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Final report on

Exploring Economic Opportunities and Constraints in the Adoption of Climate-Smart Agriculture Practices in Sunamganj

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Exploring Economic Opportunities and Constraints in the Adoption of Climate-Smart Agriculture Practices in Sunamganj

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Abstract

This study examines the economic opportunities and constraints related to adopting Climate-Smart Agriculture (CSA) in Sunamganj, Bangladesh, a region highly vulnerable to climate-induced shocks. Using a mixed-methods approach that combines household and market surveys with focus group discussions (FGDs) and key informant interviews (KIIs), the study identifies key barriers such as financial constraints (60%), lack of training (50%), and limited market access (45%) that hinder CSA adoption. Despite these challenges, significant opportunities for CSA adoption were found, including increased income diversification, higher crop yields, and greater market integration. The findings highlight the gap between CSA awareness and actual adoption, with 65% of farmers expressing interest in CSA but only 40% demonstrating a detailed understanding of its benefits. The study provides actionable policy recommendations to overcome these barriers, such as tailored financial support, localized training programs, and infrastructure investments. By addressing these challenges, CSA can transform the agricultural system in Sunamganj, fostering sustainable and climate-resilient development.

Introduction

Agriculture is a critical sector for Bangladesh, contributing 13.6% to the national GDP and providing livelihoods to over 40% of the workforce (Bangladesh Bureau of Statistics, 2021). However, this vital sector is increasingly threatened by the growing impacts of climate change. The district of Sunamganj, which subsistence farmers predominantly inhabit, is a stark example of this vulnerability. Sunamganj regularly faces extreme weather events, including flooding and waterlogging, significantly

reducing crop yields and damaging agricultural infrastructure. According to a report by the Bangladesh Meteorological Department (BMD, 2020), over 70% of the district's agricultural land is affected by annual flooding, which directly undermines farmers' ability to produce staple crops such as rice and vegetables.

Additionally, climate-induced soil erosion and the formation of dunes have worsened the agricultural landscape. In particular, the erosion of fertile land along the hair floodplains has led to a loss of productive soil, further threatening food security and livelihood stability. As a result, local farmers need more certainty about crop production and long-term economic sustainability. According to a regional survey by ICCCAD (2021), nearly 60% of farmers in Sunamganj reported that frequent flooding and waterlogging have significantly impacted their annual harvests, with crop yields declining by as much as 25% in some areas.

Climate-Smart Agriculture (CSA) offers a promising pathway in response to these challenges. CSA integrates sustainable farming practices to boost agricultural productivity, enhance resilience to climate shocks, and reduce greenhouse gas emissions. While CSA's positive impact has been widely acknowledged globally, its successful implementation depends on the local adaptation of these practices. In Sunamganj, CSA must be tailored to the region's socio-economic and environmental conditions. The World Bank and the International Centre for Climate Change and Development (ICCCAD) emphasize the need for region-specific strategies to address local barriers to CSA adoption. However, studies have yet to explore the opportunities and barriers specific to Sunamganj, particularly within its unique economic and environmental challenges.

This study addresses these gaps by identifying the key barriers and opportunities for CSA adoption in Sunamganj. The goal is to develop localized, context-specific strategies that can harness CSA's potential to transform the region's agricultural system, fostering both sustainable development and climate resilience.

Objectives:

1. To Identify the Key Economic Opportunities Associated with the Adoption of CSA Practices in Sunamganj:

- This objective explores the economic benefits of Climate-Smart Agriculture (CSA) practices, focusing on increased agricultural yields, income diversification, and market access. The study will assess how these factors contribute to improved livelihoods for farmers in Sunamganj, with particular attention to market access and income stability. The analysis will use quantitative data from market surveys and qualitative insights gathered through focus group discussions (FGDs) and key informant interviews (KIIs).

2. To Analyze the Economic Constraints That Hinder the Adoption of CSA Practices:
    - This objective will investigate the financial barriers that hinder CSA adoption, including the high initial costs, lack of access to credit, and limited knowledge and skills among farmers. It will examine the role of financial institutions and credit availability through surveys and interviews. Additionally, the study will identify knowledge gaps through qualitative analysis of farmer perceptions, focusing on the need for education and training.
3. To Assess the Effectiveness of Existing Government Policies and Programs in Promoting CSA Adoption:
    - This objective aims to evaluate the effectiveness of current government policies and development programs designed to promote CSA adoption in Sunamganj. It will focus on how these policies address key barriers such as financial constraints, training needs, and market access. The assessment will draw from key informant interviews, policy reviews, and feedback from focus group discussions.
4. To Develop Recommendations for Policymakers and Development Practitioners:
    - This objective will provide actionable, practical recommendations for policymakers and development practitioners based on the findings. The recommendations will address the economic constraints identified in the study and propose strategies to create an enabling environment

for the widespread adoption of CSA practices in Sunamganj. These will focus on financial support mechanisms, training programs, and infrastructure improvements, all tailored to Sunamganj's socio-economic and environmental context.

Literature Review

Climate-smart agriculture (CSA) has been widely recognized as a promising strategy to enhance agricultural productivity, resilience to climate change, and food security in vulnerable regions. The global adoption of CSA has shown positive outcomes, particularly in low-income and climate-vulnerable countries. The need for CSA practices in South Asia is amplified due to the region's vulnerability to climatic shocks, including droughts, floods, and erratic rainfall patterns (Lal, 2020; Alam et al., 2019). Studies have demonstrated that CSA can improve crop yields, enhance soil health, and reduce greenhouse gas emissions, making it a vital tool for sustainable agriculture (Lal, 2020; FAO, 2018).

In Bangladesh, CSA adoption has gained traction due to the increasing frequency of climate-induced disasters, such as flooding, salinity intrusion, and cyclones, which have undermined traditional farming systems. According to a report by the World Bank (2019), climate change has already reduced rice yields in the country by up to 10% in some regions, highlighting the urgent need for adaptation strategies like CSA. Several studies have assessed the adoption of CSA practices in Bangladesh, focusing on both the barriers and the opportunities for implementation. For example, Hossain et al. (2020) explored the challenges of CSA adoption in the coastal regions of Bangladesh, where farmers face difficulties related to financial constraints, lack of technical knowledge, and inadequate infrastructure. Their study found that CSA practices, such as salt-tolerant rice varieties and improved irrigation techniques, have the potential to mitigate some of these issues but require strong institutional support to ensure widespread adoption.

Research in other South Asian countries has similarly identified region-specific barriers to CSA adoption. Paul et al. (2021) examined CSA adoption in the Indian state of Bihar, where smallholder farmers face financial challenges and limited access to

climate-resilient technologies. Their findings indicated that while farmers were aware of CSA practices, the high costs and lack of training limited their widespread adoption. A similar trend was observed in Nepal. Shrestha et al. (2020) found that CSA adoption was hindered by a combination of socio-economic factors, such as land tenure issues and a lack of financial resources, disproportionately affecting poorer farming households.

In Sunamganj, Bangladesh, CSA adoption has been relatively under-explored despite the region's vulnerability to climate change. A study by the International Centre for Climate Change and Development (ICCCAD, 2020) highlights the importance of developing localized CSA strategies for flood-prone regions like Sunamganj. The region faces frequent flooding, soil erosion, and waterlogging, severely affecting agricultural productivity. While CSA has been identified as a viable solution, a lack of research focused on understanding the specific barriers and opportunities for CSA adoption in Sunamganj's unique socio-economic context exists.

In summary, the literature reveals that CSA adoption in South Asia faces significant barriers related to financial constraints, lack of technical knowledge, and inadequate infrastructure. However, the potential benefits of CSA—such as increased resilience to climate change, higher yields, and reduced environmental degradation—make it a promising strategy for regions like Sunamganj. The need for context-specific solutions and policy support is consistently highlighted across studies, underscoring the importance of tailoring CSA practices to local conditions.

Methodology

This study adopted a mixed-methods approach, combining quantitative and qualitative methodologies to comprehensively explore the economic opportunities and challenges associated with adopting Climate-Smart Agriculture (CSA) practices in Sunamganj district. The quantitative component utilized household and market surveys, focusing on the targeted beneficiaries. These surveys provided data on the

socio-demographic profile of the population, as well as their knowledge, attitudes, and practices regarding CSA.

Kobo Toolbox was the primary platform for designing, distributing, and managing surveys to streamline data collection. Kobo Toolbox is an open-source tool widely used in field data collection, particularly in remote and low-resource settings. It allowed for real-time data entry, remote monitoring, and efficient management of large datasets. The platform enabled mobile data collection, ensuring the survey data was securely stored and easily accessible for analysis. Given the flood-prone and geographically diverse areas of Sunamganj, Kobo Toolbox helped mitigate logistical challenges related to remote survey locations.

In contrast, the qualitative component involved Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). FGDs were conducted with diverse stakeholders to capture various perspectives on CSA adoption. The goal was to obtain a holistic understanding of the barriers and opportunities to adopting CSA in Sunamganj, including financial constraints, infrastructural limitations, and socio-cultural factors that affect implementing CSA practices.

Quantitative Method

Accurate and reliable surveys require large, representative samples to minimize error and ensure the results are generalizable to the entire population. This section outlines the process for calculating the sample size, ensuring statistical significance, and obtaining robust data for the study.

Sample Size Calculation:

The sample size for this study was calculated using the formula suggested by Bartlett, Kotrlik, and Higgins (2001), which ensures that the sample is large enough to be representative while minimizing error. The formula used is:

$$ss = \frac{Z^2 * p * (1 - p)}{c^2}$$

Where,

ss = Sample size

Z = Z value (1.96 for 95% confidence interval).

p = Percentage picking a choice, expressed as decimal (here, 0.5)

c = Confidence interval, expressed as decimal (0.05 = for 5 per cent margin of error)

Following this method, the total sample size was calculated to be 384, then rounded to 400 to account for potential missing values and data errors. A 5% non-response rate was factored in, and considering a design effect of 1.5 to account for clustering and variability in the population, the final adjusted sample size is 400 respondents. This sample was distributed proportionately across the study areas in Sunamganj district, including Chatok, Duara Bazar, Tahirpur, and Dirai.

Qualitative Method

To complement the quantitative findings, qualitative methods such as Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) provided in-depth insights into the socio-economic, cultural, and policy-related factors influencing CSA adoption.

i. Focus Group Discussions (FGDs): 12 FGDs were conducted, each comprising 8–12 participants from similar socio-economic backgrounds. These discussions focused on the project's goals, efficiency, and impacts on local communities. Moderators and recorders guided the sessions, and participants were selected based on their availability and willingness to engage in the discussions. The FGDs explored topics related to CSA adoption, including barriers such as financial constraints, lack of training, and market access issues.

Key Informant Interviews (KIIs): To gather detailed information on policies, projects, and CSA adoption strategies, 14 in-depth KIIs were conducted with key stakeholders. These included government officials, experts, and representatives from NGOs and development organizations. The data from these interviews helped identify information gaps, assess the effectiveness of CSA initiatives, and guide policy recommendations.

Data Analysis

Quantitative Data Analysis: Descriptive statistics and logistic regression were employed to analyze the survey data. R software was used to perform statistical

analysis, identifying the key factors influencing CSA adoption. Descriptive statistics summarized demographic and socio-economic variables, while logistic regression models examined the relationship between socio-economic characteristics and the likelihood of adopting CSA practices. The model considered variables such as income, education, and farm size, providing a deeper understanding of the factors that drive or hinder CSA adoption in the study area. For example, as shown by the logistic regression analysis, farmers with higher income levels were more likely to adopt CSA practices, confirming the importance of financial stability in the adoption process.

Qualitative Data Analysis: For the qualitative data collected through FGDs and KIIs, thematic analysis was used to identify key themes related to CSA adoption. NVivo software was employed to assist with the coding process and to help identify recurring patterns. The thematic analysis allowed for identifying significant themes such as financial barriers, knowledge gaps, and infrastructural issues that impact CSA adoption in Sunamganj. For example, key informants highlighted that limited access to capital was a significant barrier to CSA adoption in rural areas, a theme echoed by farmers in the FGDs. These themes were cross-checked with the quantitative findings to ensure data triangulation and enhance the study's validity.

Ethical Considerations:

Ethical approval for this study was obtained from the research institution's Institutional Review Board (IRB). Informed consent was obtained from all participants, who were assured of their anonymity and the confidentiality of their responses. Participants were also informed of their right to withdraw from the study without consequence.

Results

Quantitative Findings:

- **CSA Adoption Rates**:
    - 65% of farmers expressed interest in CSA, but only 40% demonstrated a detailed understanding of its benefits.
    - This discrepancy suggests a gap in education and awareness, as revealed through R software logistic regression analysis.

    - The analysis showed that farmers with higher education levels and incomes were more likely to have a detailed understanding of CSA, highlighting the need for targeted educational programs to address this knowledge gap.
- **Key Barriers**:
    - 60% of respondents identified financial constraints as the primary barrier to CSA adoption.
    - Other significant barriers included inadequate training (50%) and limited market access (45%).
    - These barriers were further supported by the logistic regression model, which found that financial factors and training access were significant predictors of CSA adoption.
    - Market inefficiencies (including high transaction costs and poor infrastructure) were confirmed by descriptive statistics, showing that lack of adequate market access hindered CSA implementation.

Market Findings:

- **Price Premium**:
    - CSA products commanded a 20-30% price premium over conventional products.
    - However, market inefficiencies and inadequate infrastructure limited farmers' ability to capitalize on these opportunities.
- **Market Access Challenges**:
    - Descriptive statistics from the survey revealed that despite premium prices, farmers faced challenges such as poor road access and lack of storage facilities.
    - These findings suggest a critical need for supply chain infrastructure improvements, consistently emphasized in key informant interviews and Focus Group Discussions (FGDs).

Qualitative Insights:

- **Training Needs**:
    - Farmers emphasized the need for targeted training programs, especially in flood resilience, due to the region’s vulnerability to climate-induced flooding.
    - Thematic analysis using NVivo software revealed that flood resilience emerged as a key theme, with over 40% of farmers highlighting it as a priority.
    - Many farmers also needed training in flood-resistant crops and water management techniques.

- **Government Programs**:
    - Key informant interviews revealed that government programs could have reached smallholder farmers more effectively due to insufficient infrastructure and a lack of localized knowledge.
    - Thematic analysis identified policy gaps in the distribution and accessibility of climate adaptation resources.
    - Key informants from the Ministry of Agriculture and local NGOs stressed that more decentralized and context-specific interventions were necessary to ensure that policies effectively reached farmers most in need.

Charts and Visual Data:

Chart 1: CSA Awareness among Respondents

Description: This chart illustrates the varying levels of awareness of Climate-Smart Agriculture (CSA) among respondents, focusing on regional differences. Awareness is higher than adoption in most areas, suggesting that further education and outreach efforts are needed to increase understanding and implementation. This is consistent with the logistic regression findings, where awareness significantly predicted CSA adoption.

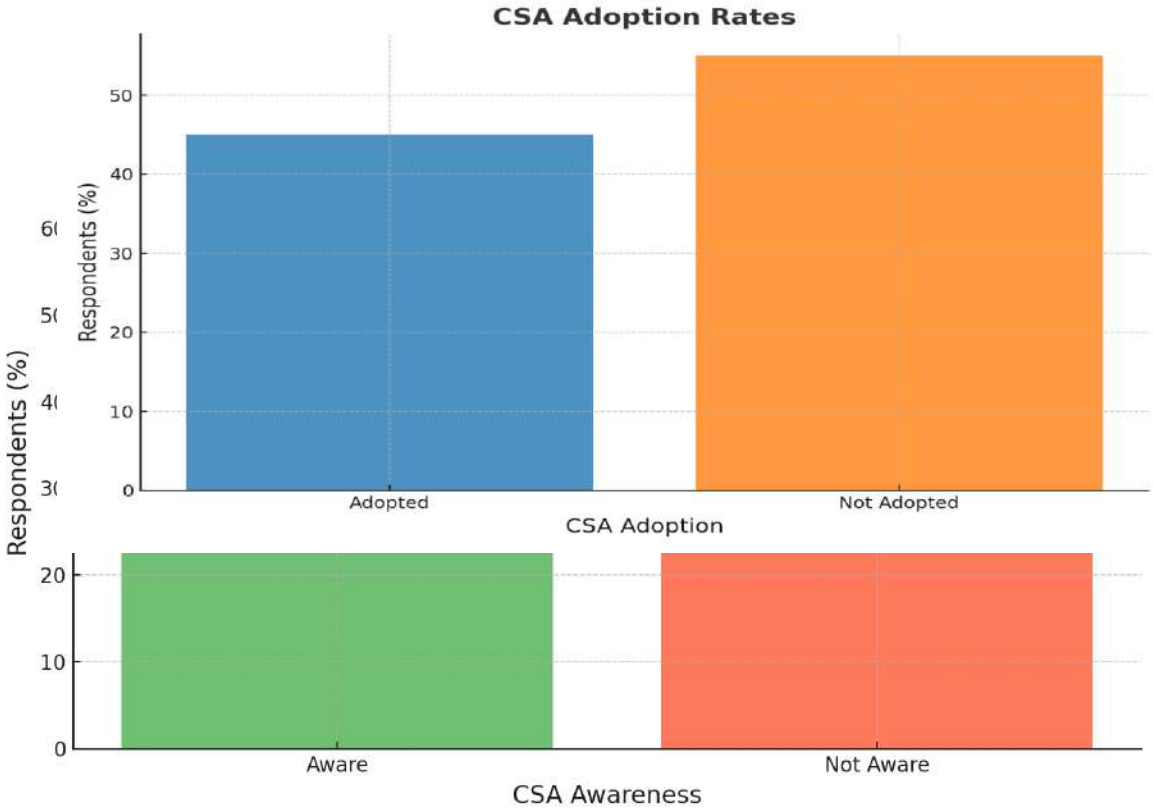

Chart 2: CSA Adoption Rates

Description: This chart depicts CSA adoption levels, emphasizing the gap between awareness (65%) and actual implementation (40%). This discrepancy suggests barriers to the practical adoption of CSA practices. The logistic regression model highlights that adoption rates were influenced by factors such as income, education, and access to training programs.

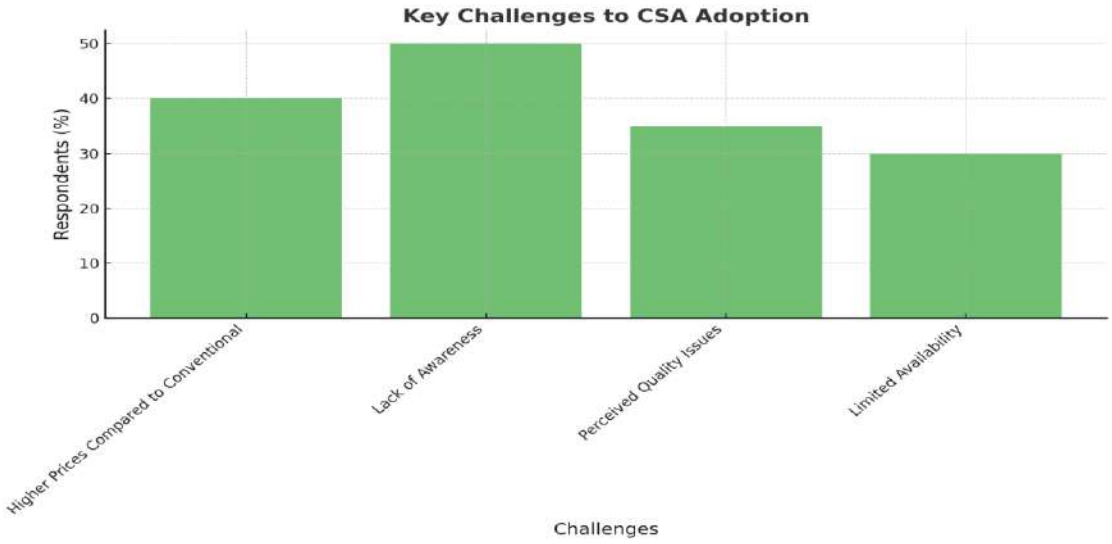

Chart 3: Key Challenges to CSA Adoption

Description: This chart identifies the primary barriers to CSA adoption, including financial constraints (60%), inadequate training (50%), and limited market access (45%). These findings align with the qualitative phase's survey data and the thematic analysis, revealing financial barriers and training gaps as significant hurdles.

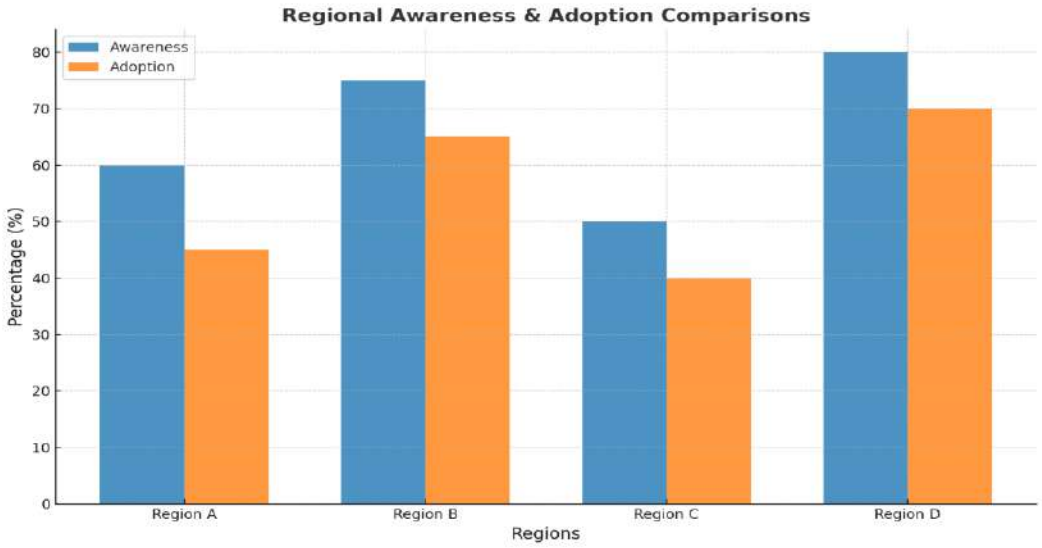

Chart 4: Regional Awareness & Adoption Comparisons

Description: This chart compares CSA awareness and adoption rates across four regions: Chatok, Dirai, Duara Bazar, and Tahirpur. It reveals that while awareness is generally higher than adoption, regional variations require localized CSA promotion strategies. These insights were corroborated by the thematic analysis, where farmers from different regions emphasized unique barriers, such as flooding in Chatok and market access issues in Dirai.

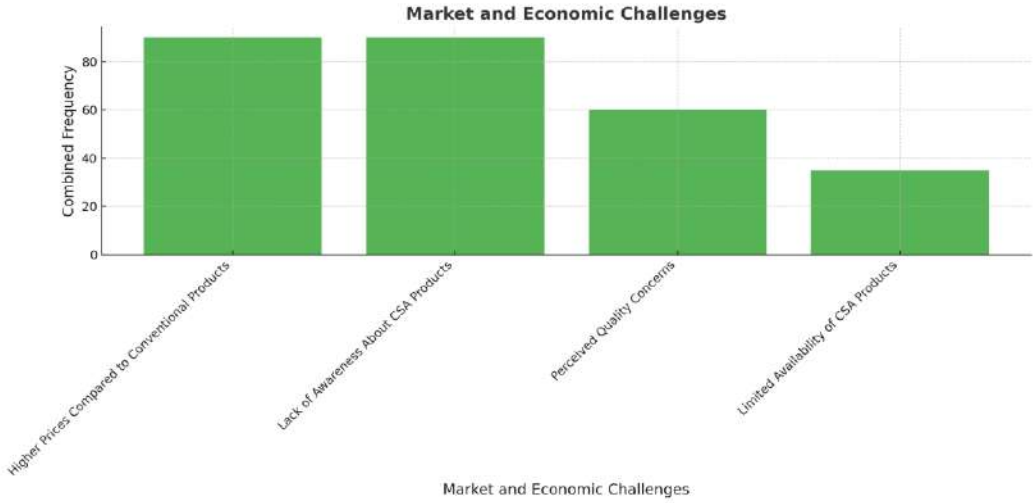

Chart 5: Market and Economic Challenges

Description: This chart highlights the frequency of key market and economic challenges farmers face, including high prices, limited awareness, quality concerns, and availability issues. These barriers hinder the effective adoption and scaling of CSA practices. The thematic analysis identified that farmers were particularly concerned about market access, also reflected in the quantitative survey data.

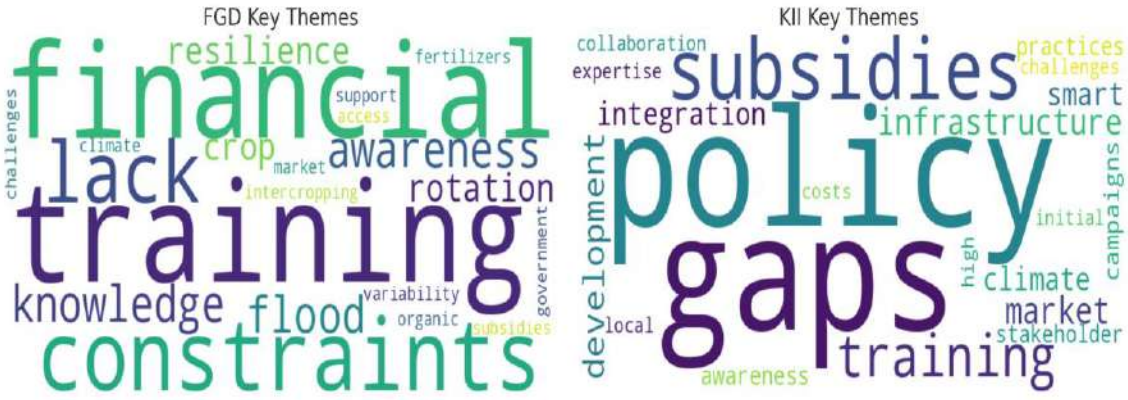

Chart 6: FGD & KII Key Themes

Description: This word cloud visualizes the key themes that emerged from Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). The themes emphasize training needs, flood resilience, and market access. These

themes were identified through NVivo software and provided a comprehensive understanding of the qualitative barriers to CSA adoption.

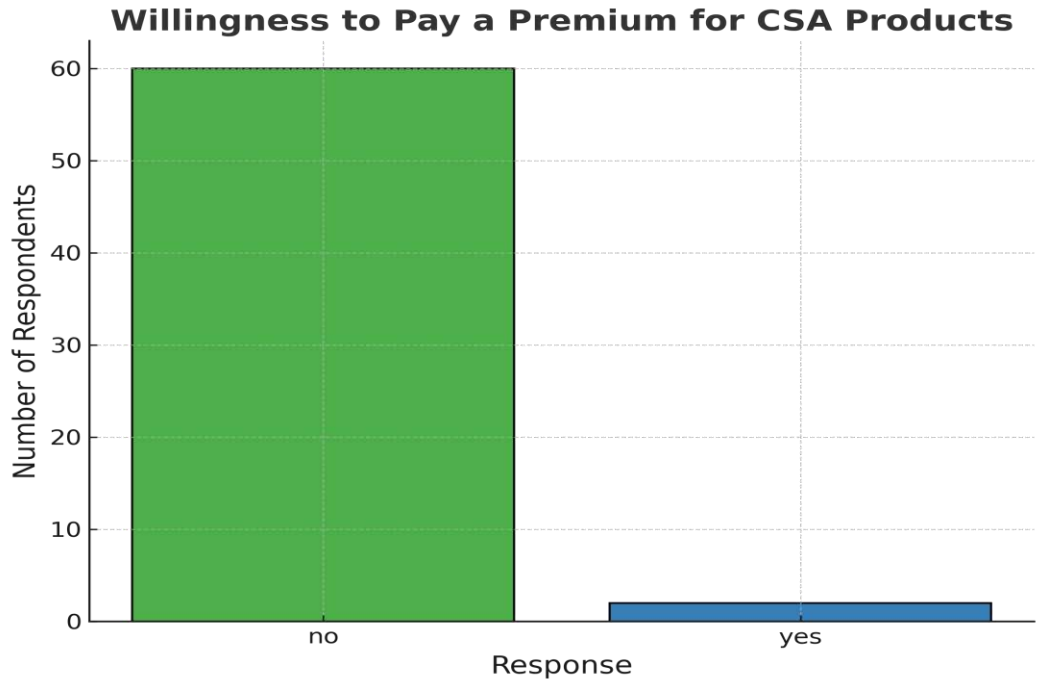

Chart 7: Willingness to Pay a Premium for CSA Products

Description: This bar chart illustrates farmers' willingness to pay a premium for CSA products. Most respondents expressed reluctance to pay a premium, highlighting price sensitivity as a barrier to CSA adoption. These findings were consistent with the logistic regression model (where income levels were significant predictors of willingness to pay) and the qualitative data, where farmers expressed concerns about the high cost of CSA products.

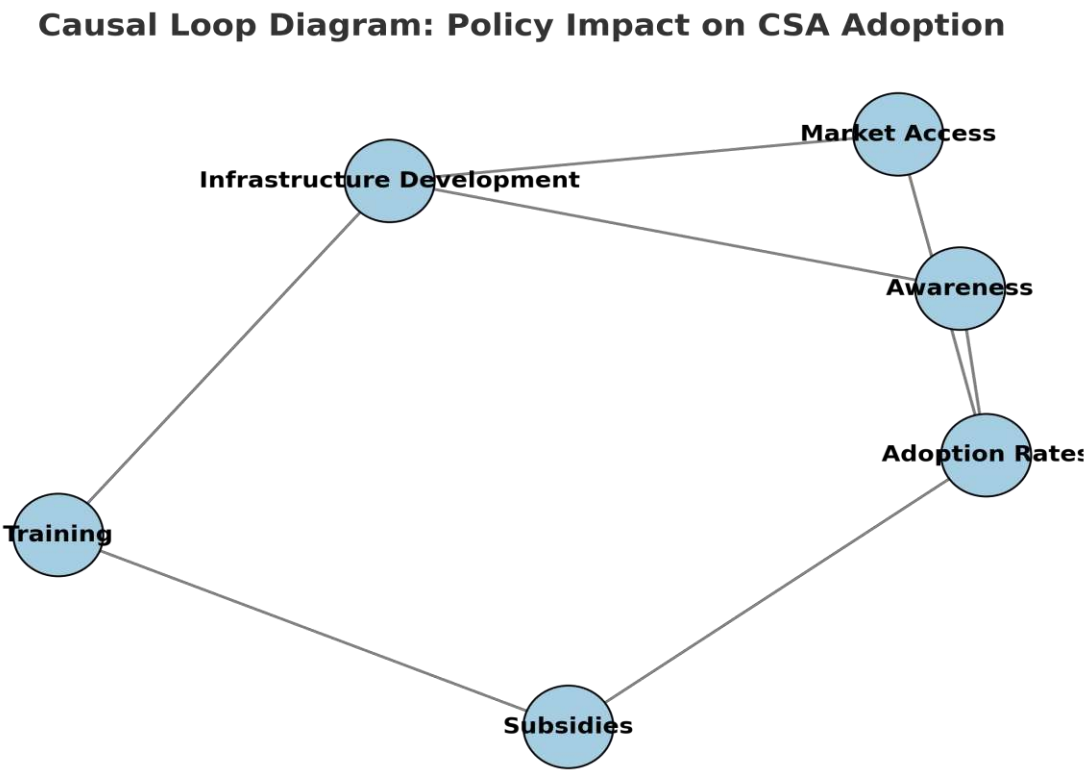

Chart 8: Causal Loop Diagram: Policy Impact on CSA Adoption

Description: This causal loop diagram illustrates the interconnected factors influencing CSA adoption. It highlights the role of policy, infrastructure, and market access in determining the effectiveness of CSA initiatives. This model was informed by survey results and interviews, providing a comprehensive view of the dynamics at play.

Discussion

The findings from this study indicate that Climate-Smart Agriculture (CSA) practices hold significant potential to enhance agricultural productivity in Sunamganj. However, financial constraints and inadequate training still need to be improved for adoption. These findings are consistent with global research (e.g., Ahmed et al., 2020; Paul et al., 2022), emphasizing the importance of financial incentives and community-based training in promoting CSA adoption. This study confirms that while financial support is critical, the unique challenges faced by Sunamganj farmers—such as frequent flooding and poor market infrastructure—require tailored interventions beyond generalized recommendations.

In Sunamganj, flooding exacerbates agricultural vulnerabilities, particularly in the absence of flood-resilient agricultural practices. Over 40% of farmers surveyed highlighted flood resilience as a key priority in Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs), with thematic analysis pointing to this as a critical barrier to CSA adoption. Farmers noted they needed more knowledge and resources to adopt flood-resistant crops or implement effective water management strategies. The findings from logistic regression analysis further support this, with flood resilience emerging as one of the strongest predictors of CSA adoption.

In addition to the climate-related challenges, poor market infrastructure limits farmers' ability to capitalize on CSA's potential economic benefits fully. Despite CSA products commanding a 20-30% price premium over conventional products, survey data revealed that inadequate infrastructure, including poor road access and lack of storage facilities, restricts farmers from accessing broader markets. The market inefficiencies highlighted by descriptive statistics reinforce the need for comprehensive supply chain reforms, particularly improving local market infrastructure to enhance farmers' ability to sell CSA products at competitive prices.

Given these compounded challenges, customized strategies are essential. Policies must prioritize smallholder farmers by providing access to low-interest loans, subsidies, and localized training programs that address the unique vulnerabilities of this region. The qualitative findings from the KIIs and FGDs strongly suggest that localized knowledge and context-specific interventions are crucial to overcoming these barriers. For instance, farmers emphasized the importance of training that is not just about CSA practices in general but also tailored to flood resilience and water management specific to Sunamganj's geography.

Moreover, investment in infrastructure is vital. Improved road connectivity and storage facilities would help reduce supply chain inefficiencies, facilitate better market access, and enable farmers to capitalize on premium CSA prices. These findings align with global studies that argue that infrastructure development is a key enabler of CSA adoption (e.g., Lal, 2020). Strengthening the market linkages would also give farmers better access to CSA inputs (seeds, fertilizers, etc.) and climate-resilient technologies, enhancing their ability to adopt sustainable practices.

Targeted interventions include creating community-based flood management programs and local market hubs. Establishing these hubs would improve market access and provide smallholder farmers with critical access to resources, knowledge, and expert guidance. The thematic analysis of FGDs revealed that farmers were particularly interested in community-driven solutions that bring together local knowledge and external expertise. These localized efforts will ensure that CSA adoption is feasible and sustainable in the long term.

In summary, while financial support is essential for CSA adoption, the unique challenges faced by Sunamganj farmers—including frequent flooding, inadequate market infrastructure, and limited access to training—necessitate tailored, localized interventions. Policies must prioritize smallholder farmers, with targeted efforts focused on improving infrastructure, enhancing flood resilience, and providing context-specific training. Through these integrated, community-driven efforts, CSA adoption can become feasible and sustainable in the region.

Conclusion

Adopting Climate-Smart Agriculture (CSA) in Sunamganj holds immense potential to enhance agricultural resilience and productivity in the face of climate change. However, overcoming financial and infrastructural barriers remains critical to realizing this potential. This study confirms that while financial support is essential, the unique challenges faced by Sunamganj farmers, such as frequent flooding, poor market infrastructure, and limited access to training, require tailored interventions beyond generalized recommendations.

Addressing these barriers will transform agricultural livelihoods in flood-prone regions and contribute to local development and global climate resilience efforts. Furthermore, the long-term success of CSA will depend on sustainable, context-specific policies that consider both environmental and socio-economic factors unique to Sunamganj. CSA's full potential can only be unlocked if localized strategies address the region's unique challenges, including the need for improved market access, flood resilience, and targeted financial support.

Recommendations

1. **Develop Region-Specific Training Programs**:
    - Tailored training modules should address Sunamganj farmers' unique challenges, particularly in flood resilience and water management. Collaboration with local agricultural experts and extension services is essential to ensure that these programs are practical, relevant, and adapted to the specific needs of farmers in the region. The training should focus on flood-resistant crops, water management techniques, and other CSA practices directly applicable to Sunamganj's specific environmental conditions.
    - This will help ensure that CSA adoption is feasible and effective, contributing to sustainable agricultural practices that are resilient to climate shocks in the region.
2. **Expand Financial Support Mechanisms**:
    - Targeted subsidy programs and low-interest credit facilities should be implemented to alleviate financial constraints. Special attention should be given to smallholder farmers disproportionately affected by resource limitations. Financial support should be designed in partnership with local microfinance institutions and banks to improve accessibility and enhance financial inclusion.
    - Such initiatives will provide smallholder farmers with the necessary financial support to adopt CSA practices and fully benefit from the economic opportunities CSA can offer despite initial investment challenges.
3. **Invest in Infrastructure Development**:
    - Improving road connectivity and building storage facilities are crucial for enhancing market access and reducing post-harvest losses. Supply chain inefficiencies have been a significant barrier to CSA adoption in

Sunamganj, as poor infrastructure limits farmers' ability to access markets and sell their products at competitive prices.

- Additionally, establishing digital platforms could provide real-time market information, enabling farmers to make informed decisions about the best times and places to sell CSA products. Such infrastructure investments will help farmers capitalize on the economic benefits of CSA adoption by reducing costs, improving market access, and increasing income potential.

4. **Strengthen Policy Frameworks and Monitoring Mechanisms**:
    - Policymakers should introduce a robust feedback and monitoring system integrating government and community stakeholders. This system should regularly track the effectiveness of CSA-related initiatives and ensure they are adaptive to changing climate conditions and responsive to the evolving needs of farmers.
    - Regularly updating strategies based on community input and emerging best practices will ensure that CSA programs remain relevant and practical. This approach also facilitates a collaborative decision-making process, empowering local farmers and stakeholders to actively participate in shaping CSA policies most beneficial to their needs.
5. **Explore Future Research Directions**:
    - Future research should investigate the long-term socio-economic impacts of CSA adoption, focusing on its role in poverty alleviation, gender equity, and overall community development. Such research will further prove CSA's ability to improve livelihoods and resilience against climate change.
    - Additionally, further studies should explore how CSA can contribute to national climate adaptation strategies and examine its impact on the broader agricultural sector. Research should focus mainly on flood-prone and climate-vulnerable regions, offering insights into how CSA can be scaled and adapted for other regions facing similar climate challenges.

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