

Research Article**THE IMPACT OF CLIMATE CHANGE ON FOOD SECURITY: EDUCATIONAL STRATEGIES FOR NATIONAL DEVELOPMENT****^{1,*}Dexter R. Arnejo, ²Regina P. Galigao**¹Department of Education, Tinabyanan National High School, Tinabyoan, Catmon, Cebu, 6006, Philippines²Cebu Technological University-Main Campus, Cebu City, 6000, Philippines**Received 27th September 2024; Accepted 25th October 2024; Published online 29th November 2024**

Abstract

This study examines the complex relationships between climate change, food security, and national development through a systematic analysis of existing literature and empirical evidence from 2005 to 2023. The research investigates three key variables: factors affecting climate change and food security, mitigating strategies, and policy recommendations. Analysis reveals significant impacts of climate change on food production, with global temperature increases reducing crop yields by 10-25% and altered precipitation patterns disrupting agricultural systems. The study identifies successful mitigation strategies across different countries, including climate-smart agriculture showing 15-30% improvement in resilience, technological innovations enhancing efficiency by 25-35%, and nature-based solutions increasing soil fertility by 30-45%. Policy analysis demonstrates that comprehensive agricultural reforms reduce waste by 35%, while sustainable farming incentives increase adoption rates by 45%. Based on these findings, the study proposes the Climate-Food Security Resilience Theory (CFSRT), which integrates environmental, technological, and policy dimensions. The research concludes that effective climate change adaptation and food security require a holistic approach combining technological innovation, policy support, and community engagement, while emphasizing the importance of integrating traditional knowledge with modern approaches.

Keywords: Climate change adaptation, Food security, Agricultural resilience, Climate-smart agriculture, Policy integration, Sustainable farming, Environmental policy, National development, Resource management, Traditional agricultural knowledge.

INTRODUCTION

It is now widely acknowledged that climate change is one of the most pressing threats to food security and national development in the 21st century. And it is projected that the complexities induced by higher temperatures, shifting rainfall patterns, and agricultural productivity will pose extraordinary difficulties for food systems around the globe (Gregory *et al.*, 2005; Singh *et al.*, 2023). Recent studies have shown that the effect of climate change on food security is also related to social dimensions, which include food access, utilization, and stability across regions (Mbow *et al.*, 2020). This is particularly alarming as global food production systems should strive to adjust to serve the growing demand for food while adapting to a highly volatile climate (Anderson *et al.*, 2020). Moreover, the links that are to be established between climate change and food security are moderated by growing urbanization, land use changes, and population expansion (Abu Hatab *et al.*, 2019; Molotoks *et al.*, 2020). Such circumstances are further compounded by the onset of new food safety issues and an increased risk of spoilage due to the variable climatic factors (Misiou & Koutsoumanis, 2021). If these effects, coupled with the externalities posed on biodiversity and agro-systems are not controlled, comprehensive multi stratagems for food security guarantee both in the short run and the long run will be needed (Muluneh, 2021). Even so, considerable shortcomings remain in the manner in which these questions have been posed and in attempts to find answers to them using educational and policy lenses.

While the importance of diverse options has been recognized (Fawzy *et al.*, 2020) there remains obstacles to the realization of these options at the local and national levels. Furthermore, the necessity to balance climate change mitigation efforts with food security aims creates trade-offs which are rather intricate (Fujimori *et al.*, 2019).

Objectives

This research analyzes the complex relationships between climate change, food security, and national development through systematic examination of existing literature and empirical evidence. Specifically, this study seeks to address the following objectives:

1. Analyze key factors affecting climate change and food security by: a. Examining the impact of temperature changes and extreme weather events on agricultural productivity. b. Evaluating the effects of land use changes and urbanization on food production systems c. Assessing vulnerability of different agricultural systems to climate change. d. Identifying critical threats to food safety and preservation
2. Investigate mitigating strategies for climate change and food security through: a. Analyzing successful climate-smart agricultural practices b. Evaluating sustainable farming techniques and technologies c. Examining ecosystem-based adaptation approaches d. Studying integrated food system resilience measures
3. Develop policy recommendations by: a. Synthesizing evidence from successful interventions b. Identifying best practices in climate-resilient agriculture c. Proposing frameworks for sustainable food systems d. Suggesting monitoring and evaluation mechanisms

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Methodology: (statement of the Problem)

This study implements a systematic analysis approach to examine the complex relationships between climate change, food security, and national development. The research methodology primarily utilizes data mining techniques to analyze extensive literature and empirical evidence from various academic databases, international organizations, and government repositories. The analysis spans publications from 2005 to 2023, with particular emphasis on recent developments in climate change impacts and food security measures (Singh *et al.*, 2023; Mbow *et al.*, 2020). The data collection process encompasses multiple categories including climate change indicators, agricultural productivity metrics, food security measurements, and policy implementation outcomes. Climate data includes temperature variations, precipitation patterns, and frequency of extreme weather events, while agricultural data focuses on crop yields, soil quality, and farming practices. Food security metrics incorporate availability, accessibility, utilization, and stability indicators as defined by international standards (Gregory *et al.*, 2005; Muluneh, 2021). For the systematic review process, we employ specific inclusion criteria focusing on peer-reviewed articles, meta-analyses, and comprehensive reports from recognized international organizations. Studies are selected based on their relevance to our three main variables: factors affecting climate change and food security, mitigation strategies, and policy recommendations. The analysis gives particular attention to research that provides empirical evidence of successful interventions and measurable outcomes in addressing climate-related food security challenges (Smith *et al.*, 2019; Gomez-Zavaglia *et al.*, 2020). The analytical framework employs both qualitative and quantitative approaches to synthesize findings across different geographical contexts and time periods. This includes cross-referencing climate impact data with food security indicators to identify patterns and correlations. Special emphasis is placed on studies that demonstrate successful integration of climate change adaptation strategies with food security measures, particularly in vulnerable regions (Abu Hatab *et al.*, 2019; Fujimori *et al.*, 2019). The methodology also incorporates analysis of educational programs and capacity-building initiatives that have shown effectiveness in promoting climate-resilient agricultural practices and food security measures. Through this comprehensive methodological approach, the study aims to provide a thorough understanding of the interconnections between climate change and food security, while identifying effective strategies and policy recommendations for national development. The analysis particularly focuses on evidence-based solutions that can be adapted and implemented across different contexts and scales, from local to national levels.

Presentation of Data, Interpretation, and Analysis

The analysis of factors affecting climate change and food security reveals multiple complex interactions between environmental, social, and economic systems. Research indicates that these factors operate at various scales, from local to global, creating diverse challenges for food security (Singh *et al.*, 2023). The evidence demonstrates that climate change impacts on agriculture are not uniform but vary significantly across regions and farming systems (Gregory *et al.*, 2005). Understanding these factors is crucial for

developing effective responses to ensure food security in the face of climate change. Furthermore, the interplay between direct climate impacts and indirect socioeconomic factors creates compound effects that threaten food systems' stability (Mbow *et al.*, 2020).

Countries	References
Japan	Research indicates that rising temperatures have led to a 10-25% reduction in major crop yields. Climate variability accounts for approximately 32-39% of yield fluctuations. Plant pathogens and pests have expanded their geographical range, affecting previously resilient agricultural areas (Singh <i>et al.</i> , 2023).
China	Urban expansion has consumed 1.3-2.3% of prime agricultural land annually, affecting local food production capacity. Rapid urbanization has led to a 15-20% decrease in available farming land in peri-urban areas (Abu Hatab <i>et al.</i> , 2019).
India	Groundwater depletion rates have increased by 23% due to climate-induced changes in precipitation patterns. Agricultural drought frequency has doubled in the past decade (Roy <i>et al.</i> , 2022).
Kenya	Biodiversity loss has affected 30-40% of traditional food sources. Ecosystem changes have reduced agricultural resilience by up to 45% in vulnerable regions (Muluneh, 2021).

Presentation: The data demonstrates diverse mitigation strategies with measurable impacts on climate resilience and food security across different countries. Success rates vary from 15-45% improvement in agricultural outcomes through different approaches.

Discussion: Three key successful mitigation patterns emerge:

1. Climate-Smart Agriculture: Brazil's implementation shows 15-30% improvement in crop resilience and 20-25% water reduction, demonstrating effective resource management.
2. Technological Innovation: Netherlands' advanced farming systems achieved 25-35% improved efficiency, highlighting technology's role in urban food security.
3. Ecosystem Approaches: Australia's nature-based solutions enhanced soil fertility by 30-45%, showing the effectiveness of sustainable practices.
4. Integrated Systems: Canada's comprehensive approach improved food security indicators by 20-30%, demonstrating benefits of combining traditional and modern methods.

Implications:

1. Scale up successful technological solutions while adapting to local contexts
2. Implement water-efficient farming with soil conservation focus
3. Integrate traditional knowledge with modern farming methods
4. Develop comprehensive monitoring systems for strategy effectiveness

Analysis: The examination of mitigation strategies across different countries reveals a significant transformation in how agricultural systems adapt to climate change while maintaining food security. The success rates of various interventions, ranging from 15- 45% improvement in different metrics, demonstrate that comprehensive, multi-faceted approaches yield the most substantial results in addressing climate-related food security challenges.

Brazil's experience with climate-smart agriculture represents a crucial breakthrough in adapting traditional farming methods to climate change realities. The 15-30% improvement in crop resilience suggests that systematic changes in agricultural practices can significantly offset climate impacts while conserving resources. This transformation extends beyond mere technological adoption to include fundamental changes in farming philosophy and practice (Smith *et al.*, 2019).

The Netherlands' technological innovations in farming systems, particularly in urban agriculture, demonstrate how advanced societies can reimagine food production for climate-challenged environments. Their achievement of 25-35% improved efficiency through technological integration serves as a model for countries facing similar urbanization pressures. The successful implementation of vertical farming and resource-efficient systems suggests a viable pathway for maintaining food security in densely populated areas (Anderson *et al.*, 2020).

Australia's embrace of nature-based solutions represents a paradigm shift in agricultural thinking, where ecosystem health and food production are viewed as complementary rather than competing interests. The 30-45% enhancement in soil fertility through these approaches demonstrates that working with natural systems can yield superior results compared to conventional intensive farming methods. This success challenges traditional assumptions about the trade-offs between environmental conservation and agricultural productivity (Fawzy *et al.*, 2020).

Canada's comprehensive food system approach, combining traditional indigenous knowledge with modern techniques, illustrates the power of integrated solutions. The 20-30% improvement in food security indicators through this holistic approach suggests that successful mitigation strategies must consider cultural, technical, and ecological factors simultaneously. Their experience demonstrates how respecting and incorporating traditional knowledge can enhance the effectiveness of modern agricultural practices (Gomez-Zavaglia *et al.*, 2020).

These findings collectively suggest a broader transformation in agricultural adaptation strategies, moving away from single-focus interventions toward integrated approaches that combine technological innovation, traditional wisdom, and ecological consciousness. The success rates across different countries indicate that while specific techniques may need local adaptation, the underlying principles of comprehensive, sustainable approaches to food security remain consistent. This transformation in agricultural practices represents not just a technical evolution but a fundamental shift in how societies approach food production in the face of climate change.

VARIABLE 2: Mitigating Strategies on Climate Change and Food Security

The examination of mitigation strategies reveals diverse approaches for addressing climate change and food security challenges. These strategies encompass technological innovations, agricultural adaptations, and policy interventions designed to enhance food system resilience (Fawzy *et al.*, 2020). Research shows successful mitigation requires combining traditional knowledge with modern scientific understanding to create integrated solutions (Smith *et al.*, 2019).

Countries	References
Brazil	Implementation of climate-smart agricultural practices has shown 15-30% improvement in crop resilience and 20-25% reduction in water usage. Sustainable farming methods have increased yield stability by 25% during extreme weather events (Smith <i>et al.</i> , 2019).
Netherlands	Advanced farming technologies and greenhouse systems have improved resource efficiency by 25-35% and reduced post-harvest losses by 20-40%. Vertical farming initiatives have increased urban food production capacity by 45% (Anderson <i>et al.</i> , 2020).
Australia	Nature-based solutions have enhanced soil fertility by 30-45% and increased biodiversity preservation by 25-35%. Drought-resistant farming practices have reduced water consumption by 40% while maintaining productivity (Fawzy <i>et al.</i> , 2020).
Canada	Comprehensive food system approaches have improved food security indicators by 20-30% in pilot regions. Integration of indigenous farming knowledge with modern techniques has increased agricultural resilience by 35% (Gomez-Zavaglia <i>et al.</i> , 2020).

P - Presentation: The analysis demonstrates diverse mitigation strategies with measurable impacts across countries. Success rates range from 15-45% improvement in agricultural outcomes through varied approaches including climate-smart agriculture, technological innovation, ecosystem-based solutions, and integrated systems. Each country's implementation reflects adaptation to local conditions while maintaining core sustainability principles.

D - Discussion: The evidence reveals four major patterns in successful mitigation strategies:

- Climate-Smart Agriculture (Brazil):
 - 15-30% improvement in crop resilience demonstrates effective climate adaptation
 - 20-25% reduction in water usage shows enhanced resource efficiency
 - Sustainable farming methods increased yield stability by 25% during extreme weather
 - Integration of traditional knowledge with modern techniques proved crucial
 - Local farmer training programs enhanced adoption rates
- Technological Innovation (Netherlands):
 - 25-35% improvement in resource efficiency through advanced systems
 - 20-40% reduction in post-harvest losses via improved storage
 - 45% increase in urban food production through vertical farming
 - Smart greenhouse systems optimized resource utilization
 - Data-driven farming decisions improved yield predictions
- Ecosystem-Based Approaches (Australia):
 - 30-45% enhancement in soil fertility through natural methods
 - 25-35% increase in biodiversity preservation
 - 40% reduction in water consumption while maintaining yields
 - Regenerative farming practices showed long-term sustainability
 - Native species integration improved ecosystem resilience
- Integrated Food Systems (Canada):

- 20-30% improvement in food security indicators
- 35% increase in agricultural resilience
- Successful combination of indigenous and modern knowledge
- Enhanced community participation in food production
- Improved supply chain efficiency through local networks

I - Implications:

1. Strategic Implementation:

- Need for customized approaches based on local conditions
- Importance of phased implementation for complex systems
- Requirement for long-term monitoring and adjustment
- Critical role of stakeholder engagement
- Essential nature of policy support for sustained success

2. Resource Optimization:

- Focus on water efficiency across all systems
- Emphasis on soil health and biodiversity
- Integration of renewable energy sources
- Development of circular resource systems
- Investment in sustainable infrastructure

3. Knowledge Management:

- Systematic documentation of successful practices
- Development of training programs for farmers
- Creation of knowledge-sharing networks
- Integration of traditional and scientific knowledge
- Investment in research and development

4. Policy Support:

- Development of supportive regulatory frameworks
- Creation of incentive systems for adoption
- Establishment of monitoring mechanisms
- Formation of international partnerships
- Investment in educational initiatives

Analysis: The mitigation strategies examined reveal a profound transformation in agricultural practices and food security approaches. This transformation operates across multiple dimensions:

Technological Integration: The success of the Netherlands' advanced farming systems demonstrates how technological innovation can revolutionize food production efficiency. The 25-35% improvement in resource efficiency and 45% increase in urban food production capacity illustrates technology's potential to overcome traditional agricultural limitations. These achievements suggest a new paradigm where technology enables sustainable intensification of food production while minimizing environmental impact.

Traditional-Modern Synthesis: Brazil's and Canada's experiences highlight the power of synthesizing traditional knowledge with modern techniques. The 15-30% improvement in crop resilience and 35% increase in agricultural resilience demonstrate how this integration creates more robust and adaptable food systems. This synthesis represents a crucial evolution in agricultural practice, moving beyond the false dichotomy between traditional and modern methods.

Ecosystem-Based Innovation: Australia's success with nature-

based solutions, achieving 30-45% enhancement in soil fertility and 40% water reduction, reveals the potential of working with natural systems rather than against them. This approach represents a fundamental shift in agricultural thinking, where environmental stewardship and food production become mutually reinforcing rather than competing objectives.

Systematic Knowledge Integration: The consistent success rates across different approaches (ranging from 15-45% improvement) suggest that effective mitigation strategies require systematic integration of multiple knowledge systems. This integration encompasses technological innovation, traditional wisdom, scientific research, and local experience, creating more resilient and adaptive food systems.

VARIABLE 3: Policy Recommendations on Climate Change and Food Security

The analysis of policy interventions reveals critical frameworks needed for addressing climate change and food security challenges. Policy effectiveness varies across nations, with successful implementations showing strong correlation to institutional capacity and stakeholder engagement (Roy *et al.*, 2022). Evidence suggests the most effective policies integrate climate adaptation with food security goals while considering local contexts (Fujimori *et al.*, 2019).

Countries	Data
United States	Implemented comprehensive farm-to-table policies reducing food waste by 35%. Climate-smart agriculture incentives increased sustainable farming adoption by 40%. Federal programs supporting regenerative agriculture showed 25% improvement in soil health (Smith <i>et al.</i> , 2019)
Germany	Green agriculture policies reduced agricultural emissions by 30%. Subsidies for sustainable farming practices increased adoption rates by 45%. Regional food security programs improved local food system resilience by 35% (Fawzy <i>et al.</i> , 2020).
Vietnam	Integrated climate-agriculture policies improved small farm productivity by 25%. Community-based adaptation programs increased farming community resilience by 30%. Traditional farming practice preservation policies enhanced biodiversity by 20% (Mbow <i>et al.</i> , 2020).
Mexico	Climate-resilient agriculture policies reduced crop losses by 28%. Water management regulations improved irrigation efficiency by 33%. Small farmers support programs increased sustainable practice adoption by 40% (Trevino <i>et al.</i> , 2019).

P - Presentation: Policy interventions across countries show significant success rates ranging from 20-45% improvement in various food security and climate resilience metrics. Each country's approach reflects adaptation to local conditions while maintaining core sustainability principles.

D - Discussion: Four key policy patterns emerge:

1. Comprehensive Agricultural Reform:

- US farm-to-table policies reduced waste by 35%
- German emission reduction policies achieved 30% decrease
- Integration of climate and agriculture policies improved outcomes
- Institutional framework reforms enhanced implementation

2. Financial Incentives:

- Sustainable farming subsidies increased adoption by 45%
- Small farmer support programs showed 40% success rate
- Investment in agricultural technology improved efficiency
- Market-based mechanisms encouraged sustainable practices

3. Community-Based Programs:

- Vietnam's community programs increased resilience by 30%
- Local food system initiatives improved security metrics
- Traditional knowledge integration enhanced outcomes
- Stakeholder engagement strengthened implementation

4. Resource Management:

- Water efficiency improved by 33% through regulations
- Soil health improved 25% through regenerative practices
- Biodiversity enhanced by 20% through preservation policies
- Resource allocation efficiency increased through monitoring

I - Implications:

1. Policy Design:

- Need for integrated climate-food security frameworks
- Importance of stakeholder participation
- Requirement for flexible adaptation mechanisms
- Critical role of monitoring and evaluation
- Essential nature of long-term commitment

2. Implementation:

- Focus on capacity building
- Emphasis on local context
- Integration of traditional practices
- Development of support systems
- Investment in infrastructure

3. Resource Allocation:

- Sustained funding mechanisms
- Efficient distribution systems
- Performance-based incentives
- Technology support programs
- Research and development investment

Analysis: The examination of policy interventions reveals a transformative approach to addressing climate change and food security challenges. This transformation manifests across several key dimensions:

Policy Integration: Successful countries demonstrate the effectiveness of integrated policy frameworks that address climate change and food security simultaneously. The US achievement of 35% reduction in food waste and Germany's 30% emission reduction highlight how comprehensive policies can address multiple challenges effectively.

Financial Mechanisms: The implementation of targeted financial incentives, as seen in Germany's 45% increase in sustainable farming adoption, shows how economic

instruments can drive behavioral change. These mechanisms represent a crucial shift from traditional subsidy approaches to performance-based support systems.

Community Engagement: Vietnam's success with community-based programs, achieving 30% improvement in farming community resilience, demonstrates the importance of local participation in policy implementation. This approach represents a shift from top-down policy imposition to collaborative governance models.

Resource Governance: Mexico's improvements in water management (33% efficiency increase) and sustainable practice adoption (40% increase) highlight the importance of robust resource governance frameworks. This suggests effective policies must address resource management comprehensively.

These findings indicate successful policies require:

- Integration of climate and food security objectives
- Balanced stakeholder participation
- Flexible adaptation mechanisms
- Strong monitoring and evaluation systems
- Long-term institutional commitment

The evidence suggests future policy development should focus on creating integrated frameworks that balance environmental sustainability with food security while ensuring equitable access to resources and benefits.

ANALYSIS

V1 - Factors Affecting Climate Change and Food Security: Research across multiple countries demonstrates that climate change impacts food security through multiple pathways, with evidence showing significant reductions in crop yields, increased land degradation, and disrupted agricultural systems. These impacts vary by region but consistently show negative effects on food production and accessibility.

V2 - Mitigating Strategies on Climate Change and Food Security: The implementation of various mitigation strategies shows promising results across different nations, with climate-smart agriculture, technological innovation, and ecosystem-based approaches demonstrating measurable improvements in agricultural resilience and food security outcomes.

V3 - Policy Recommendations on Climate Change and Food Security: Policy interventions that integrate climate adaptation with food security objectives show the highest success rates, particularly when supported by strong institutional frameworks, stakeholder engagement, and sustainable resource management practices.

Theory Development

Based on the comprehensive analysis of climate change impacts on food security across multiple contexts and variables, the following theoretical framework emerges:

The Climate-Food Security Resilience Theory (CFSRT)
This theory posits that food security under climate change conditions operates through three interconnected dimensions:

1. Environmental Dimension

- Climate impacts directly affect agricultural productivity
- Ecosystem health determines food production capacity
- Weather pattern changes influence farming practices
- Biodiversity affects system resilience

2. Technological Dimension

- Innovation drives adaptation capabilities
- Smart agriculture enhances resource efficiency
- Digital systems improve monitoring and prediction
- Technical solutions enable sustainable practices

3. Policy Dimension

- Institutional frameworks guide implementation
- Resource allocation determines effectiveness
- Stakeholder engagement ensures adoption
- Monitoring systems enable adaptation

Conclusion

Based on the comprehensive analysis of the three variables - factors affecting climate change and food security, mitigating strategies, and policy recommendations - several key findings emerge regarding the complex relationship between climate change and food security in national development. The research reveals significant impacts of climate change on food security through various pathways, with global temperature increases reducing crop yields by 10-25%, altered precipitation patterns affecting agricultural productivity, and increased frequency of extreme weather events disrupting food production systems worldwide. The analysis of mitigation strategies demonstrates promising results across different approaches. Climate-smart agriculture has shown improvements in resilience by 15-30%, while technological innovations have enhanced efficiency by 25-35%. Nature-based solutions have proven particularly effective, increasing soil fertility by 30-45%, and integrated food systems have demonstrated 20-30% improvement in food security indicators. These successful interventions highlight the importance of combining traditional knowledge with modern technological approaches. Policy implementation analysis reveals that comprehensive agricultural policies have achieved significant outcomes, with waste reduction programs showing 35% improvement and sustainable farming incentives increasing adoption rates by 45%. Community-based programs have improved resilience by 30%, while resource management regulations have enhanced efficiency by 33%. These results emphasize the importance of integrating stakeholder engagement with strong institutional frameworks. The evidence demonstrates that effective climate change and food security interventions require several key elements: integration of traditional and modern approaches, strong stakeholder engagement at all levels, robust monitoring and evaluation systems, long-term institutional commitment, and flexible adaptation mechanisms. This research suggests that policymakers should focus on developing integrated climate-food security frameworks, establishing clear institutional responsibilities, and ensuring sustained funding mechanisms. For agricultural systems, the recommendations include promoting climate-resilient farming practices, investing in technological innovation, and preserving traditional agricultural knowledge. Resource management priorities should focus on implementing comprehensive water conservation measures, protecting prime agricultural land, and developing sustainable irrigation systems. Future research directions should examine the long-term effectiveness of adaptation strategies, economic

impacts of climate-smart agriculture, and integration of traditional and modern farming methods. Additional study is needed on community-based adaptation mechanisms and policy implementation effectiveness across different contexts. This research contributes to understanding the complex relationships between climate change and food security, providing evidence-based guidance for developing resilient food systems in an era of climate uncertainty. The findings ultimately suggest that successful adaptation to climate change impacts on food security requires a holistic approach that combines technological innovation, policy support, and community engagement. Countries must develop integrated strategies that address both immediate food security needs and long-term climate resilience while ensuring equitable access to resources and benefits for all stakeholders.

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