Review Article
ISSN: 3041-5403
Journal Homepage: https://bitsjournal.researchfloor.org/

Climate Change, Agriculture, and Trade – A Review of Economic Adaptation Strategies in Developing Regions

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Citation: SK Parvez (2025). Climate Change, Agriculture, and Trade – A Review of Economic Adaptation Strategies in Developing Regions. *Journal of Business, IT, and Social Science*. **DOI: https://doi.org/10.51470/BITS.2025.04.02.29**

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14 August 2025: Received | 10 September 2025: Revised | 13 October 2025: Accepted | 19 November 2025: Available Online

ABSTRACT

Climate change has emerged as a major constraint to sustainable development in many low- and middle-income countries, where agriculture plays a central role in livelihoods, food security, and trade performance. Increasing temperatures, altered rainfall patterns, prolonged droughts, flooding, and extreme climate events continue to reduce crop yields, degrade natural resources, and disrupt supply chains. These impacts further weaken the competitiveness of agricultural exports and exacerbate economic vulnerabilities. This review synthesizes synthesises current evidence on how climate change affects agriculture and trade in developing regions and evaluates the effectiveness of key economic adaptation strategies. Particular emphasis is placed on climate-smart agricultural practices, resilient technological innovations, improved market access, integrated water and soil management, and financial instruments such as crop insurance, credit access, and early-warning systems. The review also highlights the importance of strong institutional frameworks, supportive trade policies, and regional cooperation in enhancing adaptation capacity, t. The findings suggest that a combination of technological adoption, economic diversification, and policy-driven interventions is essential for building climate-resilient agricultural systems and strengthening trade competitiveness across developing regions.

Keywords: *Climate change; Agricultural productivity; Trade dynamics; Economic adaptation; Climate-smart agriculture.*

1. Introduction

Climate change stands as one of the most critical global challenges of the twenty-first century, with profound implications for economic stability, environmental sustainability, and human well-being. Its impacts are neither uniformly distributed nor evenly experienced across the world; instead, they disproportionately affect developing regions that rely heavily on climate-sensitive economic sectors. Sub-Saharan Africa, South Asia, Southeast Asia, and parts of Latin America remain particularly vulnerable due to their geographic exposure, limited adaptive capacity, dependence on rain-fed agriculture, and structural socioeconomic constraints [1]. These regions face a combination of biophysical stressors—rising temperatures, erratic rainfall, prolonged droughts, flooding, extreme weather events, and increased pest and disease outbreaks—that directly undermine agricultural productivity and, by extension, national economic stability.

Agriculture holds a pivotal role within the economic systems of developing regions. It provides employment foremploys a substantial proportion of the population, particularly rural communities, and serves as a major source of household income. In many low- and middle-income countries, agriculture contributes significantly to gross domestic product (GDP), supplies raw materials for agro-processing industries, and represents a primary source of export earnings. Despite this importance, the sector is highly sensitive to climate variability. Even modest shifts in temperature or precipitation can lead to substantial reductions in crop yields, livestock productivity, soil fertility, and water availability [2]. These impacts can, in turn, worsen food insecurity, diminish rural livelihoods, and increase poverty rates.

The consequences of climate change extend beyond domestic food production and significantly influence agricultural trade dynamics. International trade is often considered a stabilizing stabilising mechanism that enables countries to compensate for local production deficits by importing food or exporting surplus commodities. However, climate-induced disruptions in production, quality, and supply chain reliability can reduce a country's competitiveness in global markets. For many developing nations that depend heavily on agricultural exports—such as coffee, cocoa, tea, cotton, palm oil, or cereal crops—climate variability can alter commodity prices, shift comparative advantage, and undermine foreign exchange earnings. Moreover, changes in global climate policies, sustainability standards, carbon taxes, and trade regulations may introduce additional complexities for exporting countries that lack the financial or technological resources required for compliance [3].

Understanding the economic adaptation strategies that can mitigate these challenges has therefore become a critical area of policy interest. Economic adaptation strategies refer to the set of actions, investments, and institutional reforms designed to minimize minimise climate risks while enhancing the resilience and productivity of agricultural systems. These strategies encompass a wide spectrum of interventions, including climate-smart agricultural technologies, drought-tolerant crop varieties, efficient irrigation systems, soil and water conservation practices, and digital climate advisory tools [4], e. Economic instruments such as crop insurance schemes, credit access, market incentives, and public–private partnerships can help farmers manage risk and adopt innovative technologies.

Adaptation also requires strong institutional frameworks and supportive trade policies. Government-led initiatives, such as early-warning systems, land-use planning, agricultural extension services, and infrastructure development, are essential for building long-term resilience. Regional cooperation—particularly in Africa and Asia—further enhances countries' abilities to share resources, harmonize harmonise trade standards, and coordinate responses to climate-induced food supply disruptions. At the international level, climate finance mechanisms and global adaptation funds offer opportunities for developing countries to invest in resilience-building measures; however, access remains limited due to bureaucratic barriers and insufficient technical capacity. Another dimension of climate change and trade involves the increasing importance of diversification [5]. Overreliance on a narrow range of export commodities leaves countries highly exposed to climate shocks and market volatility. Diversifying agricultural production, value-added agro-processing, and broader economic sectors can significantly reduce vulnerability while enhancing competitive advantage. Digitalization Digitalisation, green technology adoption, and innovations in supply chain management also play growing roles in shaping trade resilience in a climate-impacted world.

While many developing countries have initiated adaptation measures, challenges remain. Limited financial resources, fragmented institutions, inadequate climate data, weak policy implementation, and low awareness among farmers continue to hinder effective adaptation. Additionally, gender inequalities and sociocultural factors often restrict women—who form a substantial portion of the agricultural workforce—from accessing credit, land, and training opportunities, thereby constraining overall adaptive capacity. Given these complexities, a comprehensive understanding of the interactions between climate change, agriculture, and trade is essential for informed policy design [6]. This review synthesizes synthesises existing literature on climate impacts and evaluates the most effective economic adaptation strategies for developing regions. Through this analysis, the review highlights the pathways through which developing countries can enhance agricultural resilience, strengthen trade competitiveness, and promote sustainable economic development in an era of increasing climatic uncertainty.

2. Climate Change and Agricultural Vulnerability in Developing Regions

Climate change continues to intensify agricultural vulnerability across developing regions, where farming systems are predominantly climate-sensitive and heavily reliant on natural weather cycles. Among the most significant stressors is the steady rise in global temperatures, which imposes direct physiological constraints on both crops and livestock. Higher temperatures accelerate evapotranspiration, depleting soil moisture and reducing water availability during critical growth periods [7]. This often results in suppressed yields for staple crops such as maize, rice, wheat, millet, and sorghum, which form the backbone of food security in many low-income countries. Livestock production also suffers as heat stress diminishes feed intake, slows weight gain, lowers reproductive performance, and increases susceptibility to diseases. In regions where animal husbandry represents both a major livelihood and a safety net against income shocks, these temperature-driven impacts can significantly undermine household resilience.

Water scarcity further magnifies agricultural vulnerability, largely driven by increasingly erratic rainfall patterns. Climate change has altered the distribution and timing of precipitation, causing both prolonged dry spells and intense rainfall events within the same growing season. In developing regions where rain-fed agriculture dominates, the unpredictability of rainfall undermines farmers' ability to plan planting cycles, manage soil moisture, and maintain crop health. Drought conditions reduce soil water retention and make irrigation a necessity for sustaining yields. However, access to irrigation infrastructure remains limited, particularly in rural and marginal communities [8]. Even when irrigation options exist, the costs associated with pumping, maintaining water systems, or purchasing water rights can be prohibitively high for smallholder farmers. Conversely, episodes of excessive rainfall lead to waterlogging, delayed planting, and a heightened risk of crop losses. These fluctuating rainfall patterns have introduced a level of uncertainty that complicates decision-making and exacerbates production instability.

Another emerging challenge lies in the increased incidence of pests, weeds, and crop diseases. Rising temperatures and shifting climatic zones have enabled many pest species to expand beyond their historical geographic ranges. Warmer winters no longer adequately suppress pest populations, leading to greater survival rates and more frequent outbreaks. Pathogens responsible for fungal, bacterial, and viral diseases also thrive under the warmer and more humid conditions brought about by climate change. While developed countries often mitigate these threats through advanced pest-control technologies and resistant crop varieties, many developing regions lack access to such resources. Limited extension services, weak regulatory systems, and the high cost of modern agrichemicals hinder farmers' capacity to manage emerging biological threats effectively. As a result, pest and disease pressures increasingly contribute to yield variability and economic losses. Extreme weather events add another layer of vulnerability, with floods, storms, cyclones, and landslides becoming more frequent and severe [9]. These events destroy crops, kill livestock, damage infrastructure, and disrupt market access. Farmlands exposed to repeated flooding or storm surges often undergo long-term decline due to siltation, salinizationsalinisation, or erosion. Meanwhile, persistent land degradation—from desertification to nutrient depletion—reduces the productive potential of agricultural ecosystems. In many dryland areas, overgrazing, deforestation, and unsustainable cultivation practices have already weakened soil structure; climate change accelerates this degradation, diminishing the land's ability to recover. Taken together, these interconnected climate stressors severely challenge the stability, productivity, and sustainability of agriculture in developing regions, undermining food security and leaving economies increasingly exposed to climate-induced shocks.

3. Impacts of Climate Change on Agricultural Trade

Climate change has profound implications not only for domestic agricultural production but also for international trade dynamics in developing regions. Many of these countries rely heavily on a narrow set of climate-sensitive export commodities—such as coffee, cocoa, tea, cotton, fruits, and horticultural products—that form the backbone of rural livelihoods and foreign exchange earnings. As temperature patterns shift and agro-ecological zones change, the suitability of land for these high-value crops declines.

For example, coffee-producing highlands are becoming too warm for optimal cultivation, forcing farmers to move to higher elevations or abandon production altogether. Similar challenges affect cocoa and tea, whose yields and quality deteriorate under heat and irregular rainfall [9]. The decline in exportable surpluses not only reduces national income but also leads to job losses and diminished economic opportunities for rural communities dependent on these sectors.

Climate change also contributes to increased volatility in global commodity markets. Extreme weather events—droughts, floods, or heat waves—create sudden supply shortages, which drive fluctuations in international prices. For net-importing developing countries, these price spikes elevate the cost of essential food imports, placing pressure on foreign exchange reserves and widening trade deficits. Even countries that traditionally export staple or cash crops may become less competitive if climate variability reduces production consistency or affects product quality. Unpredictable harvests discourage long-term trade contracts, decrease investors' confidence, and may shift global demand toward more stable markets in temperate regions.

As domestic agricultural output becomes increasingly unstable, many developing countries resort to greater import dependency to meet food needs. This growing reliance on external markets exposes them to price swings, currency depreciation risks, and logistical bottlenecks. The resulting vulnerability has implications for national food security, particularly for low-income households that spend a large share of their income on food. When imports become more expensive, governments often face pressure to subsidize subsidise food prices, contributing to fiscal strain. Moreover, the weakened performance of the agricultural sector diminishes its contribution to national GDP, undermining economic growth and rural development.

Climate change also disrupts agricultural supply chains and trade infrastructure, further compounding trade challenges [10]. Extreme weather events increasingly damage critical transportation networks, such as rural roads, ports, and rail systems, which are essential for moving goods from farms to markets and export terminals. Floods and storms can destroy storage facilities, processing centerscentres, and cold-chain systems, leading to significant post-harvest losses. When value chains are interrupted, the cost of doing business rises for both farmers and traders, reducing competitiveness in regional and global markets. These disruptions ultimately create an environment where trade flows become unpredictable and costly, highlighting the urgent need for resilient infrastructure and adaptive logistical systems.

4. Economic Adaptation Strategies in Developing Regions

Given the widespread and interconnected impacts of climate change on agriculture and trade, developing regions are increasingly adopting comprehensive economic adaptation strategies to strengthen resilience. One of the most prominent approaches is the promotion of Climate-Smart Agriculture (CSA), which aims to simultaneously increase productivity, build resilience, and reduce greenhouse gas emissions. CSA interventions include the adoption of drought-tolerant and heat-resistant crop varieties that can withstand climatic stress; conservation agriculture practices such as minimum tillage and mulching; intercropping and crop diversification to reduce risk; efficient irrigation systems that conserve water; and integrated soil fertility management.

These strategies help stabilize stabilise yields even under unpredictable weather conditions and protect rural incomes.

Technological innovations and digital agriculture also play a vital role in enhancing climate resilience. Tools such as remote sensing, geographic information systems (GIS), and climate information services allow farmers to access real-time data on weather patterns and crop conditions. Mobile-based early-warning systems provide timely alerts on extreme weather events, pest outbreaks, or market changes, enabling farmers to make informed decisions. Precision agriculture technologies—such as automated irrigation, soil sensors, and drones—improve resource-use efficiency and reduce production losses. Advances in biotechnology, including improved seed varieties and genetically modified crops, offer additional pathways for enhancing disease resistance and productivity in challenging environments [11]. Digital platforms further improve farmers' access to credit, extension services, and regional markets, strengthening economic inclusion.

Strengthening market access and trade infrastructure is another crucial adaptation strategy. Investments in transportation networks, rural storage facilities, agro-processing centerscentres, and cold-chain systems reduce post-harvest losses and enhance the efficiency of supply chains. These improvements enable farmers to participate more effectively in domestic, regional, and international markets. Policy measures such as trade liberalization liberalisation agreements and regional integration frameworks also help facilitate cross-border movement of goods, reducing trade barriers and opening new opportunities for agricultural exporters [12]. Financial and insurance mechanisms are essential for managing climate-related risks. Weather-index insurance programs offer compensation based on measurable weather indicators rather than physical crop losses, making them cost-effective and accessible for smallholder farmers. Microfinance institutions, agricultural credit schemes, and savings cooperatives provide the capital needed to invest in modern technologies and climate-resilient practices. Government-backed compensation initiatives offer additional protection against catastrophic events, encouraging farmers to adopt improved production systems without fearing irreversible losses.

Finally, strong policy and institutional support is are necessary to ensure long-term adaptation. Governments play a central role in formulating climate-responsive agricultural policies, funding agricultural research, strengthening early-warning systems, and fostering private-sector investment. National adaptation plans and climate-resilient development frameworks provide strategic direction for integrating climate considerations into agriculture, trade, and rural development. Building institutional capacity—through training, extension services, and regulatory reforms—helps create an enabling environment for sustainable and resilient agricultural growth.

5. Regional Case Insights

Climate change impacts agricultural economies differently across regions, yet developing areas share common vulnerabilities that shape their economic and trade outcomes. In Sub-Saharan Africa, agriculture remains the backbone of national economies, employing the majority of the population and contributing significantly to export earnings. However, the region's dependence on rain-fed farming makes it extremely susceptible to changing climatic conditions.

Staple crops such as maize, sorghum, millet, and cassava already experience declining yields due to prolonged droughts, erratic rainfall patterns, and increasing temperatures. The challenge is further intensified by land degradation, limited irrigation coverage, and widespread rural poverty. In response, countries across the region have begun promoting drought-tolerant crop varieties, expanding small-scale and community-based irrigation schemes, and strengthening early-warning systems. Regional economic communities such as ECOWAS and the East African Community are also fostering trade agreements to stabilize stabilise food availability, facilitate cross-border movement of commodities, and reduce the severity of local production shocks [13].

In South Asia, agricultural vulnerability is shaped primarily by extreme climatic events such as floods, heat waves, cyclones, and unpredictable monsoon patterns. Rice and wheat—two of the region's most essential staples—face significant declines due to heat stress and water scarcity. Large river basins, including the Ganges and Indus, confront both flooding and seasonal water shortages caused by glacial melt and altered precipitation. As these stresses intensify, countries in the region are increasingly investing in climate-resilient seed systems, including heat-tolerant rice varieties and short-duration wheat that escapes terminal heat. Micro-irrigation technologies such as drip and sprinkler systems are also gaining traction, particularly in India and Pakistan, where they help conserve water and stabilize stabilise yields. Additionally, governments are expanding crop insurance programs to protect farmers from climate-related losses, while digital advisory platforms are improving access to weather information, market prices, and best agronomic practices [14].

Latin America faces a different set of challenges, as many of its economies depend heavily on climate-sensitive export crops such as coffee, cocoa, soybeans, bananas, and various fruits. Rising temperatures and shifting precipitation patterns are altering the agro-ecological suitability for crops like coffee, which is moving to higher altitudes where land availability is limited. Cocoa production in West and Central Latin America is also threatened by diseases that spread more easily under warm and humid conditions. To adapt, several countries are adopting precision agriculture techniques, including satellite-based monitoring, soil sensors, and automated irrigation systems that help optimize optimise resource use and maintain product quality.

Reforestation and agroforestry systems—especially those integrating shade-grown coffee and cocoa—are being used to restore soil fertility, reduce temperature stress, and enhance biodiversity. These approaches support both environmental sustainability and export competitiveness, making them central to regional adaptation strategies.

6. Challenges to Adaptation

Despite notable progress across developing regions, numerous challenges continue to limit the scale and effectiveness of adaptation efforts. One of the most persistent barriers is the lack of adequate financing. Many governments and smallholder farmers operate with limited financial resources, making it difficult to invest in improved irrigation systems, modern technologies, or climate-resilient infrastructure. International climate finance mechanisms exist, but access remains uneven and often hindered by complex application processes.

Another major challenge is limited access to technology and agricultural extension services. Smallholder farmers—who make up a large share of the agricultural workforce—often lack updated knowledge, technical training, or digital tools that could enhance climate resilience. Weak market linkages further reduce farmers' ability to sell surplus produce at fair prices, limiting incentives to adopt climate-smart practices. Poor infrastructure—such as inadequate rural roads, storage facilities, and processing centerscentres—also exacerbates vulnerability by increasing post-harvest losses and restricting access to both domestic and international markets [3]. Awareness of climate risks remains low in many rural communities, where traditional farming methods dominate, and long-term climate planning is limited. Farmers may underestimate future risks or be reluctant to change practices without clear evidence of short-term benefits. Additionally, policy implementation gaps pose major constraints. While many countries have formulated climate adaptation plans and agricultural policies, weak institutional capacity, insufficient coordination, and inadequate monitoring mechanisms undermine their effectiveness. These interconnected challenges slow the widespread adoption of climate-smart agriculture, limit trade resilience, and constrain economic development. Addressing them requires sustained financial investment, stronger institutions, enhanced market systems, and inclusive policies that empower smallholder farmers—the backbone of food production in developing regions.

Table 1. Key Climate Change Impacts on Agriculture in Developing Regions

Climate Stressor	Description of Impact	Effects on Agriculture	Commonly Affected Regions
Rising Temperatures & Heat Stress	Increased evapotranspiration and disrupted plant physiology	Reduced crop yields, livestock heat stress, increased water demand	Sub-Saharan Africa, South Asia
Erratic Rainfall & Water Scarcity	Unpredictable rainfall, droughts, occasional intense storms	Decline in rain-fed farming productivity, higher irrigation costs	Sub-Saharan Africa, South Asia, Latin America
Pests & Disease Outbreaks	Expansion of pest habitats due to warmer climates	Crop losses, greater need for pest management	All developing regions
Extreme Weather Events	Floods, storms, landslides becoming more frequent	Crop destruction, livestock loss, infrastructure damage	South Asia, Latin America
Land Degradation	Soil erosion, desertification, nutrient depletion	Lower soil fertility and reduced long-term productivity	Sub-Saharan Africa

Table 2. Summary of Adaptation Strategies Adopted in Developing Regions

Adaptation Strategy	Key Components	Expected Outcomes	Regions with Strong Implementation
Climate-Smart Agriculture (CSA)	Drought-tolerant crops, intercropping, soil fertility management	Higher productivity and resilience	Sub-Saharan Africa, South Asia
Technological Innovations & Digital Tools	Remote sensing, early-warning systems, precision farming	Improved decision-making, reduced input waste	South Asia, Latin America
Market & Trade Infrastructure Improvement	Transport networks, storage facilities, processing centers	Reduced post-harvest loss, stronger trade flows	Sub-Saharan Africa, Latin America
Financial & Insurance Mechanisms	Weather-index insurance, microfinance, credit services	Risk reduction, investment in modern practices	South Asia, Sub-Saharan Africa
Policy & Institutional Support	Government R&D funding, adaptation plans, climate policies	Long-term resilience and agricultural sustainability	All developing regions

7. Conclusion

Climate change continues to reshape agricultural landscapes and trade patterns in developing regions, posing significant risks to food security, rural livelihoods, and national economies. However, effective economic adaptation strategies—such as climate-smart agriculture, technological innovation, improved market access, financial instruments, and strong institutional support—provide practical pathways for building resilience. Strengthening national and regional capacities, increasing investment, and encouraging private–public partnerships will be essential to sustain agricultural growth and stabilize stabilise trade flows in the face of mounting climate challenges.

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