

Climate Change and Its Impact on Marginal Farmers in Assam: A Review of Emerging Challenges, Adaptation Strategies and Policy Implications

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Abstract:

Climate change has emerged as one of the most significant challenges to agricultural sustainability, particularly in developing regions where farming systems remain highly dependent on climatic conditions. In India, the state of Assam is exceptionally vulnerable because of its geographical location within the Brahmaputra and Barak river basins, frequent flooding, riverbank erosion, changing rainfall patterns, and increasing temperature variability. These climatic changes have disproportionately affected marginal farmers, who constitute more than 85% of the state's farming households and generally operate on fragmented landholdings with limited access to financial resources, irrigation facilities, institutional credit, and modern agricultural technologies. This review synthesizes contemporary literature to examine the multidimensional impacts of climate change on marginal farmers in Assam. The paper critically analyses the influence of climatic variability on agricultural productivity, livelihood security, household income, food security, migration, and rural development. It further evaluates adaptation strategies adopted by farming communities and assesses the role of public policy and institutional interventions in strengthening climate resilience. The review demonstrates that climate change has intensified production risks, increased livelihood vulnerability, and widened socio-economic inequalities among resource-poor farming households. Although farmers have increasingly adopted livelihood diversification, crop diversification, integrated farming systems, and climate-resilient agricultural practices, their adaptive capacity remains constrained by inadequate institutional support, financial limitations, and unequal access to climate information. The paper argues that strengthening climate-resilient agriculture requires an integrated policy framework combining scientific innovation, indigenous knowledge, improved rural infrastructure, effective agricultural extension services, risk-transfer mechanisms, and participatory governance. Such an approach is essential for promoting sustainable agricultural development and enhancing the resilience of marginal farming households in Assam.

Keywords: Climate Change, Marginal Farmers, Agricultural Vulnerability, Climate Resilience, Sustainable Agriculture, Flood Risk, Livelihood Security.

1. Introduction:

Climate change has emerged as one of the most pressing environmental and developmental challenges of the twenty-first century, with profound implications for agriculture, food security, and rural livelihoods. The Intergovernmental Panel on Climate Change (IPCC, 2023) identifies agriculture as one of the sectors most vulnerable to climate variability because crop production, water resources, soil fertility, and ecosystem services are intrinsically linked to climatic conditions. Rising temperatures, changing precipitation patterns, increasing frequency of extreme weather events, and the growing incidence of floods, droughts, and pest outbreaks have significantly altered agricultural systems worldwide. These changes are particularly severe in developing countries where agriculture remains the principal source of livelihood and where farmers possess limited adaptive capacity to cope with climatic uncertainties. India, being an agrarian economy, is highly susceptible to the adverse consequences of climate change. Although agriculture contributes approximately one-sixth of the national Gross Value Added (GVA), it continues to provide direct and indirect employment to nearly half of the country's workforce. The dependence of Indian agriculture on the southwest monsoon makes the sector particularly vulnerable to climatic variability. Scientific studies have consistently demonstrated that increasing temperatures, irregular rainfall, changing monsoon behavior, and extreme weather events have adversely affected agricultural productivity, farm income, and rural livelihoods across different agro-climatic regions of the country (IPCC, 2023; FAO, 2022).

Within the Indian context, Assam represents one of the most climate-sensitive states owing to its distinctive geographical location and ecological characteristics. The state lies within the Brahmaputra and Barak river basins and receives one of the highest annual rainfalls in the country. While these favorable environmental conditions have historically supported agriculture and sustained rural livelihoods, they have simultaneously exposed the state to recurrent floods, riverbank erosion, landslides, and increasing climatic variability. Over the past few decades, changes in rainfall distribution, rising temperatures, delayed onset of monsoon, prolonged dry spells during crop-growing seasons, and increasing flood intensity have considerably altered the agricultural landscape of Assam. Agriculture continues to be the backbone of Assam's rural economy. According to the Government of Assam, nearly two-thirds of the state's population depends directly or indirectly on agriculture and allied activities for their livelihood. Rice occupies nearly seventy percent of the gross cropped area, followed by mustard, pulses, jute, vegetables, sugarcane, tea, and horticultural crops. However, agricultural production remains predominantly rain-fed and highly sensitive to climatic fluctuations. Consequently, even relatively small changes in temperature and rainfall frequently result in substantial reductions in crop yield and farm income.

The adverse effects of climate change are disproportionately borne by marginal farmers. In Assam, the majority of agricultural households belong to the marginal farmer category, cultivating less than one hectare of operational landholding. Such households generally possess limited financial resources, inadequate irrigation facilities, poor access to institutional credit, low levels of mechanization, and limited exposure to modern agricultural technologies. Their dependence on seasonal agricultural production makes them particularly vulnerable to climatic shocks. Crop failure resulting from floods, drought-like conditions, or pest infestations often leads to indebtedness, food insecurity, nutritional deficiencies, seasonal migration, and deterioration in household welfare. Among the various climate-

related hazards affecting Assam, floods remain the most devastating. The annual inundation of the Brahmaputra and its tributaries destroys standing crops, damages agricultural infrastructure, causes soil erosion, and disrupts rural transportation networks. Riverbank erosion further aggravates the situation by permanently removing fertile agricultural land from cultivation. Thousands of farming households have experienced displacement owing to erosion, resulting in declining agricultural production and increased socio-economic vulnerability. These environmental changes have transformed climate change from an ecological issue into a significant developmental concern affecting poverty alleviation, livelihood security, and sustainable rural development. Recent empirical studies conducted by Assam Agricultural University and other research institutions indicate that farmers across different districts have perceived noticeable changes in climatic conditions over the past two decades. These include increasing summer temperatures, delayed rainfall, shorter winter seasons, increasing frequency of floods, and growing incidence of crop pests and diseases. Farmers have responded by modifying sowing dates, adopting short-duration crop varieties, diversifying agricultural enterprises, integrating livestock with crop production, and engaging in non-farm employment. Nevertheless, the effectiveness of these adaptation strategies remains constrained by inadequate institutional support, financial limitations, limited market access, and insufficient dissemination of climate information.

The Government of India and the Government of Assam have introduced several initiatives to strengthen climate resilience in agriculture. Programs promoting climate-smart agriculture, crop insurance, watershed development, micro-irrigation, soil health management, disaster risk reduction, and agricultural extension have contributed to enhancing farmers' adaptive capacity. However, existing literature suggests that the implementation of these programs remains uneven, particularly among marginal farmers residing in remote and flood-prone regions. Administrative barriers, limited awareness, inadequate institutional coordination, and financial constraints continue to restrict the accessibility and effectiveness of these interventions. Despite the growing body of literature on climate change and agriculture in India, relatively few review studies have comprehensively synthesized the multidimensional impacts of climate change on marginal farmers in Assam. Existing studies have largely focused on agricultural productivity, flood management, or climate vulnerability independently, with limited attention to the interrelationships among environmental change, livelihood security, socio-economic vulnerability, adaptation strategies, and institutional responses. A comprehensive review integrating these dimensions is therefore essential for informing evidence-based policy and promoting sustainable agricultural development. Against this backdrop, the present study reviews and synthesizes the available literature on climate change and its implications for marginal farmers in Assam. The paper critically examines the environmental, economic, and social consequences of climatic variability, analyses existing adaptation strategies adopted by farming communities, evaluates institutional responses, and proposes policy measures for strengthening climate resilience and promoting sustainable rural livelihoods.

2. Importance of the Study

The significance of this study lies in its attempt to provide a comprehensive understanding of the complex relationship between climate change and the livelihoods of marginal farmers in Assam. Marginal farmers constitute the backbone of the state's agricultural economy, yet they remain among the most vulnerable groups to climate-induced risks. Their dependence on small landholdings, rain-fed

agriculture, and limited financial resources makes them particularly susceptible to floods, riverbank erosion, erratic rainfall, drought-like conditions, and other climatic extremes. This review is important because it synthesizes findings from diverse studies and policy documents to present an integrated understanding of climate-induced agricultural vulnerability in Assam. The study contributes to the existing body of knowledge by highlighting how environmental changes interact with socio-economic factors such as poverty, food insecurity, indebtedness, migration, and institutional support. Such an integrated perspective is essential for developing effective adaptation policies and strengthening climate-resilient agricultural systems. The findings of this review will be useful for policymakers, agricultural planners, researchers, extension agencies, non-governmental organizations, and development practitioners working towards sustainable agricultural development and rural livelihood improvement in Assam.

3. Objectives of the Study

The study has been undertaken with the following objectives:

1. To examine the impact of climate change on the agricultural productivity of marginal farmers in Assam.
2. To analyze the socio-economic consequences of climate variability on the livelihoods of marginal farming households.
3. To evaluate the adaptation strategies adopted by marginal farmers in response to climate-related risks.
4. To assess the effectiveness of government policies and institutional interventions in enhancing climate resilience.
5. To suggest policy measures for promoting climate-resilient and sustainable agriculture among marginal farmers in Assam.

4. Research Methodology

The present study is based on a qualitative review of secondary data. Relevant information has been collected from peer-reviewed journal articles, books, government reports, publications of the Intergovernmental Panel on Climate Change (IPCC), the Food and Agriculture Organization (FAO), the Ministry of Agriculture and Farmers' Welfare, Government of India, Assam Agricultural University, the Indian Council of Agricultural Research (ICAR), the Government of Assam, and other credible academic sources. The literature was identified through academic databases such as Google Scholar, Scopus, Web of Science, JSTOR, and institutional repositories using keywords including Climate Change, Marginal Farmers, Assam Agriculture, Floods, Climate Resilience, and Sustainable Agriculture. The collected literature was analyzed using a thematic review approach to identify major themes, patterns, and policy implications related to climate change and marginal farmers in Assam.

4. Literature Review

4.1 Climate Change and Agricultural Vulnerability in Assam:

Assam is widely recognized as one of India's most climate-sensitive states because of its unique physiographic setting, fragile river line ecosystem, and dependence on agriculture for rural livelihoods. It is located within the Brahmaputra and Barak River basins. As result the state experiences one of the highest annual rainfalls in the country. It is 174 cm average. While abundant rainfall has historically

supported intensive rice cultivation and diversified agricultural production, recent climatic variability has substantially altered the environmental conditions under which agriculture is practiced. Increasing temperature, erratic monsoon behavior, recurrent floods, prolonged dry spells during crop-growing seasons, and accelerated riverbank erosion have transformed climate variability from a periodic environmental concern into a persistent developmental challenge.

The agricultural economy of Assam is predominantly characterized by small and marginal landholdings. Most farming households cultivate less than one hectare of land, limiting their capacity to absorb production shocks or invest in adaptive technologies. Unlike commercial farms, these households depend primarily on seasonal agricultural income for household consumption and livelihood security. Consequently, even modest climatic disturbances frequently translate into significant economic losses, thereby reinforcing rural poverty and livelihood insecurity. Recent vulnerability assessments conducted across the North Bank Plains of Assam demonstrate that a majority of farming households fall within the medium-to-high vulnerability category because of their limited adaptive capacity, dependence on climate-sensitive agriculture, and inadequate institutional support. The interaction between exposure to climatic hazards and socio-economic constraints considerably amplifies livelihood risks among marginal farmers. The vulnerability of Assam's agricultural sector cannot therefore be understood solely in terms of environmental exposure. Rather, it reflects the interaction between climatic stressors and structural inequalities, including fragmented landholdings, inadequate irrigation, poor market integration, limited access to institutional credit, and insufficient agricultural extension services. These conditions collectively reduce farmers' resilience and constrain their capacity to respond effectively to changing climatic conditions.

4.2 Floods, Riverbank Erosion and Agricultural Transformation:

Among the various manifestations of climate change, floods remain the most destructive environmental hazard affecting Assam. The annual overflow of the Brahmaputra and its tributaries inundates vast stretches of agricultural land, causing extensive damage to standing crops, livestock, rural infrastructure, irrigation systems, and transportation networks. Although flooding has historically formed part of Assam's ecological system, several studies indicate that both the frequency and intensity of flood events have increased, thereby prolonging recovery periods for farming households. Unlike seasonal floods, riverbank erosion represents a permanent form of environmental degradation. Every year, substantial areas of fertile alluvial land are lost due to the lateral migration of river channels. For marginal farmers, whose livelihoods depend on small operational holdings, erosion often results in complete displacement from agriculture. Loss of cultivable land not only reduces agricultural production but also undermines household assets accumulated over generations.

The literature increasingly characterizes riverbank erosion as a socio-economic crisis rather than merely a geomorphologic process. Displaced farming households frequently experience landlessness, unemployment, forced migration, educational discontinuity among children, and declining access to healthcare and public services. Consequently, climate-induced displacement has emerged as a critical dimension of rural vulnerability in Assam. Moreover, repeated flood events discourage long-term agricultural investment. Farmers become reluctant to invest in improved seed varieties, irrigation infrastructure, mechanization, or soil fertility management because future crop losses remain highly

uncertain. This behavioral response creates a cycle of low investment, declining productivity, and persistent poverty, thereby reducing the long-term sustainability of agricultural production systems.

4.3 Climatic Variability and Crop Productivity:

Agricultural productivity in Assam depends heavily upon the timing, distribution, and intensity of monsoon rainfall. Traditional cropping calendars evolved under relatively predictable climatic conditions. However, increasing climatic variability has disrupted these established production systems. Rice, which occupies the largest proportion of cultivated land in Assam, has become particularly vulnerable to changing climatic conditions. Delayed monsoon onset postpones sowing operations, whereas excessive rainfall during vegetative growth frequently causes prolonged water logging. Conversely, rainfall deficiency during reproductive stages reduces grain filling and ultimately lowers productivity. Similar climatic sensitivities have also been reported for mustard, pulses, vegetables, and horticultural crops.

Temperature variability has introduced additional production constraints. Higher daytime temperatures increase evaporation, accelerate soil moisture depletion, and shorten crop duration. These physiological changes reduce biomass accumulation and adversely affect crop yields, particularly where irrigation facilities remain inadequate. Climate variability has also altered the incidence of agricultural pests and diseases. Warmer temperatures and changing humidity conditions have facilitated the expansion of insect populations and pathogenic organisms into previously unaffected areas. Consequently, farmers have experienced increasing expenditure on pesticides and crop protection measures, thereby raising production costs while reducing profitability. The cumulative effect of these climatic changes extends beyond yield reduction. Declining productivity contributes to increasing production risks, unstable household income, reduced investment capacity, and growing indebtedness among farming households. Climate change therefore influences not only agricultural output but also the broader economic sustainability of rural livelihoods.

4.4 Socio-economic Implications for Marginal Farmers:

The literature consistently demonstrates that the consequences of climate change extend far beyond agricultural production. For marginal farmers, crop failure frequently initiates a chain of socio-economic vulnerabilities affecting every dimension of household welfare. Reduced agricultural income limits the capacity of households to purchase quality seed, fertilizers, livestock, and agricultural equipment for subsequent cropping seasons. Simultaneously, increasing expenditure on healthcare, education, and food consumption places additional pressure on already constrained household budgets. One of the most significant outcomes identified in recent studies is the increasing diversification of livelihoods. Rather than depending exclusively on agriculture, many households combine farming with wage labor, livestock rearing, fisheries, petty trade, transportation services, or seasonal migration. Although diversification enhances resilience by reducing dependence on a single income source, empirical evidence indicates that these strategies frequently represent distress responses rather than pathways towards sustained economic transformation.

Migration has emerged as another important adaptation strategy among rural youth. Seasonal migration to urban centers and neighboring states provides supplementary household income but simultaneously

reduces agricultural labor availability within villages. The resulting feminization of agriculture has increased women's participation in farming activities while simultaneously expanding their workload without proportionate access to productive resources, institutional credit, or extension services. Consequently, climate change in Assam should not be interpreted solely as an environmental phenomenon. It represents a multidimensional developmental challenge characterized by interactions among ecological degradation, agricultural uncertainty, livelihood vulnerability, and social inequality. Understanding these interconnections is essential for designing effective adaptation policies capable of strengthening the resilience of marginal farming households.

5. Results and Discussion

5.1 Climate Change and Agricultural Productivity:

The review indicates that climate change has substantially altered agricultural production in Assam. Increasing temperatures, erratic rainfall, delayed monsoon onset, and frequent floods have disrupted traditional farming calendars. Rice, the principal crop of the state, has experienced significant yield fluctuations due to prolonged flooding during the kharif season and inadequate moisture during dry spells. Soil erosion and nutrient loss caused by repeated floods further reduce agricultural productivity. Marginal farmers are particularly affected because they possess limited financial resources to purchase improved seeds, irrigation equipment, or fertilizers after climate-induced crop failures. Consequently, declining agricultural productivity directly reduces household income and increases economic vulnerability.

5.2 Floods and Riverbank Erosion:

Floods remain the most serious climate-related hazard affecting Assam. Every year, thousands of hectares of agricultural land are inundated, damaging standing crops, livestock, irrigation systems, and rural infrastructure. In addition to seasonal floods, riverbank erosion permanently removes fertile agricultural land, forcing many farming households to abandon cultivation or migrate elsewhere.

The review reveals that erosion has become a long-term threat because lost agricultural land cannot easily be restored. Marginal farmers, who own very small landholdings, suffer disproportionately from this problem.

5.3 Socio-economic Impacts:

Climate change extends beyond environmental degradation and significantly affects rural livelihoods. Crop losses reduce household income, increase indebtedness, and limit farmers' ability to invest in future agricultural activities. Families often reduce expenditure on education, healthcare, and nutrition during periods of crop failure. Seasonal migration has emerged as an increasingly common coping strategy. Younger members of farming households frequently migrate to urban centers in search of temporary employment, resulting in labor shortages in rural agriculture and changes in traditional family structures. Women experience additional challenges because they often assume greater agricultural responsibilities when male family members migrate. However, they generally possess limited access to land ownership, institutional credit, agricultural training, and decision-making opportunities.

5.4 Food Security and Nutrition:

Climate variability has negatively affected household food security across many rural areas of Assam. Lower agricultural production reduces food availability at the household level, while declining farm income restricts purchasing power. During repeated flood events, local markets often become inaccessible, increasing food prices and limiting access to nutritious food. Many households respond by reducing dietary diversity and relying primarily on staple foods, increasing the risk of malnutrition, particularly among children and elderly family members.

5.5 Adaptation Strategies Adopted by Marginal Farmers:

The review identifies several adaptation measures currently practiced by marginal farmers in Assam. Crop diversification has become increasingly common, with farmers cultivating vegetables, pulses, oilseeds, and horticultural crops alongside rice to reduce production risks. Many farmers have adopted short-duration and flood-tolerant rice varieties that mature before peak flooding or can survive temporary submergence. Integrated farming systems combining crops, livestock, fisheries, and poultry provide multiple income sources and reduce dependence on a single agricultural activity. Some communities have improved water management through rainwater harvesting, improved drainage systems, and small-scale irrigation facilities. Traditional indigenous knowledge continues to play an important role in agricultural decision-making, particularly regarding planting dates, flood prediction, and local seed conservation.

5.6 Government Initiatives:

The Government of India and the Government of Assam have introduced several programmes to support climate-resilient agriculture i.e. Agriculture Infrastructure Fund (AIF), Pradhan Mantri Fasal Bima Yojana (PMFBY), Sub-Mission on Seed and Planting Material (SMSP), Tea Board initiatives, PM-KISAN, KCC, Soil Health Card, eNAM, and Paramparagat Krishi Vikas Yojana.. These include crop insurance schemes, agricultural extension services, improved irrigation infrastructure, disaster relief programs, soil conservation initiatives, and promotion of climate-smart agriculture. Although these programs have benefited many farmers, the literature indicates that access remains unequal. Limited awareness, administrative delays, inadequate institutional coordination, and financial constraints reduce program effectiveness among marginal farmers.

6. Policy Recommendations:

Based on the findings of this review, the following recommendations are proposed:

- Develop and promote flood-tolerant, drought-resistant, and short-duration crop varieties suitable for different agro-climatic zones of Assam.
- Expand irrigation infrastructure through community-based water management systems, rainwater harvesting, and micro-irrigation technologies.
- Strengthen agricultural extension services by providing regular farmer training on climate-smart agricultural practices.
- Improve the accessibility and efficiency of crop insurance schemes, ensuring timely compensation following climate-related disasters.
- Promote integrated farming systems involving crops, livestock, fisheries, and horticulture to diversify household income.

- Strengthen riverbank protection and watershed management programmes to reduce agricultural land loss caused by erosion.
- Expand digital weather forecasting and early warning systems to enable farmers to make informed agricultural decisions.
- Increase financial assistance, institutional credit, and subsidies specifically targeted at marginal farmers adopting climate-resilient technologies.
- Encourage collaborative research among universities, research institutions, government agencies, and farming communities to develop locally appropriate adaptation strategies.
- Integrate indigenous agricultural knowledge with modern scientific innovations to create sustainable and culturally appropriate climate adaptation programs.

7. Conclusion:

Climate change has emerged as one of the most significant challenges to agricultural sustainability and rural livelihoods in Assam. The findings of this review demonstrate that increasing climatic variability, characterized by recurrent floods, riverbank erosion, erratic rainfall, rising temperatures, prolonged dry spells, and the increasing incidence of pests and diseases, has substantially affected the agricultural sector of the state. As agriculture in Assam remains predominantly rain-fed and is largely dependent on favourable climatic conditions, the adverse effects of climate change have disproportionately impacted marginal farmers, who possess limited landholdings, inadequate financial resources, and restricted access to modern agricultural technologies and institutional support. The review highlights that climate change has influenced not only agricultural productivity but also the broader socio-economic well-being of farming households. Declining crop yields, loss of cultivable land due to riverbank erosion, increasing production costs, and frequent crop failures have reduced household income and intensified food insecurity, indebtedness, and livelihood vulnerability. These challenges have also contributed to seasonal migration, increased dependence on non-farm employment, and widening socio-economic inequalities within rural communities. The cumulative effects of these environmental and economic pressures pose serious threats to sustainable agricultural development and rural poverty reduction in Assam.

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