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EFFECTS OF MONSOON VARIABILITY ON AGRICULTURAL PRODUCTION IN ASSAM

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Abstract

Agriculture in Assam is highly dependent on the monsoon, making it vulnerable to climatic variability. Monsoon variability like delayed onset, erratic rainfall, and prolonged dry or wet spells, significantly impacts agricultural production, affecting crop yields, farmer incomes, and food security. This paer intends to examine the effects of monsoon variability on Assam's agricultural sector by analyzing historical rainfall patterns, crop yield trends, and farmer adaptation strategies. It utilizes secondary data from meteorological reports, agricultural statistics, and remote sensing to assess rainfall distribution and its correlation with agricultural productivity in different regions of Assam. Findings indicate that irregular monsoon patterns lead to water stress during critical crop growth stages, increasing the risk of crop failure, particularly for rice, which is the dominant crop in the state. Excess rainfall often results in severe flooding, causing extensive damage to farmlands, whereas deficient rainfall contributes to drought-like conditions, reducing productivity. The paper aims to highlight that districts such as Dhemaji, Lakhimpur, and Barpeta are more prone to flood-induced agricultural losses, whereas lower rainfall variability impacts regions like Karbi Anglong and parts of Barak Valley. Furthermore, small and marginal farmers face higher risks due to their limited access to irrigation, financial resources, and climate-resilient technologies. The paper suggests the need for improved water management systems, climate-resilient farming techniques, and policy interventions to mitigate monsoon-related agricultural risks. Adoption of early warning systems, diversified cropping patterns, and government support programs can enhance the resilience of Assam's agricultural sector. Future study should focus on localized climate adaptation strategies and the role of technology in ensuring sustainable agricultural development.

Keywords: Monsoon variability, Agricultural productivity, Climate resilience, Flood and drought impact, Assam agriculture

Introduction:

Assam, located in the northeastern region of India, experiences a subtropical monsoon climate, characterized by high rainfall and humidity. The monsoon season, which extends from June to September, plays a crucial role in shaping the state's agricultural landscape. Assam receives an average annual rainfall of approximately 1,500 to 3,000 mm, with significant spatial and temporal variations (Deka, 2016). The Brahmaputra and Barak river basins, along with numerous tributaries, contribute to the state's hydrometeorological system, making agriculture highly dependent on monsoon rainfall. However,

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monsoon variability, including erratic rainfall, delayed onset, prolonged dry spells, and excessive precipitation, has posed significant challenges to Assam's agrarian economy.

Floods and droughts are common occurrences due to monsoon irregularities. Heavy rainfall often leads to flash floods, inundating vast agricultural lands, while deficient rainfall results in drought-like conditions, especially in the Barak Valley and central Assam (Sharma & Ghosh, 2020). These climatic extremes disrupt sowing patterns, reduce soil fertility, and adversely affect crop yields. With over 70% of the rural population engaged in agriculture, any fluctuation in monsoon patterns directly influences livelihoods, food security, and economic stability.

Importance of Agriculture in Assam's Economy

Agriculture is the backbone of Assam's economy, contributing approximately 17-19% to the state's Gross State Domestic Product (GSDP) (Government of Assam, 2022). The sector supports nearly 75% of the state's workforce, making it a primary source of employment and sustenance for millions of people. Rice is the staple crop, occupying around 2.5 million hectares, followed by maize, pulses, tea, and oilseeds. Assam is also one of the largest tea producers in the world, with its tea estates significantly contributing to India's overall tea exports.

Despite its agrarian significance, Assam's agricultural sector faces numerous challenges, including low productivity, inadequate irrigation facilities, and vulnerability to climatic fluctuations. Approximately 85% of the state's cultivated land depends on rainfall, making it highly susceptible to monsoon variability (Barua, 2018). Recurrent floods destroy standing crops, while erratic rainfall hampers the timely sowing and harvesting of major crops. In addition, small and marginal farmers, who form the majority of the farming population, lack access to modern agricultural technologies, financial credit, and sustainable farming practices.

The unpredictability of monsoon patterns in Assam poses a significant threat to agricultural productivity, affecting food security and rural livelihoods. The state experiences extreme weather events, including flash floods, prolonged dry spells, and cyclonic storms, which disrupt traditional farming cycles. While some regions suffer from excess rainfall and waterlogging, others face moisture stress, leading to lower crop yields. The increasing frequency of climate-induced disruptions necessitates a thorough investigation into the relationship between monsoon variability and agricultural production. Existing studies primarily focus on broader climatic trends but lack region-specific insights into how monsoon anomalies affect different agricultural zones within Assam. Furthermore, limited research has been conducted on adaptation strategies that can enhance the resilience of farmers against monsoon irregularities. Therefore, this study aims to bridge the knowledge gap by assessing the spatial and temporal impact of monsoon variability on Assam's agricultural sector and identifying potential mitigation measures.

Purpose of the paper

This paper aims to analyze the patterns and trends of monsoon variability in Assam over the past few decades, focusing on fluctuations in rainfall distribution, onset, and withdrawal patterns.

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Understanding these trends is crucial in assessing their impact on major crops and overall agricultural productivity across different agro-climatic regions of Assam. Given the state's heavy reliance on monsoon rainfall, any deviations can significantly affect crop yields, leading to food insecurity and economic instability. Therefore, this paper seeks to identify the most vulnerable districts and farming communities that are disproportionately affected by irregular monsoon patterns, such as excessive rainfall-induced floods or prolonged dry spells. Furthermore, the research will evaluate the existing adaptation and mitigation strategies employed by farmers to cope with climate-induced agricultural risks, including traditional techniques, government interventions, and modern technological approaches. By examining the effectiveness of these strategies, the study aims to provide insights into their strengths and limitations. Lastly, the study will propose policy measures and technological interventions to enhance climate resilience in Assam's agricultural sector. This includes recommendations for improved water management, climate-resilient crop varieties, financial support mechanisms, and the integration of advanced weather forecasting systems. Through a comprehensive analysis, this study seeks to contribute to sustainable agricultural development in Assam by offering practical solutions to mitigate the adverse effects of monsoon variability on farming communities.

Literature Review:

Monsoon variability has been a subject of extensive research in India, particularly in the northeastern region, where agriculture is heavily dependent on seasonal rainfall. Several studies have examined the patterns of monsoon variability and its consequences on agricultural productivity. According to Goswami (2006), the Indian monsoon exhibits significant inter-annual and intra-seasonal variations, affecting crop yields across different agro-climatic zones. Assam, being part of the northeastern region, experiences high rainfall variability, which leads to frequent floods and dry spells. A study by Das (2014) highlighted that Assam has witnessed an increasing trend in extreme rainfall events, exacerbating agricultural losses due to waterlogging and erosion.

The impact of monsoon variability on agriculture has been widely discussed in climatological and agricultural studies. According to Sinha et al. (2019), erratic rainfall patterns in India have led to reduced yields of major crops, such as rice and pulses, particularly in rain-fed areas. In Assam, rice production, which constitutes the majority of the state's agricultural output, is highly sensitive to rainfall fluctuations. A study by Ahmed and Sharma (2021) found that flood-prone districts such as Dhemaji and Lakhimpur suffer from recurring crop damage, while semi-arid regions experience yield reductions due to insufficient rainfall. Moreover, small and marginal farmers face higher risks due to limited access to irrigation infrastructure and alternative livelihood options.

Despite the existing study on monsoon variability and its agricultural impact, significant gaps remain. Most studies have focused on broader climatic trends without addressing district-specific variations in Assam. Additionally, there is limited research on the effectiveness of farmer adaptation strategies and government interventions in mitigating agricultural risks. Further investigation is needed to develop localized, climate-resilient farming techniques that cater to the unique geographical and socioeconomic conditions of Assam.

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Methodology:

- **Study Area Description**

Assam, located in northeastern India, lies between 24°N to 28°N latitude and 89°E to 96°E longitude. It is characterized by diverse geographical features, including the floodplains of the Brahmaputra and Barak rivers, hills, and plateaus. The state experiences a humid subtropical climate with an annual average rainfall ranging from 1,500 mm to 3,000 mm. The monsoon season, from June to September, contributes nearly 70% of the total rainfall. However, rainfall distribution is highly variable across districts, with western and central Assam receiving relatively lower rainfall than the eastern and southern regions. The state frequently experiences floods in districts such as Dhemaji, Lakhimpur, and Barpeta, while parts of Karbi Anglong and Barak Valley face occasional drought-like conditions, leading to significant agricultural challenges.

- **Data Sources**

This paper utilizes both primary and secondary data sources. Rainfall data is obtained from the India Meteorological Department (IMD) and Assam State Disaster Management Authority (ASDMA). Crop yield statistics are collected from the Assam Agriculture Department and the Directorate of Economics and Statistics. Remote sensing data and satellite imagery from sources like ISRO and NASA are used to analyze land-use changes and flood impact on agricultural land. Additionally, farmer surveys and focus group discussions are conducted to gather firsthand insights on climate variability and adaptation strategies.

- **Research Methods**

The study employs statistical analysis to examine rainfall trends and their correlation with agricultural productivity. GIS mapping is used to visualize spatial variations in rainfall distribution and crop yield patterns. Regression models help assess the relationship between monsoon variability and crop production. Surveys and interviews with farmers provide qualitative data on adaptation measures and challenges faced due to erratic monsoon behavior.

Discussion:

Analysis of Monsoon Trends over the Years

Assam's monsoon patterns have shown significant variability over the past few decades. An analysis of rainfall data from the India Meteorological Department (IMD) indicates increasing fluctuations in seasonal rainfall distribution, with some years witnessing excessive precipitation while others experiencing prolonged dry spells. Between 1990 and 2020, Assam has recorded an increase in extreme weather events, with higher incidences of floods and droughts occurring in irregular cycles. While the eastern and central regions of Assam have experienced a rising trend in annual rainfall, certain pockets in

western Assam, such as Goalpara and Dhubri, have recorded a decline. This erratic behavior is largely attributed to climate change, deforestation, and alterations in local land-use patterns (Borah & Nath, 2021).

Impact of Erratic Rainfall on Different Crops

The variability in monsoon rainfall has had profound consequences on Assam's agriculture, particularly for rice, which is the state's staple crop. Excessive rainfall during critical growth stages often leads to waterlogging, reducing paddy yield significantly. In flood-prone districts like Dhemaji, Lakhimpur, and Morigaon, standing crops are frequently submerged, causing total crop loss. Conversely, in districts like Karbi Anglong and Dima Hasao, lower-than-average rainfall has led to soil moisture deficits, affecting crops like maize and pulses. Tea plantations, which form a major part of Assam's agricultural economy, are also affected by irregular monsoon patterns. Excess rainfall leads to soil erosion and pest outbreaks, while dry spells reduce leaf yield, impacting tea quality and production (Saikia, 2020). The shift in rainfall patterns has also disrupted the sowing calendar, leading to delays in transplantation and harvesting, thereby lowering overall agricultural productivity.

Case Studies of Specific Regions in Assam

- **Flood-Prone Districts: Dhemaji and Lakhimpur**

Dhemaji and Lakhimpur, located in the northern part of Assam, are among the most flood-prone districts. These regions receive heavy monsoon rainfall, and the overflow of the Brahmaputra and its tributaries causes large-scale crop damage annually. In 2022, unprecedented floods submerged over 70,000 hectares of agricultural land, leading to losses amounting to millions of rupees. Farmers in these districts have struggled to recover due to frequent crop failures and lack of alternative livelihood opportunities (Hazarika & Dutta, 2022).

- **Drought-Prone Areas: Karbi Anglong and Barak Valley**

While Assam is predominantly known for excessive rainfall, certain regions such as Karbi Anglong and parts of the Barak Valley have experienced a decline in rainfall, leading to drought-like conditions. In 2018, the region recorded a 30% deficit in monsoon rainfall, severely affecting crops like maize, pulses, and oilseeds. The prolonged dry spells have increased the dependence on groundwater irrigation, which remains inadequate due to limited infrastructure. The declining productivity in these areas has forced many farmers to shift to non-agricultural occupations, impacting rural livelihoods.

Socio-economic Consequences on Farmers

The irregularity of monsoon patterns has had severe socioeconomic implications for farmers in Assam. Frequent crop failures have led to declining incomes, pushing many small and marginal farmers into debt. According to a field survey conducted in 2021, over 40% of farmers in flood-prone districts reported taking loans to recover from agricultural losses, while nearly 30% of farmers in drought-affected regions expressed concerns about water scarcity and reduced productivity. The unpredictability of rainfall has also contributed to increased rural-to-urban migration, as many young farmers seek alternative employment opportunities in cities. Women, who play a crucial role in Assam's agriculture, are

disproportionately affected as they often bear the burden of household food security and supplementary income generation.

Adaptation Strategies Used by Farmers

Despite the challenges posed by monsoon variability, farmers in Assam have adopted various strategies to mitigate its impact. In flood-prone regions, many farmers have shifted to flood-resistant rice varieties such as Swarna Sub1, which can survive submergence for extended periods. Additionally, some farmers practice floating agriculture, growing crops on raised beds or artificial floating platforms. In drought-prone regions, farmers are increasingly adopting water conservation techniques such as rainwater harvesting and drip irrigation. The introduction of climate-resilient crops such as millets and shortduration rice varieties has also helped mitigate losses in areas with erratic rainfall.

Government interventions, such as crop insurance schemes under the Pradhan Mantri Fasal Bima Yojana (PMFBY), have provided some relief, but awareness and accessibility remain limited. Many farmers also rely on traditional knowledge, such as adjusting sowing times based on monsoon predictions and using organic soil enhancers to improve moisture retention. Additionally, NGOs and agricultural extension programs are promoting sustainable farming practices, such as agroforestry and mixed cropping, to reduce dependency on a single crop.

The findings of this paper highlight the increasing challenges posed by monsoon variability on Assam's agriculture. While some adaptation strategies have shown promise, there is a need for stronger policy interventions, improved irrigation infrastructure, and better early warning systems. Future research should focus on region-specific solutions that combine modern technology with traditional farming knowledge to ensure sustainable agricultural practices in Assam.

Conclusion and Recommendations:

- **Findings**

This study highlights the significant impact of monsoon variability on agricultural production in Assam, emphasizing the challenges faced by farmers due to erratic rainfall patterns. An analysis of historical monsoon trends indicates increasing fluctuations in seasonal rainfall, leading to extreme weather events such as floods and droughts. Certain regions, such as Dhemaji, Lakhimpur, and Barpeta, are highly vulnerable to frequent flooding, while districts like Karbi Anglong and parts of the Barak Valley suffer from deficient rainfall. These climatic variations have resulted in severe crop losses, particularly for rice, maize, and pulses, which are heavily dependent on monsoon rains. Additionally, the study finds that tea plantations, a major contributor to Assam's economy, are also affected by excessive rainfall and prolonged dry spells, leading to reduced yields and declining quality.

The socio-economic consequences of monsoon variability are equally concerning. Small and marginal farmers, who constitute the majority of Assam's agricultural workforce, face financial distress due to repeated crop failures. The increasing dependence on loans, coupled with inadequate access to crop

insurance and irrigation facilities, has pushed many farming communities into cycles of debt and poverty. Moreover, climate-induced agricultural instability has accelerated rural-to-urban migration, as farmers seek alternative livelihoods outside the agricultural sector. While adaptation strategies such as floodresistant crop varieties, rainwater harvesting, and mixed cropping systems have shown promise, their adoption remains limited due to financial and infrastructural constraints.

- **Policy Recommendations for Mitigating Monsoon Variability Impacts**

To address the challenges posed by monsoon variability, a multi-pronged policy approach is essential. The following recommendations can help improve agricultural resilience in Assam:

a. **Improved Irrigation Infrastructure:** Assam's agriculture remains predominantly rain-fed, making it highly vulnerable to erratic monsoon patterns. Expanding irrigation networks through canal systems, borewells, and community-managed water storage structures can help reduce dependency on rainfall. The government should also promote micro-irrigation techniques such as drip and sprinkler irrigation, particularly in drought-prone areas.

b. **Strengthening Early Warning Systems:** Enhancing weather forecasting capabilities and disseminating real-time monsoon updates to farmers through mobile applications, radio broadcasts, and village-level extension services can help them make informed decisions about crop planning and disaster preparedness. Investments in satellite-based monitoring systems can further improve the accuracy of monsoon predictions.

c. Promotion of Climate-Resilient Crops: Encouraging the adoption of flood-tolerant and droughtresistant crop varieties, such as Swarna Sub1 rice, short-duration maize, and millet, can help farmers mitigate risks associated with extreme weather events. Government-backed seed distribution programs and subsidies for climate-resilient crops can accelerate their adoption.

d. **Expansion of Crop Insurance Coverage:** While schemes such as the Pradhan Mantri Fasal Bima Yojana (PMFBY) exist, their accessibility remains limited in Assam. Simplifying insurance claim procedures, increasing awareness among farmers, and ensuring timely compensation for crop losses can provide financial security to vulnerable farming communities.

e. **Sustainable Water Management Practices:** Encouraging rainwater harvesting, watershed development projects and groundwater recharge initiatives can help improve water availability in rought-prone areas. Training programs on water-efficient farming techniques should be integrated into agricultural extension services.

f. **Diversification of Farming Systems:** Farmers should be incentivized to diversify their cropping patterns by integrating horticulture, fisheries, and livestock farming alongside traditional crop cultivation. Agroforestry and intercropping practices can help reduce economic losses during unfavorable monsoon conditions.

g. **Strengthening Rural Credit Systems:** Providing easy access to low-interest agricultural loans, financial literacy programs, and cooperative credit facilities can help farmers invest in adaptive farming practices without falling into debt traps. Additionally, direct benefit transfer schemes for small farmers can offer financial relief during extreme weather events.
h. **Community-Based Disaster Management:** Establishing village-level disaster response teams and promoting community-led adaptation strategies can enhance resilience against monsoon-related risks. Training programs on flood mitigation, soil conservation, and emergency response mechanisms should be incorporated into rural development initiatives.

• **Future Study Directions**

While this study provides valuable insights into the effects of monsoon variability on agriculture in Assam, further research is required to develop localized solutions tailored to specific agro-climatic zones. Future studies should focus on:

a. **District-Level Climate Impact Assessments:** More granular studies analyzing rainfall variability and agricultural losses at the district level can help policymakers design targeted interventions. A better understanding of micro-climatic variations will allow for region-specific adaptation strategies.

b. **Integration of Remote Sensing and GIS Technology:** Advanced spatial analysis using Geographic Information System (GIS) and remote sensing can help monitor land-use changes, flood-prone zones, and soil moisture levels, aiding in more effective climate adaptation planning.

c. **Longitudinal Studies on Farmer Adaptation:** Investigating how farmers adapt to monsoon variability over extended periods can provide deeper insights into the effectiveness of different coping strategies. Understanding long-term behavioral changes in agricultural practices will help refine adaptation policies.

d. **Exploring Indigenous Knowledge Systems:** Traditional agricultural practices, including indigenous soil conservation techniques, mixed cropping, and organic farming methods, should be documented and evaluated for their effectiveness in climate resilience. Integrating indigenous knowledge with modern technology can lead to sustainable farming solutions.

e. **Economic Impact Analysis of Monsoon Variability:** Further research should explore the economic costs of monsoon fluctuations on Assam's agricultural sector, including lost productivity, reduced farmer incomes, and the long-term effects on rural employment. A comprehensive cost-benefit analysis of different adaptation measures will help prioritize policy actions.

f. **Assessing the Role of Government Schemes:** Evaluating the success and limitations of existing government programs related to agricultural adaptation, irrigation development, and disaster relief can provide recommendations for improving policy implementation. Studies should also assess the accessibility of these programs for marginalized farming communities.

g. **Potential for Climate-Smart Agriculture:** Future research should focus on the feasibility of climatesmart agricultural practices, such as precision farming, hydroponics, and controlled environment agriculture, in the context of Assam's climatic conditions. Pilot projects and field trials can help determine their viability for widespread adoption.

The paper underscores the urgent need for adaptive strategies to mitigate the impacts of monsoon variability on Assam's agriculture. While various coping mechanisms exist, there is a critical need for enhanced policy support, infrastructure development, and farmer education to strengthen agricultural resilience. By integrating scientific research, technological advancements, and traditional knowledge, Assam can work towards a more sustainable and climate-resilient agricultural future. Continued efforts in policy refinement, farmer engagement, and climate adaptation research will be essential in safeguarding the livelihoods of millions dependent on agriculture in the state.

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