- Funding Statement:** This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.
- Conflict of Interest Statement:** The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have contributed to this work and approved the final version of the manuscript for submission to the Advanced International Journal of Business, Entrepreneurship and SME's (AIJBES).
- Ethics Statement:** Option B (For Studies Not Involving Human or Animal Subjects)
This study did not involve any human participants, animals, or sensitive data requiring ethical approval. The authors confirm that the research was conducted in accordance with accepted academic integrity and ethical publishing standards.
- Author Contribution Statement:** All authors contributed significantly to the development of this manuscript. Irlisuhayu Mohd Ramli was responsible for the conceptualization, methodology, and overall supervision of the study. Zulkhairi Nisa handled data collection, analysis, and interpretation of results. Siti Muliana contributed to the literature review, drafting, and critical revision of the manuscript. All authors read and approved the final version of the manuscript prior to submission.
-

References

- Aberman, N.-L., & Tirado, C. (2014). Impacts of climate change on food utilization. In *Global Environmental Change* (pp. 717–724). Springer. https://doi.org/10.1007/978-94-007-5784-4_124
- Aishwarya, & Kumar, P. (2024). Environmental crisis: Nourishment at risk. In *Technological Approaches for Climate Smart Agriculture* (pp. 3–7). Springer. https://doi.org/10.1007/978-3-031-52708-1_1
- Alemu, T., & Mengistu, A. (2019). Impacts of climate change on food security in Ethiopia: Adaptation and mitigation options: A review. In *Climate Change Management* (pp. 397–412). Springer. https://doi.org/10.1007/978-3-319-75004-0_23
- Anshida, M., Murugan, P. P., Senthilkumar, M., Chandrakumar, M., Vanitha, G., Rani, A. J., & Arvind, G. (2024). Climate change and food security: Exploring adaptation strategies and regional vulnerabilities through a systematic review. *Plant Science Today*, 12(sp1), 1–12. <https://doi.org/10.14719/pst.6906>
- Baars, C., Barbir, J., & Paulino Pires Eustachio, J. H. (2023). How can climate change impact human health via food security? A bibliometric analysis. *Environments*, 10(11), Article 196. <https://doi.org/10.3390/environments10110196>
- Chakraborti, J., Mondal, S., & Palit, D. (2021). Food and nutrition security in India through agroecology: New opportunities in agriculture system. In *Sustainable Intensification for Agroecosystem Services and Management* (pp. 37–68). Springer. https://doi.org/10.1007/978-981-16-3207-5_2
- Dossa, K. F., & Miassi, Y. E. (2025). Nexus between food insecurity, poverty, and climate change: A cross-regional multifactorial analysis. *Frontiers in Environmental Economics*, 4, Article 1689025. <https://doi.org/10.3389/frevc.2025.1689025>
- Durán-Sandoval, D., Uleri, F., Durán-Romero, G., & López, A. M. (2023). Food, climate change, and the challenge of innovation. *Encyclopedia*, 3(3), 839–852. <https://doi.org/10.3390/encyclopedia3030060>
- El Bilali, H. (2021). Climate change–food security nexus in Burkina Faso. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 16(9), Article 009. <https://doi.org/10.1079/PAVSNNR202116009>
- El Bilali, H., Bassole, I. H. N., Dambo, L., & Berjan, S. (2020). Climate change and food security. *Agriculture and Forestry*, 66(3), 197–210. <https://doi.org/10.17707/AgricultForest.66.3.16>
- Elkhalfi, O., Chaabita, R., Ghoujdami, M., Zehraoui, K., EL Alaoui, H., & Belhaj, I. (2025). The impact of climate change on food security in the Middle East and North Africa: Challenges and adaptation strategies. *Journal of Agriculture and Food Research*, 21, Article 101963. <https://doi.org/10.1016/j.jafr.2025.101963>
- Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change*, 18(1), 234–245. <https://doi.org/10.1016/j.gloenvcha.2007.09.002>
- Ferranti, P. (2023). Politics for food security and climate changes. In *Sustainable Food Science - A Comprehensive Approach* (Vols. 1–4, pp. V1-176–V1-182). Elsevier. <https://doi.org/10.1016/B978-0-12-823960-5.00083-4>
- Firdaus, R. B. R., Senevi Gunaratne, M., Rahmat, S. R., & Kamsi, N. S. (2019). Does climate change only affect food availability? What else matters? *Cogent Food & Agriculture*, 5(1), Article 1707607. <https://doi.org/10.1080/23311932.2019.1707607>
- Hang, V. T., Khanh, B. D., & Hang, D. M. (2025). Impacts of climate change on agriculture and food security: A review across geographic regions and research fields. In

- EAI/Springer Innovations in Communication and Computing* (pp. 121–139). Springer. https://doi.org/10.1007/978-3-031-90629-9_9
- Kandeel, W. A., Mehanna, N. S., Ellaithy, L. S., & Hammad, D. Y. (2025). Climate change impacts on pillars of food security and human health. In *Climate Change Impacts on Toxins and Health Effects* (pp. 113–148). Springer. https://doi.org/10.1007/978-981-96-3416-3_5
- Karimdjano, I., Atajanov, A., Buriyeva, D., Atabaev, B., Dadabaev, S. S., Sobirova, Z., & Qudratov, D. (2025). Effects of climate change on food security and its relationship to malnutrition and vitamin deficiencies in vulnerable human populations. *Journal of Animal Environment*, 17(3), 688–699. <https://doi.org/10.70102/AEJ.2025.17.3.56>
- Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, 319(5863), 607–610. <https://doi.org/10.1126/science.1152339>
- Maharaj, R., Singh-Ackbarali, D., & Sankat, C. K. (2014). Postharvest management strategies. In *Impacts of Climate Change on Food Security in Small Island Developing States* (pp. 221–254). IGI Global. <https://doi.org/10.4018/978-1-4666-6501-9.ch008>
- Myers, S. S., Smith, M. R., Guth, S., Golden, C. D., Vaitla, B., Mueller, N. D., Dangour, A. D., & Huybers, P. (2017). Climate change and global food systems: Potential impacts on food security and undernutrition. *Annual Review of Public Health*, 38, 259–277. <https://doi.org/10.1146/annurev-publhealth-031816-044356>
- Omokpariola, D. O., Agbanu-Kumordzi, C., Samuel, T., Kiswii, L., Moses, G. S., & Adelegan, A. M. (2025). Climate change, crop yield, and food security in Sub-Saharan Africa. *Discover Sustainability*, 6(1), Article 678. <https://doi.org/10.1007/s43621-025-01580-4>
- Onyeaka, H. (2026). The impact of climate change on global food scarcity and distribution. In *Global Food Value Chains: An In-depth Exploration of International Trade Dynamics* (pp. 199–216). Springer. https://doi.org/10.1007/978-3-032-11623-9_9
- Onyeaka, H., Nwauzoma, U. M., Akinsemolu, A. A., Tamasiga, P., Duan, K., Al-Sharify, Z. T., & Siyanbola, K. F. (2024). The ripple effects of climate change on agricultural sustainability and food security in Africa. *Food and Energy Security*, 13(5), Article e567. <https://doi.org/10.1002/fes3.567>
- Purbawan, K. W., Ar, N. H., Khusaini, M., & Efani, A. (2026). From adaptation to resilience: The impact of climate change adaptation on food security in Lamongan, Indonesia. *Decision Science Letters*, 15(2), 481–490. <https://doi.org/10.5267/j.dsl.2026.1.003>
- Quamar Ahmed, M. N., Haq, S. M. A., Lalin, S. A. A., & Ahmed, K. J. (2026). Links between perceptions of climate change and food security: Developing country context. In *Global Nexus Handbook* (Vols. 1–3, Vol. 2, pp. 461–476). Wiley. <https://doi.org/10.1002/9781394248087.ch26>
- Raj, B., Rahul, J., Gulia, S., Jagdish, J., Kumar, P., & Dwivedi, N. (2024). The need for food security under changing climate scenario. In *Food Security in a Developing World: Status, Challenges, and Opportunities* (pp. 13–28). Springer. https://doi.org/10.1007/978-3-031-57283-8_2
- Richardson, K. J., Lewis, K. H., Krishnamurthy, P. K., Kent, C., Wiltshire, A. J., & Hanlon, H. M. (2018). Food security outcomes under a changing climate: Impacts of mitigation and adaptation on vulnerability to food insecurity. *Climatic Change*, 147(1–2), 327–341. <https://doi.org/10.1007/s10584-018-2137-y>
- Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, 5(1), Article 014010. <https://doi.org/10.1088/1748-9326/5/1/014010>

- Shamshad, J., Nawaz, A. F., Khan, M. B., & Arif, M. (2024). Climate change and food security. In *Environment, Climate, Plant and Vegetation Growth* (pp. 265–284). Springer. https://doi.org/10.1007/978-3-031-69417-2_9
- Tóth, T., Villanyi, J., Balázs, P., & Kapusztai, J. (2008). Global environment change and food security: A socio-economic perspective. *Cereal Research Communications*, 36(Suppl. 5), 1771–1774.
- Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science*, 341(6145), 508–513. <https://doi.org/10.1126/science.1239402>
- Wouterse, F., Andrijevic, M., & Schaeffer, M. (2022). The microeconomics of adaptation: Evidence from smallholders in Ethiopia and Niger. *World Development*, 154, Article 105884. <https://doi.org/10.1016/j.worlddev.2022.105884>
- Ziervogel, G., & Ericksen, P. J. (2010). Adapting to climate change to sustain food security. *Wiley Interdisciplinary Reviews: Climate Change*, 1(4), 525–540. <https://doi.org/10.1002/wcc.56>