Comprehensive Study on Existing and Viable Climate Smart Agriculture (CSA) Technologies and Practices Considering Vulnerable People Including Persons with Disabilities in Northwestern and Southwestern Bangladesh

HELVETAS BANGLADESH

Comprehensive Study on Existing and Viable Climate Smart Agriculture (CSA) Technologies and Practices Considering Vulnerable People Including Persons with Disabilities in Northwestern and Southwestern Bangladesh

Actions to Climate Change Ensuring Sustainable Solutions (ACCESS) Project
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Executive Summary

The Climate Smart Agriculture (CSA) study explores the potential of CSA practices to address the pressing challenges posed by climate change to agriculture in Bangladesh, with a focus on the northern and southwestern regions. These regions face unique vulnerabilities-flooding in the north and salinity intrusion in the southwest-that threaten agricultural productivity, food security, and livelihoods. The study provides an in-depth analysis of the adoption, barriers, and effectiveness of CSA practices, offering critical insights and actionable recommendations for promoting sustainable and resilient agricultural systems. Employing a mixed-methods approach, the study integrates quantitative and qualitative data collection methods. A total of 428 farmers were surveyed, complemented by 18 Focus Group Discussions (FGDs), 24 Key Informant Interviews (KIIs), and 12 In-Depth Interviews (IDIs). The data were collected from Kurigram, Khulna, Satkhira, and Bagerhat districts, representing diverse environmental and socio-economic contexts. Stratified random sampling was used to ensure a balanced representation of the northern and southwestern regions, reflecting their distinct vulnerabilities and agricultural practices.

The study shows that CSA technology and techniques are beneficial in Bangladesh when addressing climate challenges. Urea Depp Placement (UDP) used by 45.6% of northern farmers, zero tillage (30.2%), crop rotation (35.7%) and flood-tolerant crop varieties like BINA dhan 11 (used by 35.6% in the southwestern region) improve soil health, nutrient efficiency, and waterlogging and flooding effects. Saline-tolerant seeds like BINA dhan 10 (39.7%) and BRRI dhan 67 (9.4%), vermicomposting (15.3% of farmers) and effective irrigation techniques like the Fita method (67.8%) help reduce soil salinity and water shortages in the southwestern area. These methods boost productivity, resilience and sustainability. CSA implementation has many challenges. Farmers lack information since 60.5% are not trained. Financial constraints are a major issue with 68.7% of respondents lacking funding for CSA technology investment. Insufficient institutional assistance and 72.3% of farmers' inadequate input access hinder adoption. Due to gender discrepancies, 67.59% of northern respondents and 84.38% of southwestern respondents are women who often lack expertise, resources and decision-making power. The fact that 43.2% of farmers doubt the benefits of CSA methods shows that resistance to change and distrust of new technologies hinder adoption. To address these issues, the report suggests strengthening distribution networks for resilient seeds, bio-pesticides and modern agro-machinery. Customized training programs and practical demonstrations must target local requirements, especially by include women in CSA projects. Subsidies, grants, and microfinance are essential for vulnerable groups to acquire CSA technologies. Promoting digital tools like the "Khamari App," used by 11.9% of southwest farmers may enhance adoption. Region-specific interventions are crucial. Flood-resilient crops like BRRI dhan 52 and AWD irrigation, now 46.3% must be prioritized in northern regions. Prioritize salt-tolerant types and use Fita water management in the southwest.

The study emphasizes the need for region-specific interventions to overcome barriers and fully realize the potential of CSA technologies. Key recommendations include improving access to inputs by strengthening distribution networks for resilient seeds, bio-pesticides, and advanced agro-machinery to ensure timely availability in vulnerable regions. Capacity-building initiatives, such as training programs, practical demonstrations, and awareness campaigns, should be tailored to local needs to highlight the benefits and applications of CSA practices. Financial support in the form of subsidies, grants, and microfinance schemes is essential to make CSA technologies accessible to smallholder farmers and marginalized groups. Strengthened institutional support is also critical, requiring enhanced agricultural extension services, collaborations between research institutions and local organizations, and robust policy frameworks. Additionally, promoting digital and technological solutions, such as mobile applications and digital platforms, can provide farmers with real-time weather updates, market information, and tailored CSA recommendations.

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Abbreviations

- **CSA**: Climate Smart Agriculture
- **CPP**: Crop Protection Products
- **BADC**: Bangladesh Agriculture Development Corporation
- **FAO**: Food and Agriculture Organization
- **FGD**: Focus Group Discussion
- **KII**: Key Informant Interview
- **IDI**: In-Depth Interview
- **UDP**: Urea Deep Placement
- **INM**: Integrated Nutrient Management
- **IPM**: Integrated Pest Management
- **PTOS**: Power Tiller Operated Seeder
- **AWD**: Alternate Wetting and Drying
- **BRRI**: Bangladesh Rice Research Institute
- **BARI**: Bangladesh Agricultural Research Institute
- **BINA**: Bangladesh Institute of Nuclear Agriculture
- **HYV**: High-Yielding Variety
- **DAE**: Department of Agricultural Extension
- **NGO**: Non-Governmental Organization
- **GHG**: Greenhouse Gas
- **MoA**: Ministry of Agriculture
- **MSP**: Machinery Service Provider
- **SRI**: System of Rice Intensification
- **PRA**: Participatory Rural Appraisal
- **PIO**: Project Implementation Officer
- **LSP**: Local Service Provider
- **HH**: Household

1.

Introduction

Bangladesh is one of the world's most climate-vulnerable countries, with its agriculture sector heavily impacted by climatic adversities[1]. The nation faces a range of challenges, including flooding, salinity intrusion, erratic weather patterns, and water scarcity, which threaten food security and the livelihoods of millions. The northern regions experience frequent flooding and drought, while the southwestern areas suffer from salinity intrusion, degrading arable land and water resources.[2] These challenges demand immediate and adaptive solutions to ensure sustainable agricultural productivity. Climate-Smart Agriculture (CSA) has emerged as a critical approach to addressing these challenges effectively and efficiently. CSA integrates a wide range of practices and technologies that simultaneously enhance productivity, improve resilience to climatic hazards, and mitigate environmental impacts. The CSA framework aligns closely with the needs of Bangladesh's diverse agro-ecological zones. In the northern regions, strategies such as drought-tolerant crop varieties, efficient water management practices, and flood-adaptive farming systems help mitigate vulnerabilities[3]. Conversely, in the salinity-affected southwestern regions, salt-tolerant rice varieties, innovative irrigation systems, and soil rehabilitation techniques have proven essential[3].

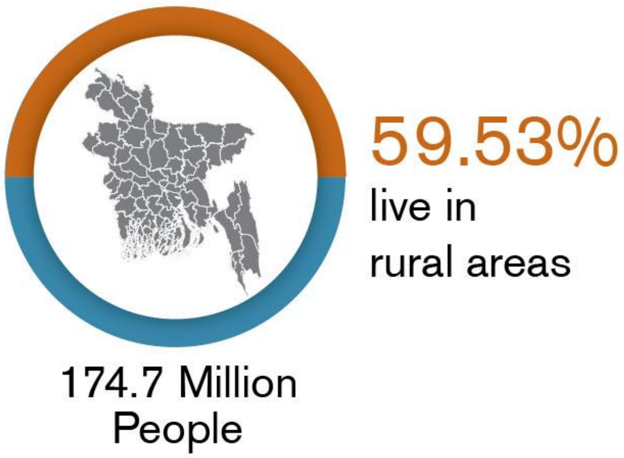

Fig. 1: *Population of Bangladesh*

Bangladesh's agriculture sector is the backbone of its economy, contributing significantly to GDP and employing nearly half of its labor force. However, the compounding effects of climate change demand transformational changes in agricultural practices. CSA provides a pathway to balance the urgent need for food security, economic stability, and environmental sustainability. By leveraging CSA technologies and practices, Bangladesh can bolster its capacity to adapt to climate variability, safeguard its agricultural systems, and secure livelihoods for its vulnerable farming communities. CSA focuses on three core pillars: productivity, climate change adaptation, and mitigation of GHG[4]. In Bangladesh, the adoption of CSA technology and practices is essential for supporting vulnerable farming communities. In the northern regions, where flooding and

[1] Eckstein, D., Künzel, V., & Schäfer, L. (2021). **Global Climate Risk Index 2021**: Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2019 and 2000–2019. Germanwatch.

[2] Shahid, S. (2010). Climate of Bangladesh: Temperature and Rainfall Changes, and Impact on Agriculture. In *Climate Change and Food Security in South Asia* (pp. 23–38).

[3] Bhuiyan, M. A. R., & Molla, M. M. (2018). Climate Smart Crops: Flood and Drought-Tolerant Crops. In *Climate Smart Agriculture in South Asia* (pp. 45–62).

[4] CGIAR. (n.d.). *What is climate-smart agriculture (CSA)?*

drought coexist, the promotion of flood-tolerant and drought-resilient crop varieties, conservation agriculture, and efficient water management techniques are critical. Practices such as alternate wetting and drying (AWD) and community seed banks further enhance farmers' ability to adapt to environmental stresses. In the southwestern region, salinity intrusion poses a significant barrier to traditional farming. CSA practices here prioritize the use of salt-tolerant rice varieties, integrated soil and fertilizer management techniques, and innovative irrigation systems like fita pipes. Additionally, vermicompost, crop rotation, and integrated pest management (IPM) provide long-term solutions to improve soil health and ensure food security. Technologies like rice transplanters and urea deep placement (UDP) applicators further enable efficient resource use while reducing environmental impacts. Some of the technologies are given below,

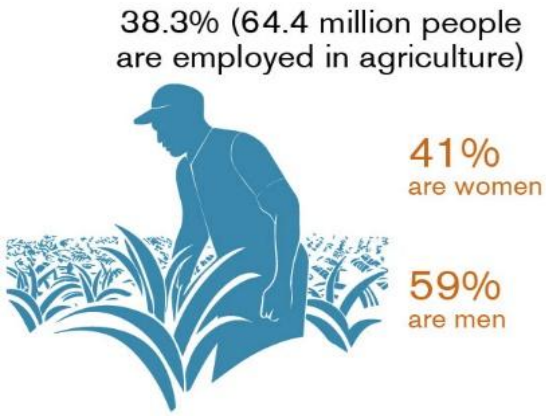

Fig. 2 *People Engage with Agriculture*

a) **Urea Deep Placement (UDP):** UDP is an innovative fertilizer application technique where nitrogen-rich urea briquettes are placed 7–10 cm deep into the soil near the plant roots. This method reduces nitrogen losses due to leaching, runoff, and volatilization, thereby improving nitrogen use efficiency, increasing crop yields and minimizing environmental pollution.

b) **Zero Tillage:** Zero Tillage is a conservation agriculture practice that eliminates traditional plowing or soil disturbance before planting. Seeds are directly sown into undisturbed soil, preserving soil structure, improving organic matter content, reducing erosion and conserving moisture.

c) **Crop Rotation:** Crop rotation is the practice of growing different types of crops sequentially on the same piece of land. This approach prevents nutrient depletion, breaks pest and disease cycles and improves soil fertility, resulting in higher productivity and sustainable land use.

d) **Alternate Wetting and Drying (AWD):** AWD is a water-saving irrigation technique used in rice cultivation. It involves alternating periods of wet and dry conditions in the paddy fields instead of continuous flooding. This method conserves water, reduces methane emissions and promotes healthy root development, enhancing productivity.

e) **Fita Method Practice:** The Fita Method involves using plastic pipes or "fita" for precise irrigation in agricultural fields. This technique ensures efficient water distribution, reduces wastage, and maintains optimal soil moisture levels, particularly in saline-affected areas.

f) **Floating Vegetable Cultivation:** Floating vegetable cultivation is a unique adaptation to waterlogged or flooded conditions. It involves growing vegetables and spices on floating beds made from water hyacinth and other organic materials. This practice sustains production during inundation, enhances food security and utilizes otherwise unproductive waterlogged areas.

g) **Pond-Dyke Cropping System:** The pond-dyke cropping system integrates aquaculture and horticulture. Ponds are used for fish farming, while the dykes (edges) surrounding the ponds are utilized for growing vegetables and fruits. This method maximizes land use efficiency, enhances income diversification and is especially suitable for saline-affected and waterlogged regions.

1.1 Context and Background

Bangladesh, as one of the most climate-vulnerable countries in the world, faces multifaceted environmental challenges that threaten agricultural sustainability and rural livelihoods. The northern and southwestern regions are acutely impacted by two distinct climate vulnerabilities: flooding in the north and salinity intrusion in the southwest. These challenges undermine agricultural productivity, food security, and the resilience of rural communities, emphasizing the need for adaptive solutions such as Climate Smart Agriculture (CSA). The northern region, characterized by low-lying areas and proximity to the Brahmaputra River, is highly susceptible to seasonal flooding and riverbank erosion[2]. These events displace communities, degrade arable land and disrupt traditional farming practices, often leading to significant economic losses. In contrast, the southwestern region faces the creeping threat of climate change-induced salinity intrusion, exacerbated by sea-level rise and tidal surges. The increasing salinization of soil and water resources has rendered traditional agricultural methods ineffective, compounding the risks of water scarcity and reduced crop yields[5].

Fig. 3 *Economic Role in Agriculture*

Agriculture plays a critical role in Bangladesh's economy, contributing around 12-16% of GDP and employing nearly 40% of the labor force[6]. The country's agricultural system is characterized by its reliance on rice cultivation, which accounts for 70% of the caloric intake for the population[6]. Bangladesh has achieved notable progress in modernizing its agricultural practices, including the adoption of high-yielding crop varieties, improved irrigation techniques, and climate-resilient farming strategies[7]. Agricultural sustainability in Bangladesh faces significant threats due to a combination of socio-economic, environmental, and climatic challenges[8]. Climate change amplifies these challenges by introducing more frequent and severe weather events, such as flooding, salinity intrusion, and droughts, which directly affect crop yields and water availability. Coastal regions experience rising sea levels, contaminating freshwater resources and rendering vast tracts of farmland unsuitable for cultivation. Simultaneously, riverbank erosion in northern floodplains leads to displacement and reduces agricultural productivity.

These vulnerabilities are not uniform across the country. Geographic and climatic differences create region-specific challenges. For instance, flooding and waterlogging are predominant issues in the northern floodplains, whereas salinity is a critical concern in the southwest coastal region. This heterogeneity demands tailored strategies that incorporate both traditional agricultural practices and innovative, climate-smart technologies to address localized risks while ensuring long-term sustainability. The combined impacts of these factors necessitate urgent interventions that balance the competing demands of food security, environmental preservation, and climate adaptation. Comprehensive efforts to integrate resource-efficient practices, such as improved irrigation systems, soil conservation techniques and climate-resilient crop varieties, are essential to safeguarding the livelihoods of Bangladesh's agricultural communities.

HELVETAS Bangladesh is devoted to promoting sustainable development by fostering resilience and improving the livelihoods of marginalized communities across the country. With extensive expertise in implementing climate-resilient initiatives, HELVETAS prioritizes empowering vulnerable populations, particularly smallholder farmers, to adapt to the adverse impacts of climate change. The Climate Smart Agriculture (CSA) study is a testament to this mission, aiming to address critical regional challenges, such as flooding in the north and salinity intrusion in the southwest. This study emphasizes sustainable farming practices, resource-efficient technologies, and capacity-building efforts to enhance productivity and strengthen resilience against climate-induced risks. Through this initiative, HELVETAS not only tackles immediate vulnerabilities but also contributes to long-term goals of food security, environmental sustainability, and social equity. By integrating innovative approaches and participatory planning, HELVETAS ensures that the CSA study aligns with the needs of local communities while contributing to national and global efforts to combat climate change.

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[5] Miah, M. A. M., Islam, M. S., & Rahman, M. M. (2020). Impact of salinity intrusion on agriculture of Southwest Bangladesh: A review. *International Journal of Agricultural Policy and Research*, 8(2), 43–52.

[6] Bangladesh Bureau of Statistics. (2023). *Yearbook of Agricultural Statistics 2022*. Ministry of Planning, Government of the People's Republic of Bangladesh.

[7] U.S. Department of Commerce. (n.d.). *Bangladesh - Agriculture Sectors*. International Trade Administration. Retrieved December 9, 2024.

[8] Tabassum, N., & Rezwana, F. (2021). Bangladesh Agriculture: A Review of Modern Practices and Proposal of a Sustainable Method. *Proceedings*, *11*(1), 12.

1.2 Study Objectives

There are some specific objectives of the study including:

- Document and evaluate current CSA technologies, practices, and varieties specific to the targeted Unions/locations.
- Analyze factors hindering the adoption of CSA technologies in the region.
- Investigate the current adoption rate of CSA technologies.
- Identify and evaluate viable CSA technologies practices that can be adapted to changing soil and water conditions due to climate change, with special consideration for vulnerable communities, including persons with disabilities.
- Propose a value chain and business model for those suitable CSA technologies and evaluate constraints within the value chain in response to climate change.
- Develop a comprehensive guideline for the introduction and implementation of these CSA practices in the specified Unions.

1.3 Research Questions

The research questions in this report guide the CSA study's exploration of innovative solutions for addressing the agricultural challenges of flooding and salinity intrusion in Bangladesh. These questions aim to uncover the current state, barriers, and potential of CSA technologies, fostering actionable insights to promote sustainable agriculture and resilience in vulnerable farming communities.

- What are the current Climate Smart Agriculture (CSA) technologies, practices, and crop varieties adopted in the northern and southwestern regions of Bangladesh?
- What are the primary barriers (socioeconomic, technical, and institutional) hindering the adoption of CSA technologies in these regions?
- How effective are the existing CSA technologies in enhancing agricultural productivity, adaptation to climate challenges, and mitigation of greenhouse gas emissions?
- What are the viable CSA technologies and practices that can address region-specific challenges such as flooding in the northern region and salinity intrusion in the southwestern region?
- How can CSA technologies and practices be made more accessible and inclusive, particularly for women, youth, and persons with disabilities?
- What are the opportunities for scaling CSA technologies through cooperative models, social enterprises, and digital platforms?
- How can the value chains for CSA technologies be strengthened to benefit marginalized farmers in the study areas?

2.

Literature Review

Climate Smart Agriculture (CSA) is a transformative approach to agricultural development that addresses the challenges posed by climate change. It focuses on achieving three primary objectives: enhancing productivity, adapting to climate variability, and mitigating greenhouse gas (GHG) emissions (FAO, 2013). By integrating these objectives, CSA offers a framework to ensure food security while promoting environmental sustainability.

2.1 Practices Present in Bangladesh

Bangladesh, with its diverse agricultural landscape, has adopted numerous CSA practices tailored to its region-specific vulnerabilities. Key practices include salinity-tolerant crop varieties in the southwestern coastal regions and flood-resistant rice in the northern areas. Efficient water management systems such as Alternate Wetting and Drying (AWD) and fita pipe irrigation are widely employed. Farmers are increasingly utilizing Integrated Nutrient Management (INM) techniques combining organic compost and inorganic fertilizers to enhance soil fertility. Other innovations include agro-machineries like power tiller-operated seeders and climate-smart pest management practices like using pheromone traps and biopesticides.

In Bangladesh, the significance of CSA is particularly pronounced due to its climate-vulnerable geography, characterized by frequent flooding in the north and salinity intrusion in the southwest. Studies highlight the potential of CSA to transform the country's agricultural sector by introducing adaptive practices and technologies that align with global sustainability goals. For instance, urea deep placement (UDP) and alternate wetting and drying (AWD) irrigation techniques have been successfully implemented to address region-specific challenges, offering both environmental and economic benefits[9]. Farmers in Bangladesh demonstrate varying levels of awareness and acceptance of CSA technologies. In the southwestern region, many perceive salinity-tolerant seeds as essential for combating soil degradation, though cost and availability remain significant barriers. In the flood-prone northern areas, CSA practices such as floating vegetable beds and flood-tolerant rice are viewed as lifesaving innovations[10]. However, farmers often highlight the lack of training, financial support, and knowledge dissemination as obstacles to broader adoption. Some remain skeptical about the long-term benefits due to the uncertainty of outcomes and the initial investment required. Despite its potential, CSA adoption in Bangladesh faces barriers such as knowledge gaps, financial constraints, and limited institutional support[11]. Behavioral frameworks and adoption models emphasize the need for targeted awareness campaigns, capacity-building initiatives, and financial incentives to overcome these challenges and scale CSA practices effectively.

[9] Islam, M. R., Sarker, M. N. I., & Rahman, M. M. (2018). Adoption of climate-smart agricultural technologies in Bangladesh: A review. *Journal of Agricultural Science and Technology*, 20(1), 21–31.

[10] France24. (2021, October 28). *Floating farms, salt-resistant rice: Bangladeshis adapt to survive*.

[11] Rogers, E. M. (2003). *Diffusion of Innovations* (5th Edition.).

2.2 Region-Specific Climate Smart Agriculture (CSA) Interventions in Bangladesh

Bangladesh faces dual region-specific agricultural vulnerabilities that necessitate targeted Climate Smart Agriculture (CSA) interventions. In the northern region, districts like Kurigram are frequently impacted by severe flooding and waterlogging caused by seasonal monsoon rains and the overflow of the Brahmaputra River. These conditions result in widespread damage to crops, soil erosion, and loss of arable land. CSA practices such as flood-tolerant crop varieties, zero tillage, and improved water management techniques like Alternate Wetting and Drying (AWD) play a pivotal role in adapting to these challenges by ensuring productivity and sustainability in waterlogged conditions[12]. Conversely, the southwestern region, including Khulna, Satkhira, and Bagerhat, faces the creeping threat of salinity intrusion driven by sea-level rise, tidal surges, and reduced upstream freshwater flow. These conditions degrade soil quality and reduce freshwater availability, making traditional agriculture unsustainable. CSA strategies tailored for this region focus on salinity-tolerant rice varieties, integrated nutrient management combining organic and inorganic fertilizers, and efficient irrigation methods like fita pipes and solar-powered pumps to ensure resilience against salinity-related stresses[13]. Integrating these regional vulnerabilities into the CSA framework aligns with the three FAO pillars—productivity, adaptation, and mitigation. In flood-prone areas, the focus is on enhancing water and soil resilience, while in salinity-affected zones, the emphasis is on soil health and water efficiency. These practices not only improve productivity but also minimize environmental impacts, such as greenhouse gas emissions, supporting sustainable agricultural development[14]. Additionally, these vulnerabilities underscore the importance of socio-economic inclusivity, particularly for marginalized groups such as smallholder farmers, women, and youth. Tailored CSA interventions that address region-specific needs contribute to building resilient communities while enhancing food security and environmental sustainability.

[12] Ahmed, S., Rahman, M., & Jahan, S. (2018). Flood resilience and sustainable agriculture in northern Bangladesh. *International Journal of Agricultural Research*, 12(4), 123–134.

[13] Hossain, T., Alam, Z., & Khatun, F. (2020). Tackling salinity intrusion through adaptive agriculture. *Journal of Coastal Zone Management*, 18(3), 67–78.

[14] Hasan, M., Karim, R., & Anwar, H. (2021). The role of CSA in mitigating climate challenges in Bangladesh. *Climate and Agriculture Review*, 5(2), 34–49.

3.

Conceptual Framework

3.1 FAO CSA Pillars

FAO's Climate Smart Agriculture (CSA) pillars focus on productivity, adaptation, and mitigation, providing a comprehensive framework to address agricultural challenges in the context of climate change.

- Productivity aims to ensure food security by increasing agricultural yields and resource efficiency. Practices like saline-tolerant rice and AWD irrigation are examples of productivity-focused initiatives in Bangladesh[15].
- Adaptation enhances resilience to climate risks like floods and salinity. Techniques such as crop rotation, zero tillage, and community seed banks are critical to adapting agricultural systems to specific regional vulnerabilities.
- Mitigation targets reducing GHG emissions. Practices like integrated nutrient management (INM), organic composting, and bio-pesticides help balance productivity with environmental sustainability.

These pillars form the basis for implementing region-specific CSA practices that simultaneously address food security, resilience, and environmental conservation.

3.2 Rogers' Diffusion of Innovations Framework

Rogers' framework highlights the dynamics of innovation adoption, providing critical insights for CSA implementation. The framework identifies five attributes:

- **Relative Advantage:** The perceived benefit of CSA technologies, such as reduced input costs and increased productivity, encourages farmers to adopt practices like UDP and AWD[16].
- **Compatibility:** Technologies that align with existing cultural practices and regional conditions, such as saline-tolerant seeds, gain faster acceptance among farmers in Bangladesh's coastal regions.
- **Complexity:** Simplifying CSA techniques through training and support enhances adoption. Farmers who find technologies less complicated are more likely to embrace them.
- **Trialability:** Demonstration plots and pilot study allow farmers to test CSA innovations, building trust and confidence in their effectiveness[17].

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[15] Rahman, M., Hossain, M., & Khan, T. (2020). Resilience of agriculture to climate change: A CSA approach. *Agricultural Systems in South Asia*, 15(4), 311–326.

[16] Islam, M. S., & Aktar, R. (2018). Adoption of CSA practices: Evidence from Bangladesh. *Climate Change and Agriculture Research*, 10(1), 23–34.

[17] Ahmed, S., Sarker, R., & Kabir, A. (2022). Promoting trialability in CSA practices: Lessons from Bangladesh. *CSA Policy Brief*, 12(3), 34–41.

- **Observability:** Tangible success stories, such as higher crop yields in neighboring farms using CSA, drive adoption by providing real-world validation of benefits.

3.3 Behavioral Adoption Framework

The Behavioral Adoption Framework emphasizes socio-economic inclusivity and highlights barriers faced by vulnerable groups, including women, youth, and persons with disabilities[18]. Key elements include:

- **Gender Inclusion:** Women often have limited access to resources and training. CSA practices like home-based polyhouse farming empower women by promoting low-input technologies that align with their socio-economic realities.
- **Financial Constraints:** Financial barriers remain a significant challenge. Subsidies, microfinance options, and grants help bridge the gap for smallholder farmers adopting CSA technologies[19].
- **Youth Engagement:** Digital tools like mobile applications provide younger farmers with resources, connecting them to CSA markets and advisory services.
- **Capacity Building:** Training programs and farmer field schools build technical expertise and foster a culture of innovation, enabling sustainable agricultural practices.

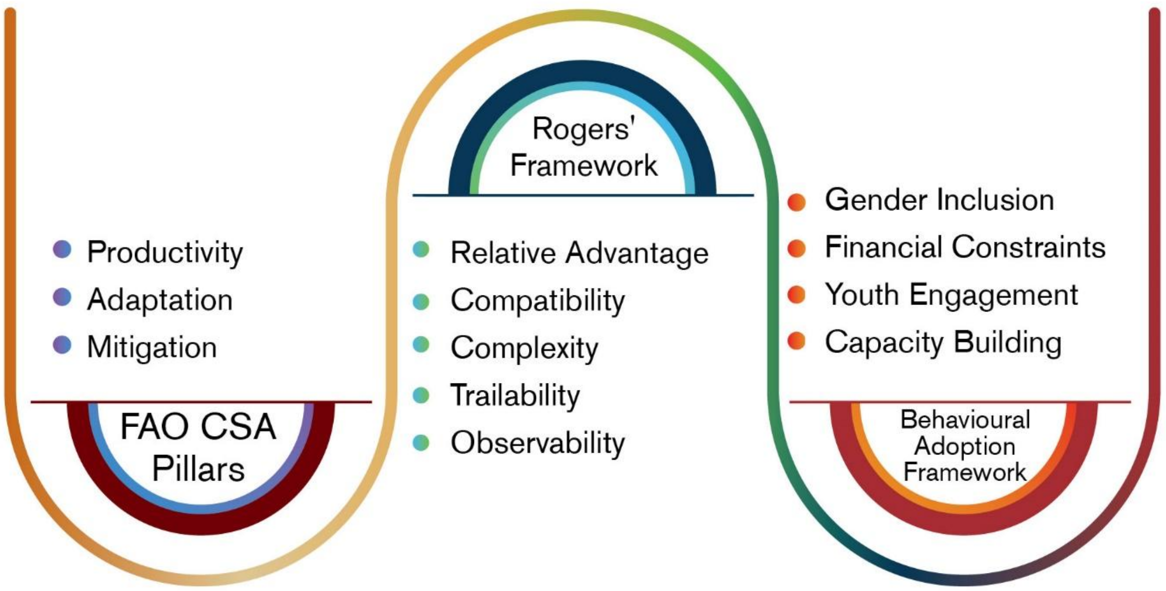

Fig. 4 Conceptual Framework of the Study

[18] Ali, A., Jahan, N., & Uddin, K. (2020). Behavioral adoption framework for CSA technologies in Bangladesh. *Journal of Social Inclusion in Agriculture*, 5(1), 78–96.

[19] Hassan, T., Khan, S., & Alam, A. (2018). Addressing financial constraints in CSA adoption: A review. *Agricultural Development and Policy Journal*, 14(5), 56–72.

3.4 Research Matrix

Table 1. Research Matrix

Objectives	Indicators/Key Issues/Areas of Inquiry	Data Sources	Data Collection Methods/Tools	Data Analysis Methods	Framework (if applicable)
Objective 1: Document and evaluate current CSA technologies, practices, and varieties specific to the targeted Unions/locations.	• Inventory of existing CSA technologies, categorized by FAO CSA pillars: productivity, adaptation, and mitigation. • Compatibility of technologies and practices with local soil, water, and climate conditions (Rogers' compatibility element). • Effectiveness: cost, adoption rates, profitability, and environmental benefits (relative advantage from Rogers' framework). • Barriers to adoption related to trialability and perceived complexity (Rogers' framework).	• Farmers • Extension workers • Secondary reports (scientific evidence and policies)	• Documents review- • Household Survey • Key Informant Interviews (KIIs) • In-depth Interviews (IDIs) • Focus Group Discussions (FGDs) • Literature review • Field observations	• Descriptive statistics • Qualitative thematic analysis	CSA technologies (e.g., FAO CSA pillars)
Objective 2: Analyze factors hindering the adoption of CSA technologies in the region.	• **Socioeconomic barriers:** access to inputs, costs, gender disparities. • **Technical barriers:** knowledge gaps, skill levels, trialability (Rogers' framework). • **Policy/institutional barriers:** lack of incentives, extension services (Behavioral Adoption Framework).	• Farmers • Local institutions • NGOs	• FGDs • KIIs • IDI • Surveys	• SWOT analysis • Regression analysis for key factors	Behavioral adoption frameworks (e.g., Theory of Planned Behavior)
Objective 3: Investigate the current adoption rate of CSA technologies.	• Adoption rates across technologies, categorized by demographics (gender, age, disability status). • Patterns of early adopters, majority, and laggards (Rogers' adopter categories). • Perceived benefits and user experiences (relative advantage and observability).	• Farmers • Extension workers	• Household surveys • FGDs	• Adoption curve analysis • Comparative statistics	Rogers' Diffusion of Innovations framework

Objectives	Indicators/Key Issues/Areas of Inquiry	Data Sources	Data Collection Methods/Tools	Data Analysis Methods	Framework (if applicable)

Objective 4: Identify and evaluate viable CSA technologies/practices for changing soil and water conditions, considering vulnerable groups.	• CSA technologies suited for salinity, waterlogging, and drought (FAO CSA adaptation pillar).
	• Cost-effective technologies for marginalized farmers (Rogers' compatibility and trialability).
	• **Inclusivity:** suitability for women, youth, and persons with disabilities (Behavioral Adoption Framework).
		• Farmers
		• Agricultural experts
		• Local organizations
			• KIIs, IDI
			• Participatory Rural Appraisal (PRA), specifically using:
			  ○ Transect Walks
			  ○ Seasonal Calendars
			  ○ Venn Diagrams
			  ○ Matrix Ranking/Scoring
			  ○ Resource Mapping
			• Expert consultations
				• Multi-criteria decision analysis (MCDA)
				• Thematic analysis
					Climate vulnerability and adaptive capacity frameworks

Objective 5: Propose value chains and business models for suitable CSA technologies and evaluate constraints in response to climate change.	• Key actors in CSA value chains (Porter's primary and support activities). • Gaps in input supply, marketing, and finance (Porter's value chain constraints). • Business models: opportunities for scaling CSA technologies.	• Farmers • Traders • Input suppliers • Financial institutions	Value chain mapping through • KIIs • IDI • FGDs	• Value chain analysis • Business model canvas	Porter's Value Chain Model
Objective 6: Develop a comprehensive guideline for the introduction and implementation of these CSA practices in the specified Unions.	• Best practices categorized under FAO CSA pillars: productivity, adaptation, and mitigation. • Training and capacity-building needs based on gaps identified in the adoption framework. • Strategies for inclusive implementation (gender, disability, youth participation).	• Policy documents • Local leaders • Farmers	• Literature review • Policy analysis • Stakeholder workshops	• Content analysis • Policy gap analysis	Inclusive development frameworks

4.

Research Area

The CSA study is focused on four districts in Bangladesh, selected for their climate vulnerabilities and significance in promoting climate-smart agricultural practices. In the northern region, the study covers Kurigram with its upazilas, Kurigram Sadar and Ulipur, known for their susceptibility to flooding and waterlogging. In the southwestern region, the study includes Khulna (Paikgasa and Koyra Sadar), Satkhira (Tala and Assasuni), and Bagerhat (Morrelganj and Sarankhola), which face severe salinity intrusion and cyclones that challenge traditional farming methods and community resilience. The study aims to implement adaptive CSA strategies tailored to each area's unique environmental conditions to enhance agricultural sustainability and support vulnerable communities.

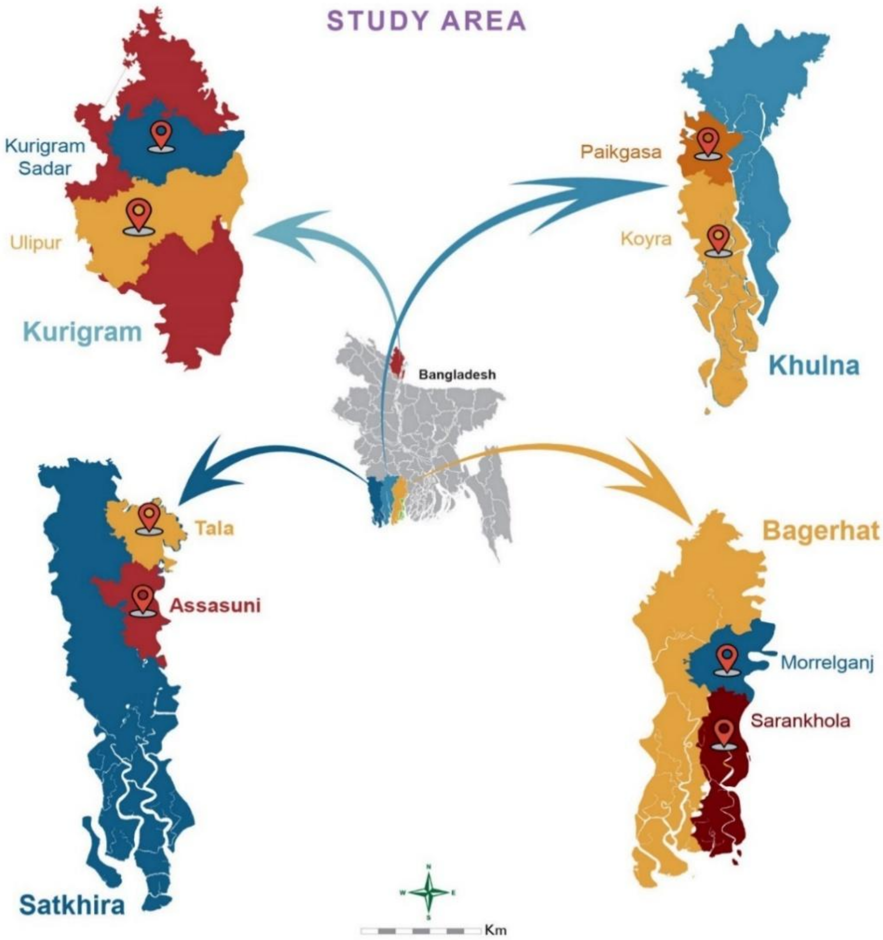

***Fig. 5** Study Areas*

5.

Methodology

5.1 Data Collection Methods

This study employs a comprehensive, multi-faceted approach to data collection, integrating both qualitative and quantitative methods to thoroughly assess Climate Smart Agriculture (CSA) practices and their impacts in the target regions. By combining these approaches, the study seeks to capture a holistic understanding of CSA adoption, addressing both tangible and intangible factors influencing its implementation.

Qualitative data collection was conducted through Focus Group Discussions (FGDs) with farmers and Key Informant Interviews (KIIs) with agricultural experts, policymakers, and extension officers. The FGDs provided a platform for farmers to share their lived experiences, highlighting the challenges, opportunities, successes, and cultural practices associated with CSA adoption. Concurrently, the KIIs drew on the expertise of stakeholders to identify systemic barriers, technological gaps, and policy shortcomings that may impede the wider adoption of CSA technologies. This qualitative component ensures the study captures nuanced insights into the socio-cultural and institutional dynamics shaping CSA practices.

Quantitative data collection involved structured surveys administered to a representative sample of farmers across the northern and southwestern regions. This approach facilitated the collection of robust, measurable data on farmers' practices, adoption rates, and the effectiveness of CSA technologies.

5.2 Sampling Techniques

The Climate Smart Agriculture (CSA) study employs stratified random sampling as its primary method to ensure a comprehensive and representative analysis of the target population. Stratified random sampling is particularly well-suited for this study because it divides the population into distinct strata based on specific regional vulnerabilities, such as flooding in the northern region and salinity intrusion in the southwestern region. This approach allows for more precise data collection by ensuring that each stratum is adequately represented in the sample, reflecting the unique challenges and opportunities faced by farmers in these areas.

In this study, the population was divided into two primary strata based on geographic and climatic vulnerabilities:

- **Northern Region:** This includes Holokhana union in Kurigram Sadar and Buraburi union in Ulipur Upazila.
- **Southwestern Region**: This includes unions of Paikgasa and Koyra Sadar Upazilas in Khulna, Morrelganj and Sarankhola in Bagerhat, and Tala and Assasuni in Satkhira.

Within each stratum, a random sampling method was employed to select respondents, ensuring that every farmer or relevant stakeholder had an equal chance of being included in the study. This approach mitigates selection bias and guarantees the inclusion of diverse farming practices, socio-economic backgrounds, and levels of CSA adoption across the regions. The sample size for the study was calculated using Cochran's formula, tailored to the study's context, with adjustments for design effect and stratification. The study aimed to achieve proportional representation by allocating samples in proportion to the population size of each stratum. For example, the southwestern region, with a higher population density and greater exposure to salinity, was assigned a larger sample size compared to the northern region. Stratified random sampling ensures that the study accurately reflects regional differences in agricultural practices, adoption rates of CSA technologies, and the socio-economic characteristics of farming communities.

5.3 Sampling Distributions

The Climate Smart Agriculture (CSA) study involved a comprehensive data collection process designed to gather diverse perspectives and insights from stakeholders across the northern and southwestern regions of Bangladesh. The study utilized multiple methods, including questionnaire surveys, Focus Group Discussions (FGDs), In-Depth Interviews (IDIs), and Key Informant Interviews (KIIs), to ensure a strong and representative dataset for analysis.

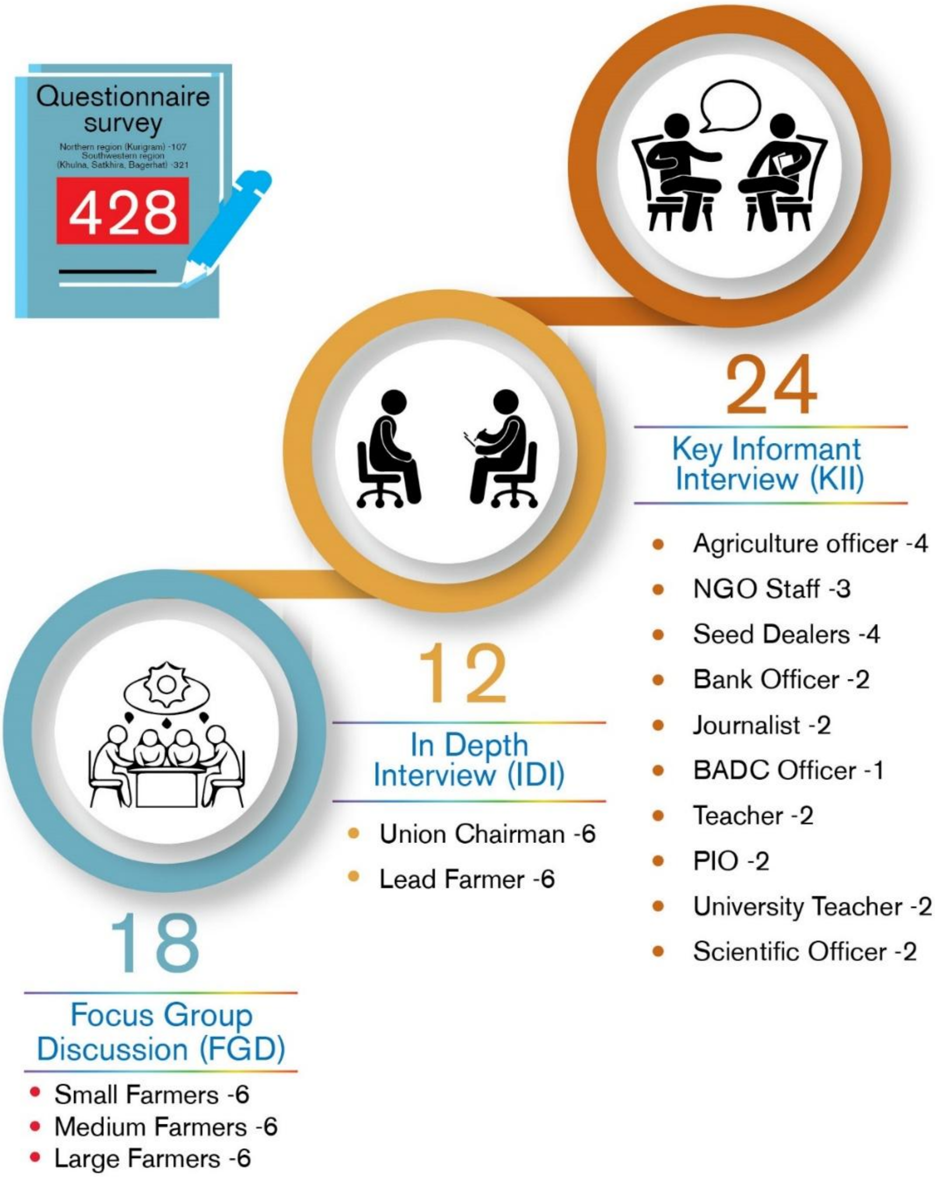

Fig. 6 *Sample Distribution*

A total of 428 questionnaire surveys were conducted with farmers to capture quantitative data on the adoption rates, impacts, and challenges associated with CSA practices. These surveys provided insights into key socio-economic factors, including household characteristics, farm size, income levels, and awareness of CSA technologies. The study also incorporated 18 Focus Group Discussions (FGDs) with various community groups, including farmers and local leaders. These FGDs facilitated open dialogue to explore collective experiences, perceptions, and barriers to adopting CSA practices, fostering a deeper understanding of localized challenges and opportunities. In-Depth Interviews (IDIs) were conducted with 12 participants, focusing on individuals who could provide detailed, context-specific insights. These included lead farmers, marginalized community members, and beneficiaries of CSA-related initiatives. The IDIs highlighted personal narratives and unique challenges faced by these stakeholders, adding depth to the study's findings. Additionally, 24 Key Informant Interviews (KIIs) were carried out with agricultural extension officers, local government representatives, university researchers, seed dealers, NGO staff, journalists, union chairpersons, and lead farmers. These interviews provided expert opinions on policy frameworks, institutional capacities, and technical support mechanisms relevant to CSA adoption.

5.4 Quantitative Assessment

Quantitative data collection for this study involves structured surveys that assess the adoption rates and impacts of Climate Smart Agriculture (CSA) technologies. The surveys focus on soil and water quality, socio-economic factors, and farmers' perceptions. Data is gathered from a representative sample of farmers across the northern and southwestern zones of Bangladesh. With a total population of 789,149, including 191,001 in the northern zone and 589,150 in the southwestern zone, the sample is proportionately stratified to reflect these regional differences. This approach ensures that the survey captures the diverse experiences and challenges faced by communities in these climate-affected areas. A standard sampling formula tailored to the study's context guides the sample size calculation, ensuring robust and representative data for analysis. This quantifies CSA adoption and its effectiveness in enhancing agricultural resilience to climate change. The study uses Cochran's formula, a widely recognized method for estimating an appropriate sample size in quantitative research. The formula is as follows:

$$n_0 = \frac{Z^2\, p(1-p)}{d^2}$$
$$= \frac{(1.645)^2 \times 0.50 \times 0.50}{(0.05)^2}$$
$$= 270.6 \approx 271$$

Cochran's formula is tailored to this study as it provides a statistically robust sample size suitable for large populations, ensuring a 90% confidence level and a 10% margin of error. The proportion p is set at 0.50 to account for maximum variability, which is appropriate for this study given the diverse adoption rates of CSA technologies in the heterogeneous regions of Bangladesh.

Where, n0= Desired sample size, Z = Standard normal deviate usually set at 1.645 which corresponds to the 90% confidence interval; P = Proportion in the target population estimated to have characteristic and here it takes to be 0.50 such as p+q = 1; d = Desire precision (here desire precision is to be considered as 5% i.e., 0.05). For this study we use the total directly affected vulnerability. The design effect accounts for the increase in sample size due to clustering within the study.

The formula for design effect (DE) is:

$$DE = 1 + (m-1)\rho$$

Here,
m= Average cluster size= 30
ρ= 0.02 (moderate level of similarity) for CSA study

$$DE = 1 + (30-1) \times 0.02$$
$$DE = 1.58$$

Multiply the initial sample size (n0) by the design effect (DE):

$$n_{adjusted} = n_0 \times DE$$
$$n_{adjusted} = 271 \times 1.58$$
$$n_{adjusted} = 428.18 \approx 428$$

Given the significant heterogeneity between the two study regions, Kurigram in the north and Khulna in the southwestern coast- a stratified random sampling technique is employed rather than simple random sampling. This approach divides the population into distinct strata (e.g., by region, gender, or livelihood type), ensuring that each subgroup is proportionally represented in the sample.

5.4.1 Qualitative Assessment through Comprehensive Approach

In the qualitative data collection for the study on Climate Smart Agriculture (CSA) technologies in the north and southwestern regions of Bangladesh, a comprehensive approach is employed. Focus Group Discussions (FGDs) are conducted with farmers and community leaders to explore the challenges they face and the current agricultural practices in the region. These discussions provide valuable insights into the local context, uncovering barriers and opportunities for implementing CSA technologies. Additionally, Key Informant Interviews (KIIs) are held with experts, policymakers, and study staff to gather in-depth perspectives on the barriers to CSA adoption and effective strategies. The combination of FGDs and KIIs enriches the understanding of local experiences, helping identify opportunities for enhancing resilience to climate change. This qualitative data informs us of the development of targeted, context-specific interventions to promote sustainable agricultural practices in the region.

5.5 Data Analysis Method

This section outlines the systematic approach used to interpret data collected through surveys, interviews and discussions. By combining quantitative and qualitative analysis techniques, the study provides a comprehensive understanding of Climate Smart Agriculture (CSA) adoption, effectiveness and challenges. This integrated approach ensures that the findings are reliable, meaningful, and relevant for promoting sustainable agricultural practices in the northern and southwestern regions of Bangladesh.

5.5.1 Quantitative Analysis

The data analysis focuses on assessing the adoption and effectiveness of Climate-Smart Agriculture (CSA) practices in the northern and southwestern regions. Using SPSS, we analyzed how CSA practices, such as drought-resistant crop varieties and water management in the north, and salt-tolerant crops and coastal soil management in the southwest, are perceived and implemented in each area. The analysis explores the perceived effectiveness of these practices in enhancing agricultural productivity and resilience to climate impacts. It also examines the challenges faced by farmers in both regions, including access to resources and knowledge. SPSS helped identify regional variations in the adoption of CSA practices and evaluate how factors like institutional support and local climate conditions influenced these practices.

5.5.2 Qualitative Analysis

The CSA study follows a systematic approach to identify and interpret key patterns within the qualitative data. This process begins with familiarization, where data is thoroughly reviewed to gain initial insights. Next, important segments are coded, highlighting relevant details aligned with the study's objectives. These codes are then grouped into potential themes, which are carefully reviewed and refined to ensure accuracy and relevance. Finally, themes are clearly defined and integrated into the findings, forming the basis for a comprehensive narrative that reflects the challenges, opportunities, and insights surrounding CSA adoption in the northern and southwestern regions of Bangladesh. This stepwise approach ensures a clear and meaningful interpretation of the qualitative data.

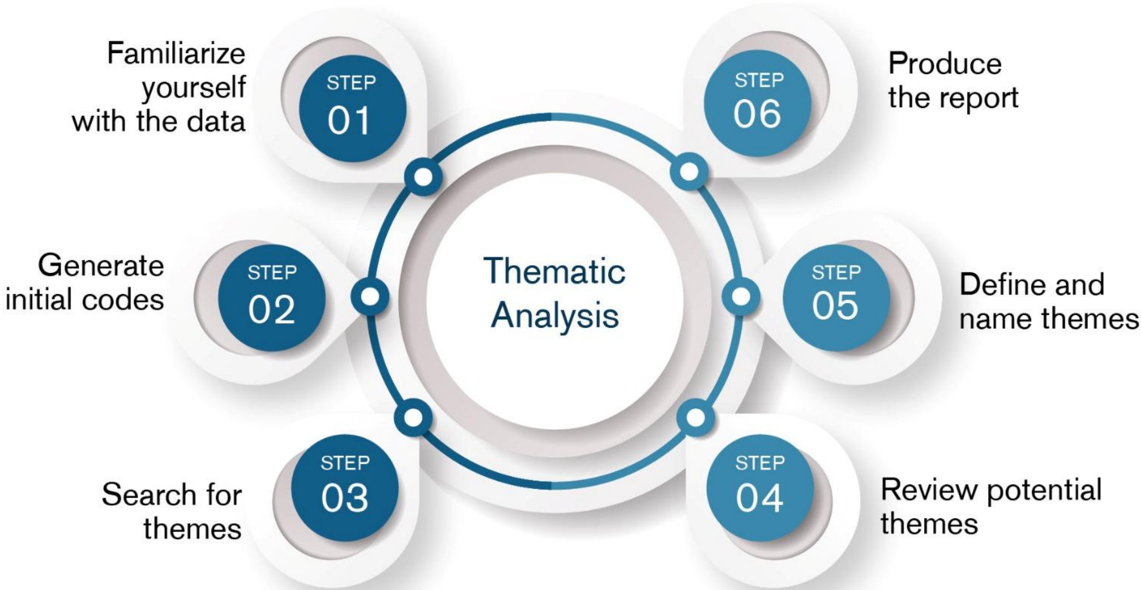

Fig. 7 *Qualitative Analysis*

5.6 Challenges and Limitations

The study encountered several challenges and limitations that may have influenced the results and interpretation of the findings. One of the primary challenges was the reliance on self-reported data from farmers and other stakeholders. Respondents may have overestimated or underestimated the adoption of CSA practices, or the benefits derived from them due to social desirability bias or a lack of complete knowledge of certain practices. Additionally, the northern and southwestern regions of Bangladesh present diverse agricultural environments and climate challenges, which may have affected the adoption of CSA practices in ways that are difficult to fully capture. Regional differences in local conditions, such as soil types, water access, exposure to climate risks, and the availability of resources, further complicated the assessment.

Moreover, the level of knowledge, awareness, and access to information on CSA practices varied significantly among respondents, potentially leading to discrepancies in reported data. Logistical constraints and limited time for fieldwork posed additional challenges, restricting the depth of exploration into some issues. While efforts were made to ensure the inclusion of marginalized groups, such as women, youth, and persons with disabilities, barriers to participation-such as mobility issues, cultural norms, or time constraints-may have limited their representation in the study.

6.

Results and Discussion

6.1 Demographic Information

Understanding the demographic characteristics of participants is crucial for evaluating the adoption and impact of Climate Smart Agriculture (CSA) technologies in the northern and southwestern regions of Bangladesh. This section delves into four key demographic factors-age, gender, education, and occupation-that shape the farming practices and decision-making processes within these communities. By analysing these attributes, the study aims to provide a comprehensive perspective on how demographic diversity influences the interest of CSA practices, enabling tailored interventions that align with the unique needs and challenges of different groups.

Age distribution highlights generational involvement in agriculture, shedding light on experience, adaptability, and openness to innovation. Gender analysis explores the roles and contributions of men and women in farming, addressing disparities in access to resources and technology. Education levels reveal the capacity for understanding and adopting new agricultural techniques, while occupation profiles identify the primary livelihoods and their compatibility with CSA interventions. Together, these factors create a detailed demographic landscape that informs sustainable agricultural development strategies.

6.1.1 Age of the Respondents

The CSA study examined the age distribution of respondents in the Northern (Kurigram) and Southwestern (Khulna, Satkhira, Bagerhat) regions. The 31–40 years age group was the largest, representing 33.33% in the Northern and 33.44% in the Southwestern regions, underscoring their key role in agriculture. The 41–50 years group followed, contributing 23.10% and 25.94%, respectively, reflecting the value of experience. Youth aged 15–30 years showed moderate involvement, comprising about 27% in both regions.

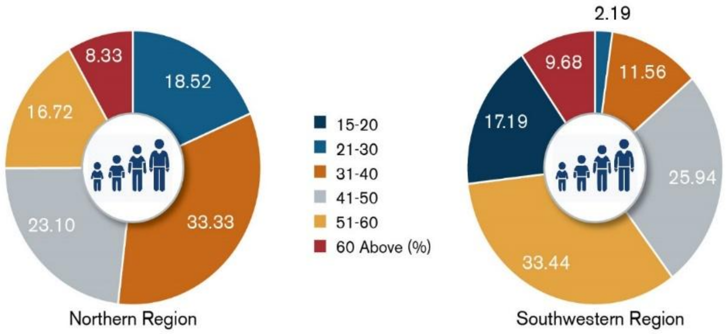

Fig. 8. *Age group of Respondents*

In contrast, older respondents (51–60 years and 60 years and above) were more prevalent in the Northern Region (16.72% and 8.33%) than in the Southwestern Region (11.56% and 2.19%), reflecting regional differences in generational participation. These findings underscore the pivotal role of middle-aged individuals in agriculture, while the higher proportion of older respondents in the Northern Region points to potential differences in generational engagement and agricultural practices the 51-and-above age group provides valuable insights for designing targeted CSA interventions. However, focusing on the youth demographic is critical for the rapid adoption of CSA technologies and practices.

6.1.2 Gender

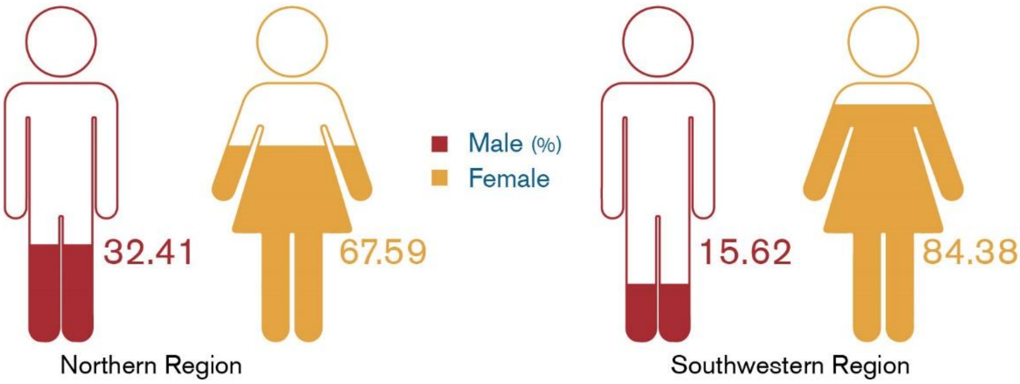

Fig. 9. Gender Distribution of Respondents

The study examined the gender distribution of respondents in the Northern and Southwestern Regions. In the Northern Region, 67.59% of respondents were female, while 32.41% were male, indicating a strong representation of women in agricultural activities. Similarly, in the Southwestern Region, women constituted an even higher proportion at 84.38%, with men accounting for only 15.62%. These findings highlight the significant involvement of women in CSA practices across both regions, with a notably higher female participation in the Southwestern Region. This gender distribution underscores the critical role of women in agricultural decision-making and livelihood activities, suggesting the need for gender-sensitive approaches in CSA interventions.

6.1.3 Education

The study explored the educational background of respondents in both the Northern and Southwestern Regions, revealing notable patterns in educational attainment.

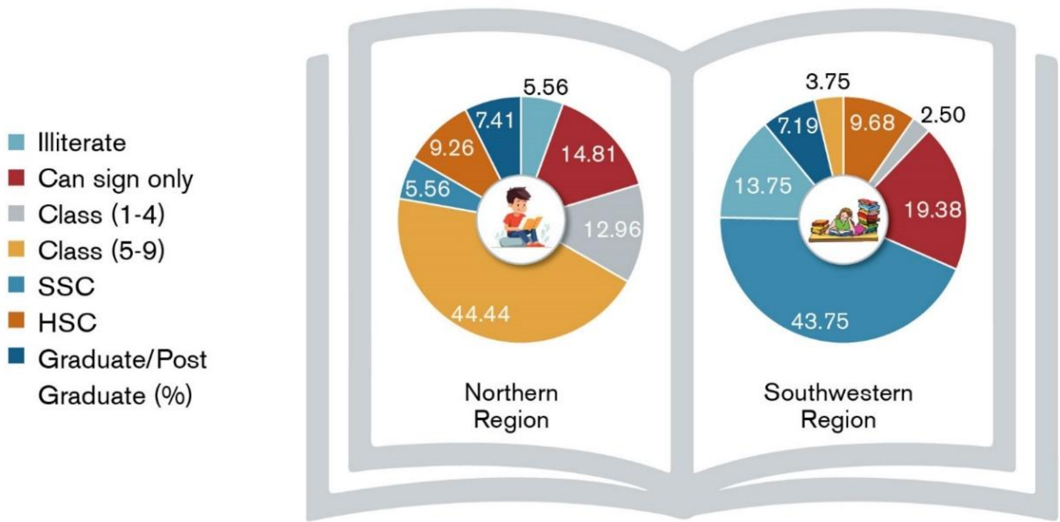

Fig. 10. Education Level of the Respondents

In the Northern Region, 44.44% of respondents had education up to Class 5–9, reflecting a foundational literacy level for adopting agricultural innovations. Minimal education levels were notable, with 14.81% able to sign only and 12.96% educated up to Class 1–4. Higher education levels were less common, with 9.26% completing SSC, 7.41% HSC, and 5.56% graduate/post-graduate degrees. In the Southwestern Region, similar trends emerged, with 43.75% educated up to Class 5–9. However, minimal literacy was more prevalent, with 19.38% able to sign only. SSC (13.75%) and HSC (7.19%) completion rates were slightly higher than in the Northern Region, while graduate/post-graduate respondents were fewer at 3.75%.

6.1.4 Occupation

The study revealed distinct occupational patterns across the Northern and Southwestern Regions, with farming dominating in both. In the Northern Region, 76.85% of respondents were farmers, complemented by non-agricultural wage labor (8.34%), small businesses (3.71%), and service jobs (1.85%). Housewives made up 4.63%, while students, skilled workers, and unemployed individuals accounted for smaller shares.

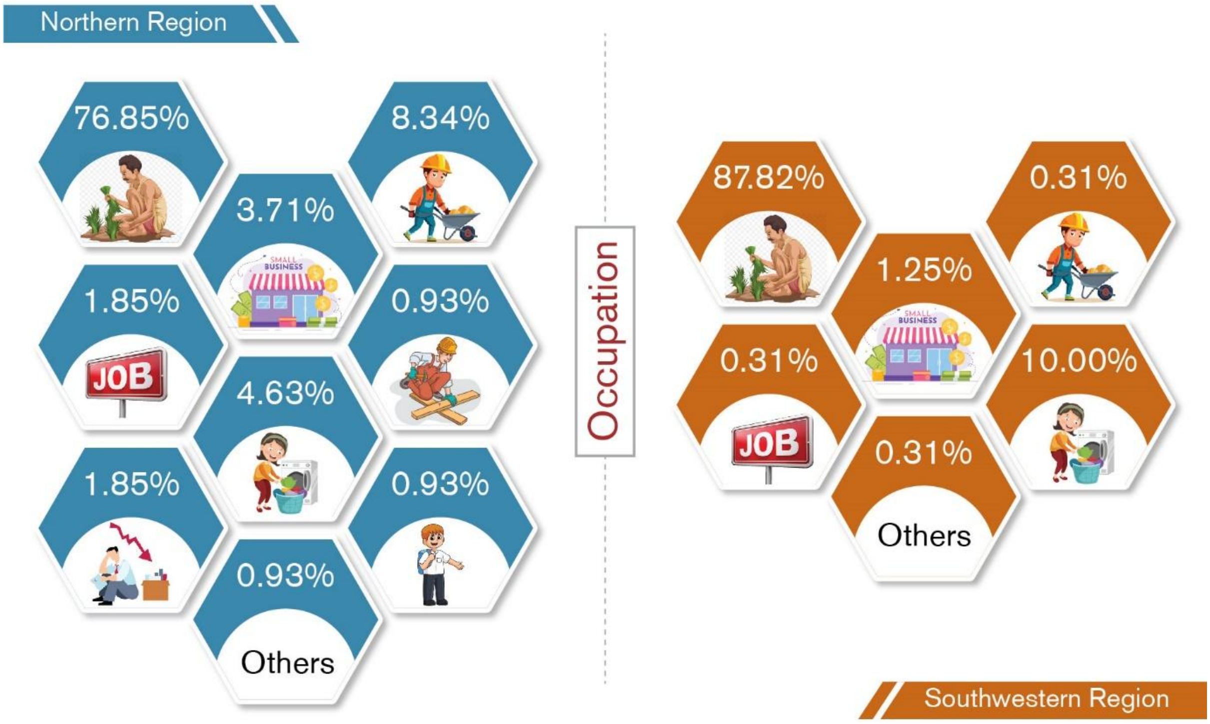

Fig. 11. Occupation of the Respondents

In the Southwestern Region, farming was even more prominent, engaging 87.82% of respondents, with housewives forming 10.00%. Small businesses and service jobs contributed marginally (1.20% and 0.31%, respectively). Unlike the North, no respondents reported unemployment or skilled labor roles. These findings emphasize farming's critical role in livelihoods, particularly in the Southwestern Region, while the Northern Region shows slightly more occupational diversity.

6.2 Current CSA technologies practices in Southwestern and Northwestern Bangladesh

6.2.1 CSA Seeds/Varieties Developed by Research Institutes (BRRI, BARI, and BINA)

To address the significant climate challenges in northern and southwestern Bangladesh, research institutes such as the Bangladesh Rice Research Institute (BRRI), Bangladesh Agricultural Research Institute (BARI), and Bangladesh Institute of Nuclear Agriculture (BINA) have developed and introduced climate-resilient seeds and crop varieties. These innovations are tailored to withstand changed climatic conditions, including salinity intrusion, excessive heat, prolonged drought, and submergence caused by floods, all of which are prevalent in these vulnerable study regions.

In the southwestern coastal regions, salinity-tolerant rice varieties have become a cornerstone of adaptation strategies. These varieties empower farmers to cultivate saline soil without losing productivity. Similarly, salinity-tolerant vegetable crops provide not only resilience but also nutritional benefits to the local communities. Heat-and drought-tolerant crop varieties have been introduced to address erratic rainfall and extended dry spells that disrupt farming cycles, particularly in water-scarce areas. In regions prone to seasonal flooding, submergence-tolerant rice and other resilient crop varieties have ensured food security by upholding agricultural productivity under extreme conditions.

These CSA (Climate-Smart Agriculture) varieties are specifically designed to perform under stress conditions. The features of CSA varieties:

6.2.1.1 Saline-Tolerant Crop Varieties

In the southern regions, where soil salinity is a prevalent issue, the adoption of saline-tolerant rice varieties such as BRRI dhan67 (9.4%) and BINA dhan10 (39.7%) is significantly higher compared to the northern regions. In contrast, northern farmers show limited use of these varieties, with only 4.6% cultivating BRRI dhan99 and 5.6% cultivating BINA dhan10.

> "Here, seedlings often die due to salinity, and they need to be planted multiple times. Additionally, during floods, the embankments break, allowing water to enter and creating many problems for agricultural activities."
>
> Dulal
> Lead Farmer, Ward 1, Morrelganj, Bagerhat

6.2.1.2 Drought-Tolerant Crop Varieties

Drought-resistant varieties like BINA dhan14 have gained considerable acceptance in the northern regions, with a 27.8% adoption rate. However, the southern regions show minimal adoption of these varieties, likely due to differences in climate and soil conditions. Other drought-tolerant varieties, such as BRRI dhan71 and BINA dhan19 are cultivated to a lesser extent in both regions. Flood/Submergence-Tolerant Varieties

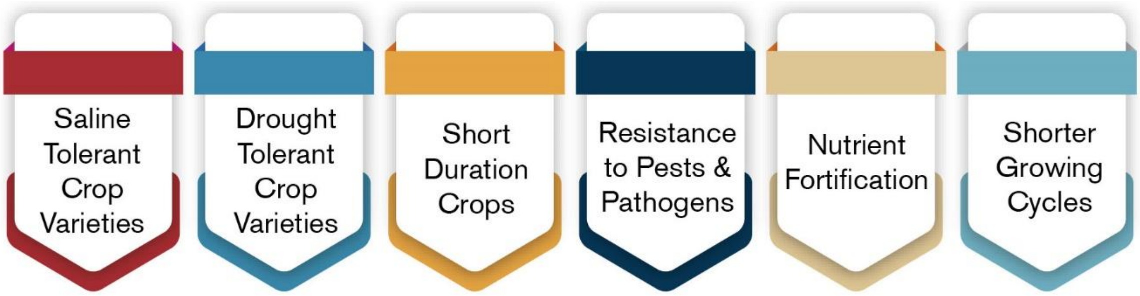

Fig. 12. *Current CSA varieties*

Table 2. CSA Technology Practices in Northwestern and southwestern Bangladesh

CSA Technology	Northern Region	Southern Region
Saline-Tolerant Varieties	Low adoption (e.g., BRRI dhan99: 4.6%, BINA dhan10: 5.6%)	High adoption (e.g., BRRI dhan67: 9.4%, BINA dhan10: 39.7%)
No Saline-Tolerant Use	56.5%	10.3%
Drought-Tolerant Varieties	Higher adoption (e.g., BINA dhan14: 27.8%)	Low adoption (e.g., <10%)
No Drought-Tolerant Use	10.2%	56.6%
Flood-Tolerant Varieties	Low adoption (e.g., BINA dhan11: 5.6%, BRRI dhan52: 1.9%)	High adoption (e.g., BINA dhan11: 35.6%, BRRI dhan52: 22.5%)
Short-Duration Varieties	Moderate to high (Hybrid: 46.3%, BINA dhan19: 5.6%)	Low (Hybrid: 3.1%, BINA dhan19: 0.9%)
Zinc-Enriched Varieties	Moderate (BRRI dhan100: 32.4%, dhan102: 19.4%)	Low (Other HYVs preferred: 35.3%)
Use of Cow Dung (Organic Fertilizer)	99.1%	77.2%
Use of Vermicompost	75.9%	6.6%
Use of Trichocompost	18.5%	7.2%
Use of NPKS Fertilizer Only	50%	95.3%
Use of Guti Urea	2.8%	39.7%
Use of Micronutrients (Zn, B, Mg)	79.6%	66.9%
No Micronutrient Use	50.9%	14.7%
AWD Irrigation	46.3%	10%
Fita Pipe Irrigation	8.3%	67.8%
Electric/Diesel Pump Use	95.4%	88.8%
Community Seed Bank Adoption	1.9%	0.6%
Floating Vegetable Cultivation	Rare/Not observed	15–20%
Pond-Dyke Cropping System	Minimal	10–12%
Power Tiller Operated Seeders (PTOS)	Increasing adoption	Increasing adoption
Rice Transplanters	Moderate adoption	Moderate adoption
Combined Harvesters	Moderate to high	Moderate to high
UDP Applicators	Low adoption	Higher adoption
GHG Mitigation Practices (overall)	Implemented through AWD, INM, conservation tillage	Implemented through saline-resilient crops, water-efficient methods

6.2.1.3 Flood-Tolerant Crop Varieties

Flood-tolerant varieties like BINA dhan11 exhibit strong adoption in southern regions (35.6%) compared to the northern areas (5.6%), aligning with the frequent flooding in southern Bangladesh. Similarly, BRRI dhan52 is more widely used in the south (22.5%) than in the north (1.9%).

6.2.1.4 Short-Duration Crop Varieties

Short-duration rice varieties, which help mitigate risks associated with extreme climatic events, show varying adoption rates. For example, BINA dhan19 is cultivated by 5.6% of northern farmers and 0.9% of southern farmers. However, 46.3% of northern farmers and only 3.1% of southern farmers reported cultivating hybrid short-duration varieties indicating a region-specific preference.

6.2.1.5 Zinc-Enriched Rice Varieties

Zinc-enriched rice varieties such as BRRI dhan100 and BRRI dhan102 have seen moderate adoption in the northern regions (32.4% and 19.4%, respectively). In contrast, the southern regions show limited use of these varieties, with a majority relying on other high-yielding varieties (35.3%).

6.2.2 Regional Challenges and Gaps

The data reveals that 56.5% of northern farmers and 10.3% of southern farmers reported not adopting any saline-tolerant varieties, while 10.2% of northern farmers and 56.6% of southern farmers did not adopt any drought-tolerant varieties.

6.2.3 Integrated Soil and Fertilizer Management

Integrated soil and fertilizer management incorporates practices that optimize nutrient use efficiency, enhance soil health, and support sustainable agriculture, particularly in climate-vulnerable regions of Bangladesh.

One key practice is urea deep placement (UDP), which involves embedding nitrogen-rich fertilizer near plant roots. This technique enhances nutrient uptake by crops while significantly reducing nitrogen losses to the environment, contributing to both productivity and environmental sustainability[20].

6.2.4 Conservation Agriculture

Conservation Agriculture (CA) practices in the northern and southwestern regions of Bangladesh focus on sustainable soil and crop management techniques that enhance resilience to climate challenges while improving productivity.

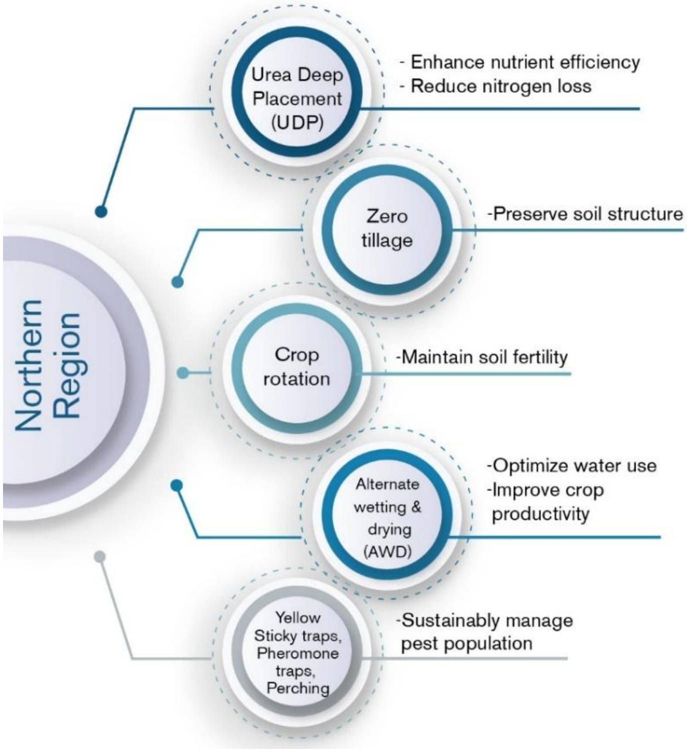

Fig. 13 CSA Technologies Practiced by Farmers in the Northern Region

Key practices include[21][22]:

- Zero tillage, which preserves soil structure by minimizing disturbance, aiding in the retention of organic matter and improving soil health over time.
- Cover cropping with legumes and pulse crops, which provides ground cover to protect against soil erosion, enhances nitrogen fixation, and boosts soil fertility, contributing to a healthier soil ecosystem.

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[20] International Fertilizer Development Center. (2016). Fertilizer deep placement in Bangladesh: A technology profile.

[21] World Bank. (2014). Adapting agriculture in disaster-prone areas of Bangladesh.

[22] Bouman, B. A. M., Humphreys, E., Tuong, T. P., & Barker, R. (2007). Rice and water. *Advances in Agronomy*, 92, 187–237.

- Crop rotation, which diversifies planting patterns to prevent nutrient depletion, breaks pest and disease cycles, and reduces dependency on chemical fertilizer and pesticides.

6.2.5 Integrated Nutrient Management (INM)

Integrated Nutrient Management (INM) combines organic and inorganic inputs to enhance soil health, optimize nutrient availability, and support sustainable agricultural practices. This approach is particularly crucial in addressing the challenges of soil degradation in waterlogged and saline-affected areas, ensuring sustainable growth and resilience in crop production.

Organic Fertilizer Use: Organic amendments such as vermicompost, trichocompost, and bio-fertilizers play a vital role in INM by improving soil structure, enhancing water retention, and stimulating microbial activity. In the northern regions, 99.1% of farmers use cow dung, compared to 77.2% in the south, demonstrating its widespread adoption as an organic input. Vermicompost usage is significantly higher in the north (75.9%) than in the south (6.6%), reflecting regional preferences and accessibility. Similarly, trichocompost is used by 18.5% of farmers in the north, compared to only 7.2% in the south. These organic amendments are critical for enhancing soil fertility, particularly in environmentally stressed areas.

Chemical Fertilizer Use: When paired with NPKS fertilizers (nitrogen, phosphorus, potassium, and sulfur) and essential micronutrients, INM ensures a balanced nutrient supply, fostering crop resilience and productivity. 50% of farmers in the north exclusively use NPKS fertilizers, while this practice is more prevalent in the south, where 95.3% of farmers rely on them. Additionally, guti urea, a nitrogen-efficient fertilizer, is adopted by 39.7% of farmers in the south, compared to 2.8% in the north, reflecting its utility in managing soil nitrogen levels effectively.

Fig. 14 Integrated Nutrient Management

Micronutrient Use: Micronutrients such as zinc (Zn), boron (B), and magnesium (Mg) play an essential role in improving crop quality and mitigating deficiencies in degraded soils. 79.6% of farmers in the north use these micronutrients, compared to 66.9% in the south. However, a considerable portion of farmers (50.9% in the north and 14.7% in the south) reported not using essential micronutrients, indicating a need for awareness and accessibility to balanced fertilizer practices.

6.2.6 Irrigation and Water Management

Effective water management practices are essential in addressing climate challenges and ensuring sustainable agricultural productivity in the northern and southwestern regions of Bangladesh.

Alternate Wetting and Drying (AWD): In the northern region, 46.3% of farmers adopt Alternate Wetting and Drying (AWD) during the boro rice season (November-April), compared to only 10% in the south. AWD involves alternating between wet and dry periods, which optimizes water usage, enhances root growth, and reduces overall water consumption. However, the majority of farmers in the south (90%) do not use this method, indicating a need for increased awareness and training in this water-efficient practice.

> "In our area, there are problems in accessing CSA technologies, seed varieties, inputs, or machinery. Modern machines are yet to arrive here. To get good-quality seeds, we have to go to the district town, and even then, the supply is very limited."
>
> Person 4, Farmer from Tala, Satkhira (FGD)

Fita Pipe Irrigation: The use of fita pipes, or plastic pipes, for irrigation is a prominent water management practice in the southwestern region, with 67.8% of farmers utilizing this method, compared to only 8.3% in the north. Fita pipe irrigation allows for precise water distribution, conserving water resources and maintaining consistent moisture levels, which is particularly crucial in saline-affected areas of the south.

Electric/Diesel Pumps: Electric and diesel pumps are the most widely adopted irrigation tools in both regions. In the northern region, 95.4% of farmers rely on electric/diesel pumps, slightly higher than the 88.8% in the south. This practice highlights the critical role of mechanized irrigation in maintaining productivity across varying climatic and soil conditions.

The significant variation in the adoption of water management practices between the northern and southwestern regions reflects differing climatic challenges and resource availability. While the north shows a higher reliance on AWD and mechanized pumps, the south excels in adopting fita pipe irrigation to address salinity and water scarcity. These insights underline the importance of tailoring water management interventions to regional needs for sustainable agricultural development.

6.2.7 Community Seed Banks

Community seed banks serve as local repositories for resilient seed varieties, ensuring quick access during emergencies and promoting climate-resilient agriculture. This practice allows farmers to collectively preserve seeds in a shared storage facility, enhancing seed security and resilience against climate-related challenges. Despite its potential, the adoption of community-based seed banks remains significantly low in both study regions.

In the northern region, only 1.9% of farmers have established community-based seed banks, while this figure is even lower in the south, at 0.6%. Overall, 99.1% of farmers across both regions reported they did not have any community-based seed banks. These findings highlight a critical gap in implementing this practice, which could strengthen seed security and provide a safety net against crop failures due to climatic uncertainties. The limited adoption underscores the need for greater awareness, capacity building and support for establishing community seed banks as a sustainable solution for seed preservation and climate resilience.

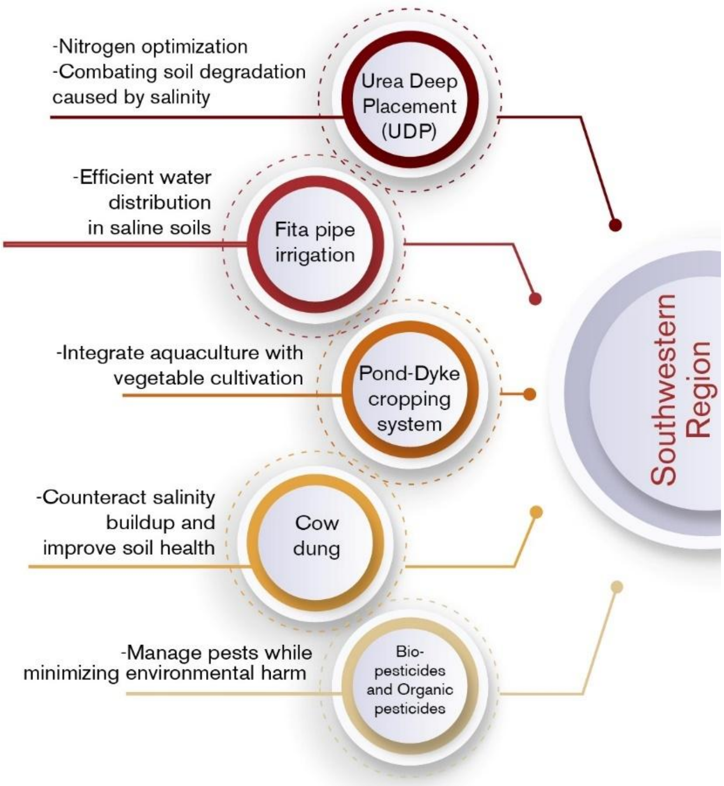

Fig. 15 CSA Technologies Practiced by Farmers in the Southwestern Region

6.2.8 Floating Vegetable Cultivation

Floating vegetable cultivation is a unique adaptation to waterlogged conditions, utilizing floating beds made from water hyacinth and other organic materials. This practice is predominantly observed in waterlogged areas, allowing farmers to sustain vegetable production during extended periods of inundation. Based on available reports and field studies, adoption of floating vegetable cultivation is primarily concentrated in the southwestern regions of Bangladesh. While specific adoption rates in the northern and southern regions are not explicitly mentioned in the data provided, studies such as those conducted by the International Water Management Institute (IWMI) indicate that floating bed farming has been adopted by approximately 15-20% of farmers in areas like Gopalganj, Barisal, and Pirojpur[23]. Further field surveys in waterlogged zones would be required to ascertain exact adoption rates.

6.2.9 Pond-dyke Cropping System

The pond-dyke cropping system integrates aquaculture with horticulture, utilizing the pond for fish farming and the dyke for growing vegetables and fruits. This method is highly suitable for areas like Sharankhola and Bagerhat, where land use efficiency is critical due to salinity and waterlogging challenges. Existing literature suggests that approximately 10-12% of farmers in the southwestern region, particularly in Bagerhat and adjacent districts, have adopted this method[24]. The adoption in the northern region remains minimal due to differing agroecological conditions, where such practices are less relevant.

6.2.10 CSA Agro-Machineries and Equipment

The adoption of climate-smart agro-machineries and equipment has played a transformative role in enhancing farming efficiency and promoting sustainable agricultural practices in the northern and southwestern regions of study area.

Currently the following CSA machinieries are available in the market:

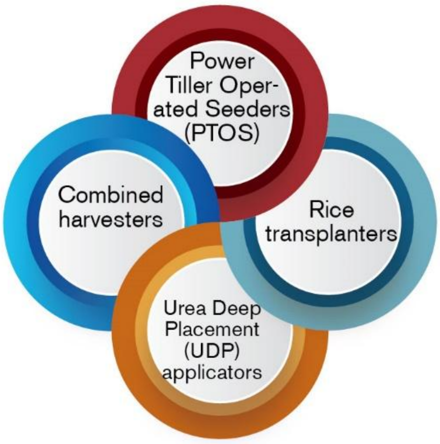

Fig. 16 *CSA Agro-Machineries and Equipment*

Power Tiller Operated Seeders (PTOS): PTOS streamline seeding operations by simultaneously tilling the soil and planting seeds. This equipment reduces labor requirements, ensures uniform seed distribution, and shortens the planting period. Studies have shown that PTOS can increase seeding efficiency by up to 30% compared to traditional methods[25].

Rice Transplanters: Mechanized rice transplanters enhance planting efficiency by automating the transplanting process, thereby reducing the physical labor required for manual transplanting. These machines are particularly beneficial in labor-scarce areas and can increase productivity by 25-40%[26].

Combined Harvesters: Combined harvesters integrate cutting, threshing, and cleaning operations, significantly reducing harvest time and labor while minimizing grain loss. Adoption of these machines has increased in both northern and southwestern regions, where they contribute to reducing post-harvest losses by 15-20% (Food and Agriculture Organization[27].

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[23] International Water Management Institute. (2016). *Sustainable floating agriculture in Bangladesh: Adapting to waterlogged conditions*.

[24] WorldFish. (2018). *Integrated pond-dyke systems in Bangladesh: Promoting sustainable aquaculture and horticulture*.

[25] Bangladesh Agricultural Research Institute. (2019). *Mechanization for sustainable agriculture: Adoption of PTOS in Bangladesh*. Gazipur, Bangladesh.

[26] International Rice Research Institute. (2021). *Rice transplanters and their impact on productivity in Asia*.

[27] Food and Agriculture Organization. (2020). *Sustainable mechanization in agriculture: Case studies from Asia*.

Urea Deep Placement (UDP) Applicators: UDP applicators optimize nitrogen fertilizer application by embedding urea briquettes directly near plant roots. This technology minimizes nutrient losses through leaching and volatilization, enhancing nitrogen use efficiency and improving crop yields by 10-20%[28].

6.2.11 GHG Emission Reduction

Reducing greenhouse gas (GHG) emissions from farming activities is crucial for mitigating climate change and promoting environmental sustainability. Through cutting-edge research and the implementation of CSA practices, such as selecting resilient seed varieties, optimizing nutrient application, and adopting sustainable tillage methods, farmers can lower emissions of methane, nitrous oxide, and carbon dioxide. These methods enhance soil carbon storage, reduce the need for synthetic fertilizers, and support efficient water management practices that lower emissions of GHG. The integrated approach to emission reduction ensures that agricultural systems contribute to a more sustainable and climate-resilient future, aligning with global environmental goals.

[28] International Fertilizer Development Center. (2016). *Fertilizer deep placement in Bangladesh: A technology profile*.

6.3 Current Adoption Rate of CSA Technologies in South and North

6.3.1.1 Saline-Tolerant Rice Varieties at southwestern Region

BINA dhan 10 is the most widely adopted saline-tolerant rice variety, with a significant usage rate of 39.70%. Other notable saline-tolerant varieties include: BRRI dhan 67 (9.40%), BRRI dhan 55 (6.90%), Other saline varieties, such as BRRI dhan 99, BRRI dhan 97, BRRI dhan 73, BRRI dhan 78, BINA dhan 8, and BRRI dhan 47, have adoption rates ranging between 0.30% and 1.90%, indicating low levels of use (Fig. 17).

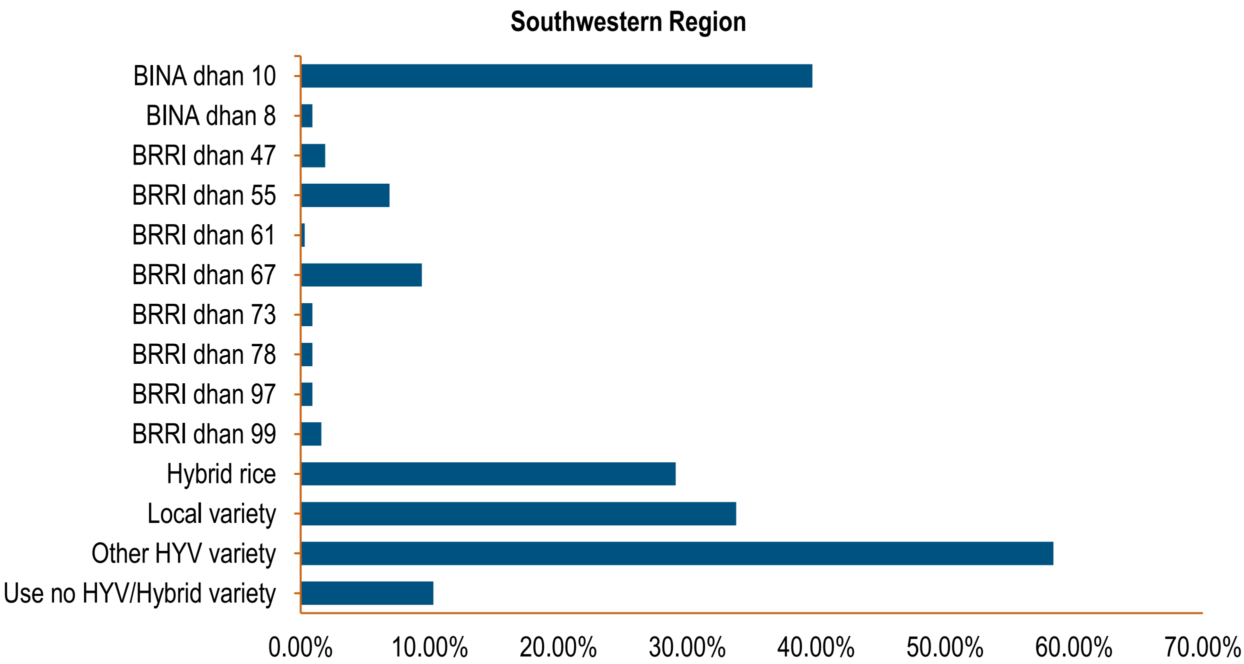

Fig. 17. Adoption Rate of Saline Tolerant Rice Varieties in Southwestern Region

The above figure 17 highlights the adoption rates of saline-tolerant rice varieties and other rice cultivation practices in the Southwestern region of Bangladesh.

6.3.2 Non-Saline-Tolerant Varieties:

- High-Yielding Varieties (HYV) dominate, with 58.40% of farmers using them.
- Local rice varieties remain significant in usage, adopted by 33.80% of farmers, likely due to traditional preferences or lack of access to saline tolerant HYVs.
- Hybrid rice varieties are also widely used, with an adoption rate of 29.10%.

6.3.3 Lack of Adoption

- 10.30% of farmers do not use any HYV or hybrid rice varieties, indicating either reliance on traditional methods, lack of resources, or other barriers.

6.3.4 Flood-Tolerant Rice Varieties

The adoption of flood-tolerant rice varieties reveals notable differences between the northern and southwestern regions of Bangladesh, shaped by their distinct climatic challenges (Fig. 18).

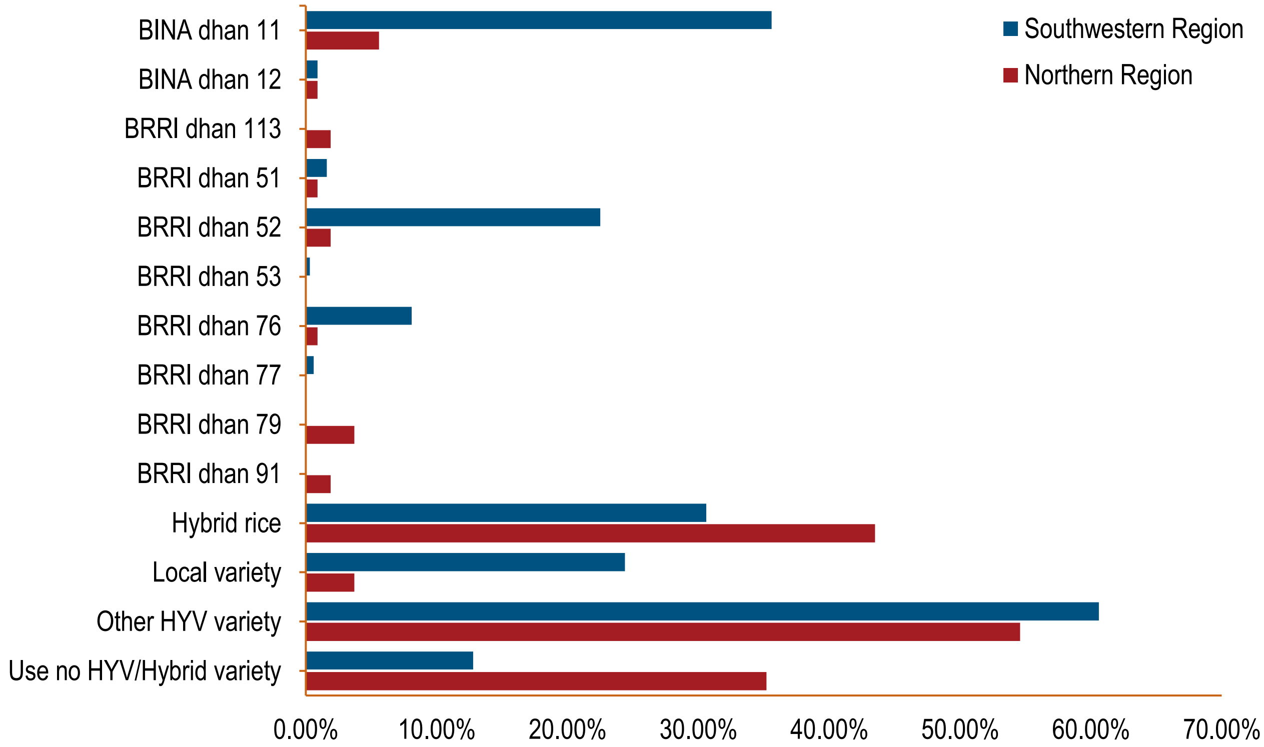

Fig. 18. *Adoption Rate of Flood Tolerant Rice Varieties in Both Region*

6.3.4.1 Southwestern Region

The Southwestern region, prone to periodic flooding and waterlogging, demonstrates a strong adoption of flood-tolerant varieties.

- BINA dhan 11 is the most widely adopted, with a significant usage rate of 35.6%.
- BRRI dhan 52 also shows substantial adoption at 22.5%, reflecting its effectiveness in mitigating flood impacts.
- Other notable flood-tolerant varieties include BRRI dhan 76 (8.1%) and BRRI dhan 51 (1.6%), though their usage is much lower.
- The reliance on other high-yielding varieties (HYVs) is high, at 60.6%, while local varieties are used by 24.4% of farmers.
- Hybrid rice adoption is also prevalent, at 30.6%.
- Only 12.8% of farmers in this region report that they are not using any HYV or hybrid varieties.

6.3.4.2 Northern Region

The Northern region, despite its need for flood resilience, shows much lower adoption rates for flood-tolerant varieties.

- The most adopted varieties are BINA dhan 11 (5.6%) and BRRI dhan 79 (3.7%), with other flood-tolerant varieties having minimal usage.
- Farmers primarily depend on other HYVs (54.6%) and hybrid rice (43.5%), emphasizing productivity over flood-specific resilience.
- A considerable 35.2% of farmers do not use any HYV or hybrid rice, suggesting significant barriers such as limited knowledge, accessibility, or affordability.

6.3.4.3 Key Insights

- **Adoption Gaps**: The northern region has lower adoption of flood-tolerant varieties compared to the southwestern region, potentially due to limited seed distribution, awareness campaigns, or infrastructure for flood-resilient agriculture.
- **Regional Preferences**: While both regions show reliance on HYVs and hybrid rice, the southwestern region's higher uptake of flood-tolerant varieties indicates better-targeted interventions or greater exposure to climate-smart technologies.
- **Challenges**: In both regions, reliance on local varieties (3.7% in the north and 24.4% in the southwest) and the percentage of farmers not using HYVs or hybrids highlight persistent gaps in the dissemination and adoption of flood-tolerant rice.

6.3.5 Drought-Tolerant Rice Varieties

The adoption of drought-tolerant rice varieties reveals a clear regional contrast between the northern and southwestern regions of Bangladesh, driven by differences in climatic challenges and agricultural priorities (Fig. 19).

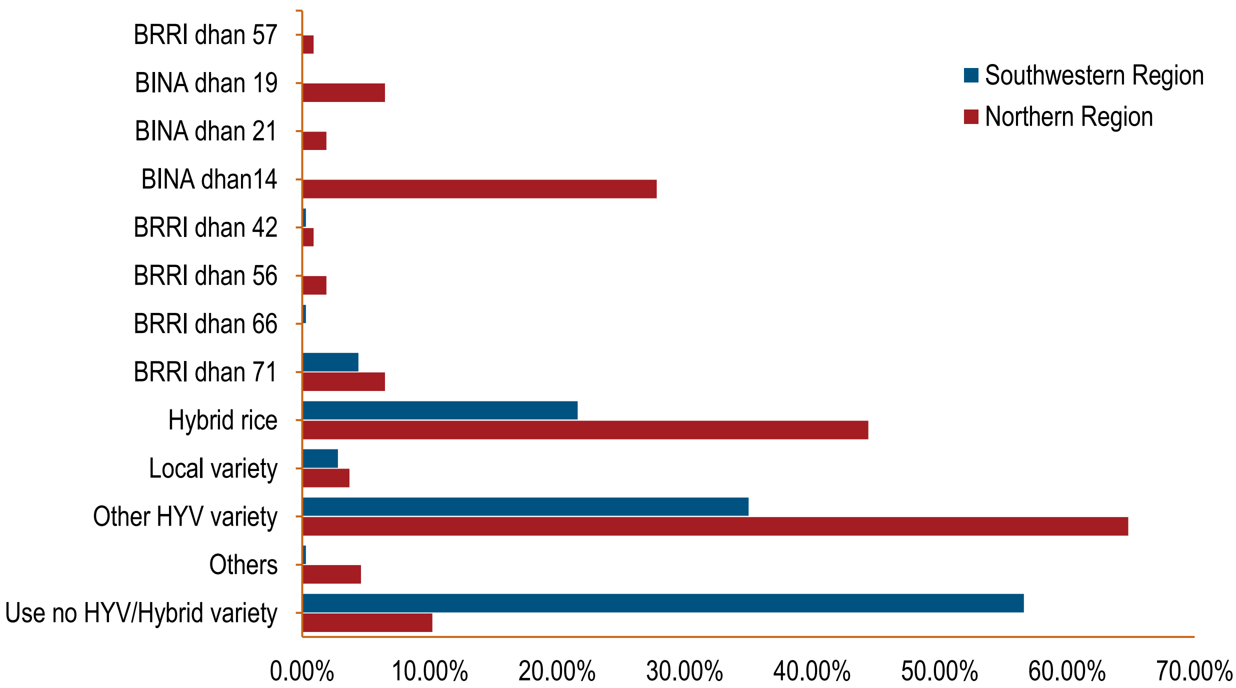

Fig. 19. Adoption Rate of Drought Tolerant Rice Varieties in Both Region

6.3.5.1 Northern Region

The Northern region, where drought conditions significantly affect agricultural productivity, shows higher adoption rates of drought-tolerant rice varieties:

- BINA dhan 14 is the most widely adopted variety, with a notable adoption rate of 27.8%.
- Other drought-tolerant varieties, such as BRRI dhan 71 and BINA dhan 19, are also utilized, each with a 6.5% adoption rate.
- Varieties like BRRI dhan 56 (1.9%) and BRRI dhan 57 (0.9%) have minimal adoption, reflecting limited use of these options.
- Farmers also rely heavily on other high-yielding varieties (HYVs), with a usage rate of 64.8%, and hybrid rice (44.4%), demonstrating a strong preference for versatile, high-performing varieties to sustain yields during dry spells.

- Only 10.2% of farmers report not using any HYV or hybrid variety, indicating relatively better access to drought-adaptive technologies.

6.3.5.2 Southwestern Region

In the Southwestern region, where drought is less of a concern compared to salinity and water management issues, the adoption of drought-tolerant rice varieties is much lower:

- BRRI dhan 71 is the most adopted drought-tolerant variety in this region, with an adoption rate of 4.4%.
- Other drought-tolerant varieties, such as BRRI dhan 66, BRRI dhan 42, and BINA dhan 14, have negligible adoption rates ranging from 0.3% to 0.0%.
- Farmers in this region prioritize varieties suited to address salinity and waterlogging, with 56.6% reporting no use of drought-tolerant HYVs or hybrid rice.
- The reliance on other HYVs (35.0%) and hybrid rice (21.6%) is moderate, further underscoring the region's focus on non-drought-related agricultural strategies.

6.3.5.3 Key Insights

- **Regional Relevance**: Drought-tolerant varieties are critical in the northern region, where water scarcity affects farming, while the southwestern region prioritizes technologies for salinity and waterlogging.
- **Adoption Gaps**: The significantly higher rate of farmers in the southwestern region (56.6%) not using HYV or hybrid varieties highlights the limited relevance or availability of drought-tolerant options there.
- **Farmer Preferences**: In both regions, the use of other HYVs and hybrid rice underscores the need for varieties that combine high productivity with climate resilience.

6.3.6 Drought-resilient Short Duration Crops

The adoption of drought-resilient short-duration crops reveals distinct regional patterns influenced by specific climatic vulnerabilities and soil conditions in the northern and southwestern regions of Bangladesh (Fig 20).

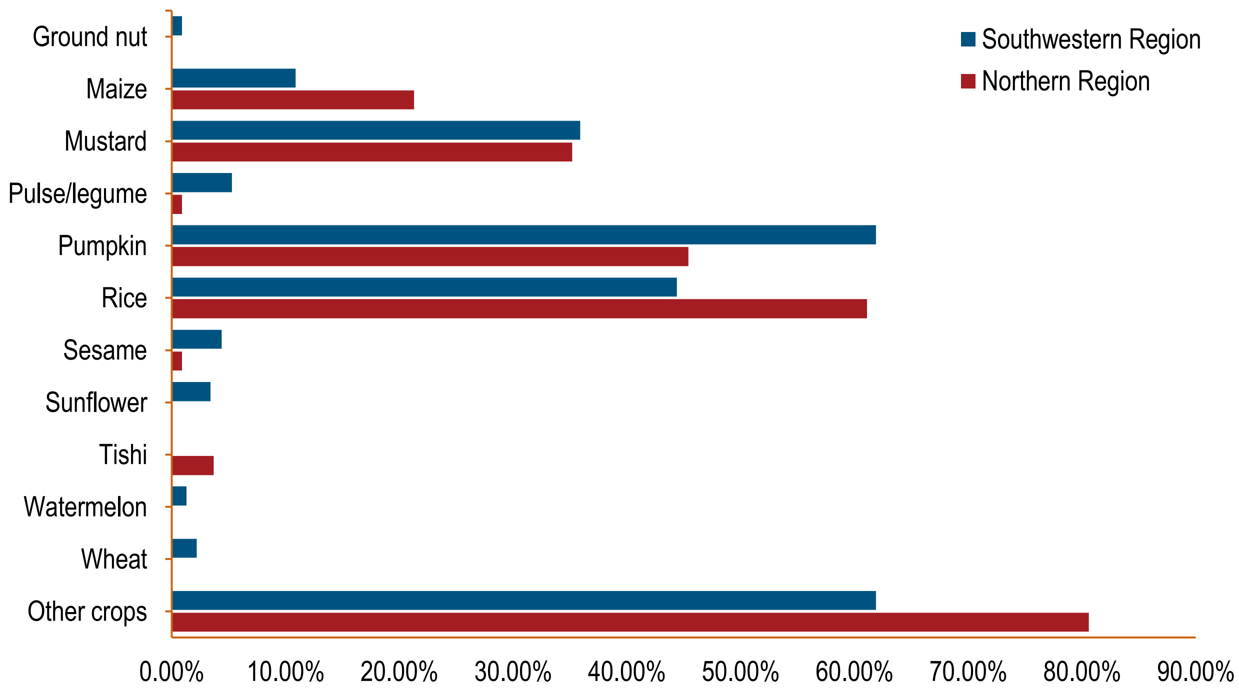

Fig. 20. Adoption Rate of Drought Resilient Short Duration Crop Varieties in Both Region

6.3.6.1 Northern Region

In the Northern region, where both drought and flooding are critical challenges, farmers prioritize crops that offer resilience to these conditions:

- Rice (61.1%) and pumpkin (45.4%) are the most widely adopted, reflecting their suitability for managing water scarcity and erratic rainfall.
- Mustard (35.2%) and maize (21.3%) are also significant, showcasing efforts to diversify cropping systems and improve resilience.
- Oil crops like sesame (0.9%), and tishi (3.7%) are less commonly grown but still contribute to mitigating the impacts of drought.
- The category of other crops (80.6%) indicates a diverse cropping portfolio aimed at enhancing food security and reducing risk under challenging climatic conditions.

6.3.6.2 Southwestern Region

In the Southwestern region, where salinity intrusion is a more pressing issue, farmers adapt their crop choices to saline soils:

- Pumpkin (61.9%) emerges as the most adopted crop, demonstrating its adaptability to both drought and saline conditions.
- Rice (44.4%) remains a key crop, highlighting its role in sustaining food production in the region.
- Mustard (35.9%) and watermelon (1.3%) are also prominent choices, offering additional income opportunities and nutritional value.
- Other alternatives, such as sesame (4.4%), sunflower (3.4%), and wheat (2.2%), reflect efforts to diversify cropping options for saline-affected areas.
- The reliance on other crops (61.9%) underscores the region's need for flexible and salt-tolerant cropping systems.

6.3.6.3 Key Insights

1. **Regional Priorities**:

   - In the northern region, crop selection is driven by the dual challenges of drought and flooding, with a focus on drought-resilient and fast-maturing varieties like rice and pumpkin.
   - In the southwestern region, salinity resilience is a critical factor, influencing the adoption of salt-tolerant crops like pumpkin and mustard.

2. **Crop Diversity**:

   - Both regions show a significant reliance on "other crops," indicating diverse cropping systems to mitigate risks and enhance resilience.
   - Less common crops, such as sesame, sunflower, and tishi, demonstrate potential for expanding options tailored to specific environmental conditions.

3. **Strategic Crop Selection**:

   - Pumpkin's dominance in both regions highlights its versatility and adaptability to varying stress conditions.
   - The northern region shows higher adoption of maize and tishi, while the southwestern region leans more toward salinity-adapted crops like sesame and sunflower.

6.3.7 Cold-tolerant Rice Variety

The adoption of the cold-tolerant rice variety BRRI dhan 36 shows a significant regional disparity between the northern and southwestern regions of Bangladesh. In the northern region, 44.40% of farmers have adopted this variety, while the remaining 55.60% have yet to do so. This higher adoption rate can be attributed to the more extreme cold weather conditions in the north, which make the use of cold-tolerant varieties like BRRI dhan 36 particularly valuable for ensuring stable rice production during the colder months. Farmers in this region likely recognize the variety's ability to withstand lower temperatures, which helps mitigate the risk of crop loss due to cold weather.

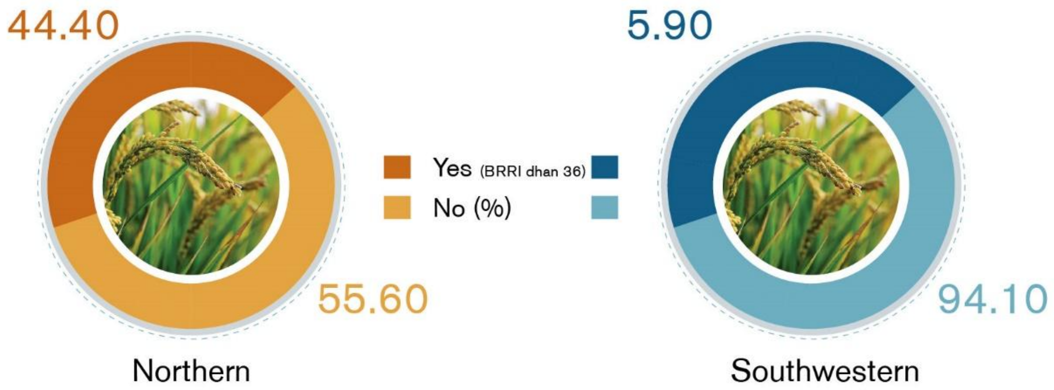

Fig. 21: Adoption Rate of Cold Tolerant Rice Variety

In contrast, the southwestern region has a very low adoption rate, with only 5.90% of farmers using BRRI dhan 36. The rest of the farmers, 94.10%, have not adopted this variety, primarily because the region does not experience extremely cold weather conditions to the same extent as the north. The relatively mild winters in the southwestern region reduce the necessity for cold-tolerant rice varieties, as traditional varieties are sufficient to withstand the local climate conditions. Therefore, the lower adoption rate in this region suggests that farmers do not see an urgent need for a variety that specifically addresses cold stress, as it does not pose a significant risk to their rice crops.

6.3.8 Legume, Pulse and Oil Seed Cultivation

The adoption of legume, pulse and oil seed cultivation is low in both the northern and southwestern regions. In the northern region, only 10.20% of farmers have adopted this practice, while 89.80% have not. In the southwestern region, 13.40% of farmers are cultivating these crops, and 86.60% are not. The low adoption rates in both regions can be directly attributed to factors such as the focus on staple crops like rice for food security. In the northern region, colder climate conditions are less favorable for cultivating legumes, pulses, and oil crops. In the southwestern region, salinity and flooding challenges limit the feasibility of growing these crops. The lack of access to necessary resources and limited awareness of the benefits of crop diversification also contribute to the low adoption in both regions.

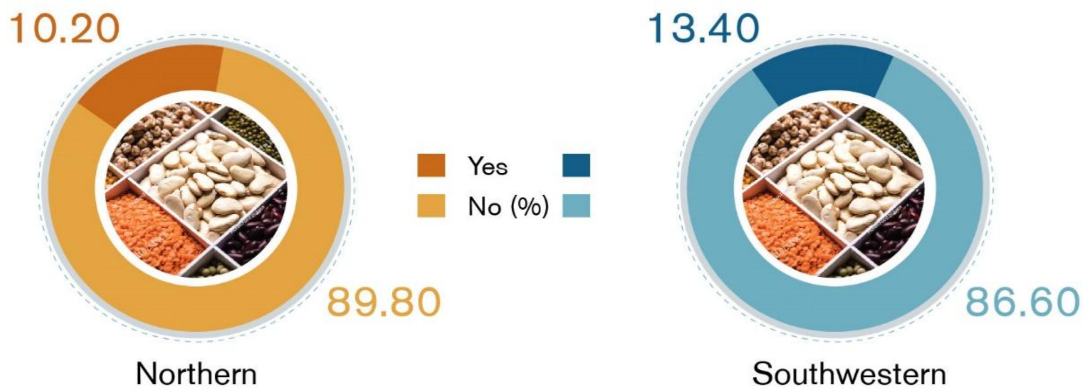

Fig. 22: Adoption Rate of Legume, Pulse and Oil Seed Cultivation

6.3.9 Alternate Wetting and Drying (AWD)

The adoption of the Alternate Wetting and Drying (AWD) technique is significantly higher in the northern region compared to the southwestern region. In the northern region, 46.30% of farmers have adopted AWD, while 53.70% have not. In the southwestern region, only 10.00% of farmers use this technique, and 90.00% are not.

The higher adoption rate in the northern region is due to the region's need for efficient water management practices. AWD helps conserve water, which is crucial in areas where water resources are limited or irregular. The moderate adoption rate in the northern region indicates that while AWD is beneficial, not all farmers are implementing it, possibly due to lack of training or initial investment requirements. In the southwestern region, the low adoption rate is due to the relative abundance of water compared to the northern region. In areas with sufficient irrigation or rain-fed water sources, farmers do not see the need for water-saving practices like AWD. Additionally, issues like salinity and flooding limit the feasibility of AWD in this region.

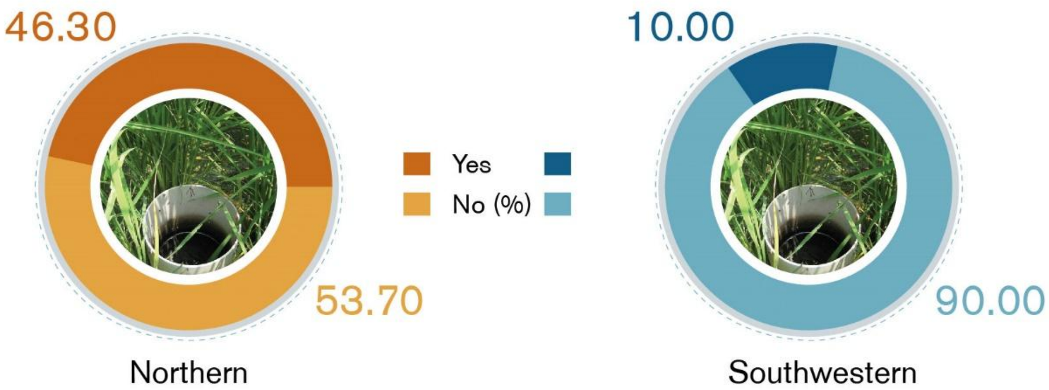

Fig. 23: Adoption Rate of Alternate Wet and Drying (AWD) Method

6.3.10 Fita Method Practice for CSA Irrigation

The adoption of the Fita Method practice differs significantly between the northern and southwestern regions. In the northern region, only 8.30% of farmers have adopted the Fita Method, while 91.70% have not. In contrast, 67.80% of farmers in the southwestern region use the Fita Method, and 32.20% do not. The low adoption rate in the northern region is due to the less favorable conditions for practicing the Fita Method, which is more suited to areas with a greater need for pest and disease management in crops. The northern region's agricultural focus and climatic conditions do not create the same urgency for adopting this method. In the southwestern region, the higher adoption rate is directly linked to the challenges posed by salinity and pest pressures, which make the Fita Method more relevant. The region's farmers face greater agricultural stress from these issues, driving the higher adoption of practices like the Fita Method to manage crop health and productivity effectively.

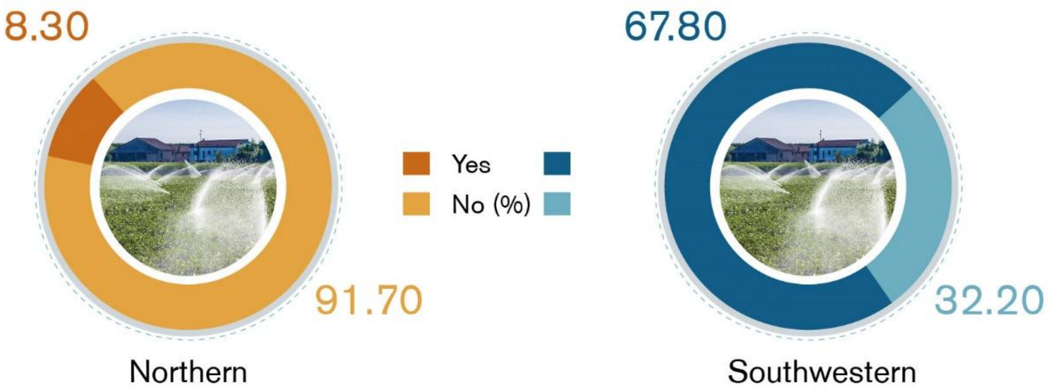

Fig. 24: Adoption Rate of Fita Method Practice

6.3.11 Pit Method Pumpkin Cultivation

The adoption of the Pit Method for pumpkin cultivation shows a clear regional difference. In the northern region, 25.00% of farmers use the Pit Method, while 75.00% do not. In the southwestern region, only 4.70% of farmers have adopted this method, and 95.30% have not.

The higher adoption rate in the northern region is due to the region's more favorable conditions for growing pumpkins, including the soil and climate, which make the Pit Method an effective practice for improving pumpkin yield. Farmers in this area are more likely to adopt this method as it helps optimize soil conditions for pumpkin cultivation. In contrast, the very low adoption rate in the southwestern region is due to the challenges posed by salinity and flooding. These conditions make the Pit Method less effective for pumpkin cultivation, as the method requires specific soil and water conditions that are not available in the southwestern region.

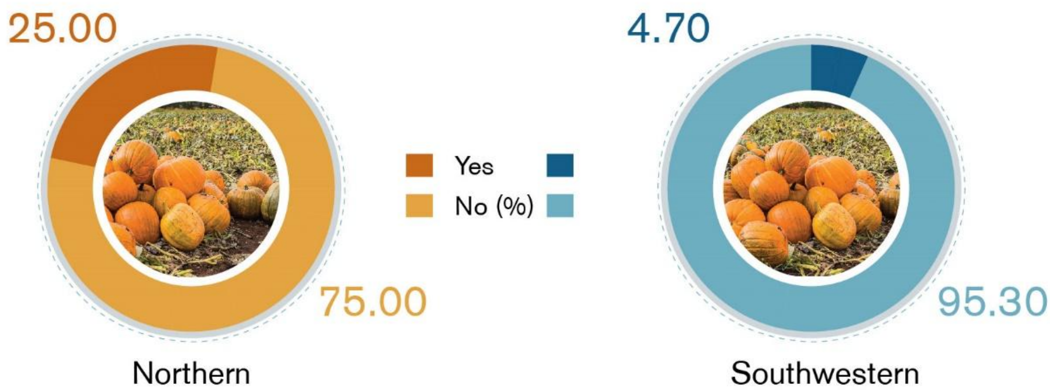

Fig. 25: *Adoption Rate of Pit Method Pumpkin Cultivation*

6.3.12 Vermicompost/Trichocompost Production

The very low adoption of Vermicompost/Trichocompost production in both the northern and southwestern regions is primarily due to a lack of knowledge on how to produce and use these composts. In the northern region, only 2.80% of farmers practice it, and in the southwestern region, only 0.30% do. Farmers in both regions are aware of the potential benefits of this practice but lack the necessary training and guidance to implement it effectively. They have expressed interest in receiving training to understand the production process and how to apply it to improve soil health and crop productivity. This desire for training highlights the potential for wider adoption if the right educational resources and support are provided.

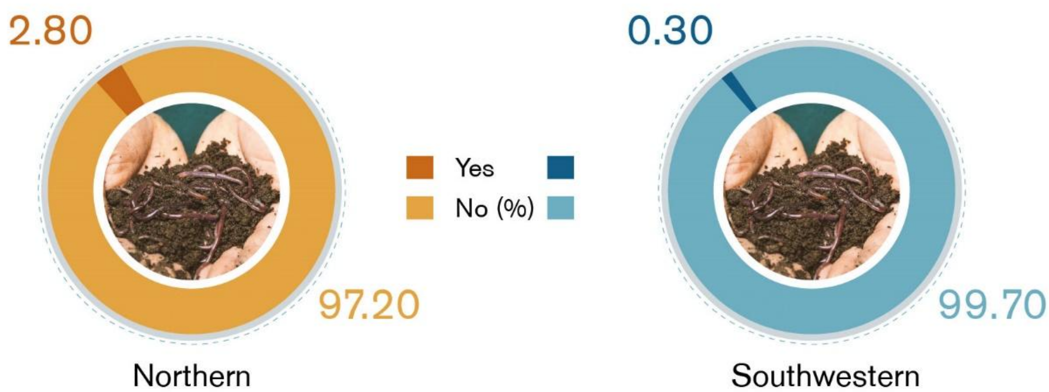

Fig. 26: *Adoption Rate of Vermicompost/Trichocompost Production*

6.3.13 Use of CSA tools

The use of Climate-Smart Agriculture (CSA) tools varies significantly between the northern and southwestern regions. In the northern region, 6.5% of farmers use a reaper for rice harvesting, 5.6% use a combined harvester, and 98.1% rely on manual harvesting. In contrast, in the southwestern region, 0.0% of farmers use a reaper or combined harvester, and 100% use manual harvesting.

The higher use of harvesting machinery in the northern region is directly due to better access to modern equipment and a greater emphasis on mechanization to improve efficiency in rice harvesting. The northern region has more developed agricultural infrastructure, which allows farmers to invest in and utilize CSA tools like reapers and combined harvesters. In the southwestern region, the complete reliance on manual harvesting is due to limited access to modern machinery. Farmers in this region do not have the same access to CSA tools, likely due to financial constraints and a lack of infrastructure for acquiring or maintaining such equipment. The region's focus on manual labor for rice harvesting reflects the limited adoption of mechanization.

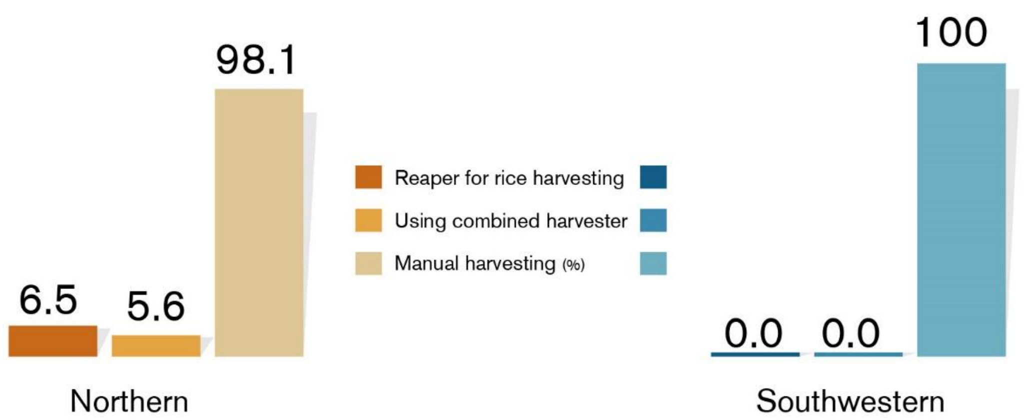

***Fig. 27:** Use of CSA tools in Both Region*

6.3.14 Khamari Apps

The use of the "Khamari App" is slightly higher in the southwestern region compared to the northern region. In the northern region, 8.30% of farmers use the app, while 91.70% do not. In the southwestern region, 11.90% of farmers use the app, and 88.10% do not. The higher use of the "Khamari App" in the southwestern region is due to better access to smartphones and mobile internet services in this area. Farmers in the southwestern region are more likely to adopt mobile technology for agricultural purposes. However, the overall adoption in both regions remains low because many farmers are not familiar with the app or lack the digital literacy to effectively use it. In the northern region, the low adoption rate can be attributed to limited access to technology and internet connectivity, making it more difficult for farmers to engage with digital tools like the "Khamari App." Additionally, farmers in this region may not see the immediate value of using the app in their daily farming practices.

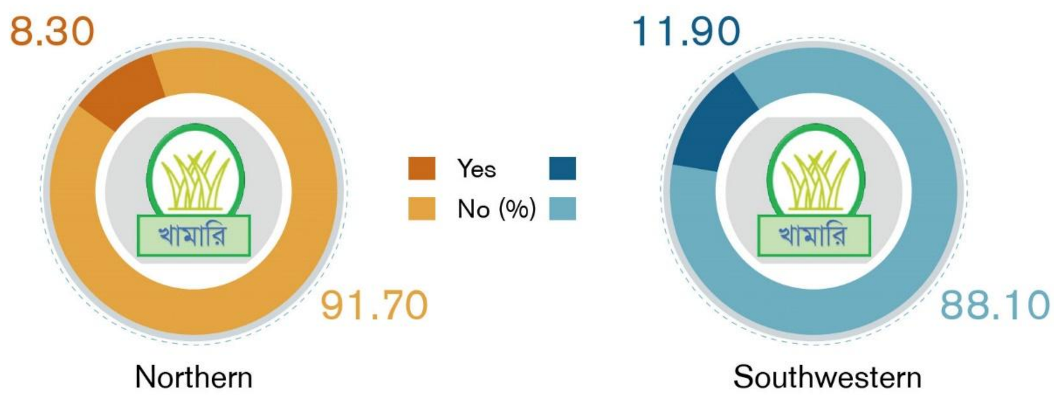

***Fig. 28:** Use of Khamari Apps by Farmers*

6.3.15 Training on CSA Technology

The low percentage of farmers trained on CSA technologies in both regions highlights the lack of access to proper training programs. In the northern region, only 8.30% of farmers received training, while 91.70% did not. This is due to limited availability of organized training initiatives and inadequate outreach to farmers in remote areas. In the southwestern region, slightly more farmers (11.90%) had access to training, while 88.10% did not. This slight increase is because of targeted programs addressing the region's unique challenges like salinity and water scarcity, but the overall low rate indicates insufficient training infrastructure and resources to meet the needs of most farmers. The lack of widespread training in both regions directly impacts the adoption of CSA technologies, as many farmers are unaware of how to implement these practices effectively.

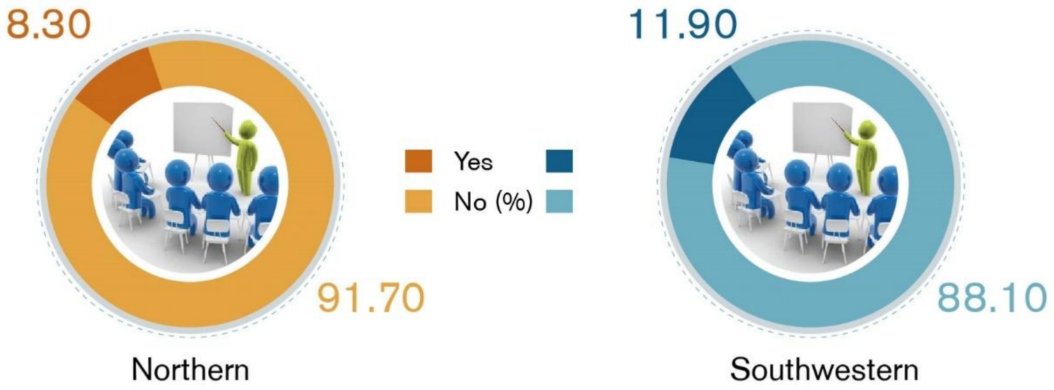

Fig. 29: *Farmers Trained on CSA Technology*

6.3.16 Climate-Adaptive Farming Practices

The adoption of climate-adaptive farming practices reflects the specific climatic challenges and needs of farmers in the Northern and Southwestern regions of Bangladesh. These practices aim to enhance resilience to climate variability, reduce risk, and increase Adoption Rate of Climate Adaptive Farming (Fig. 30).

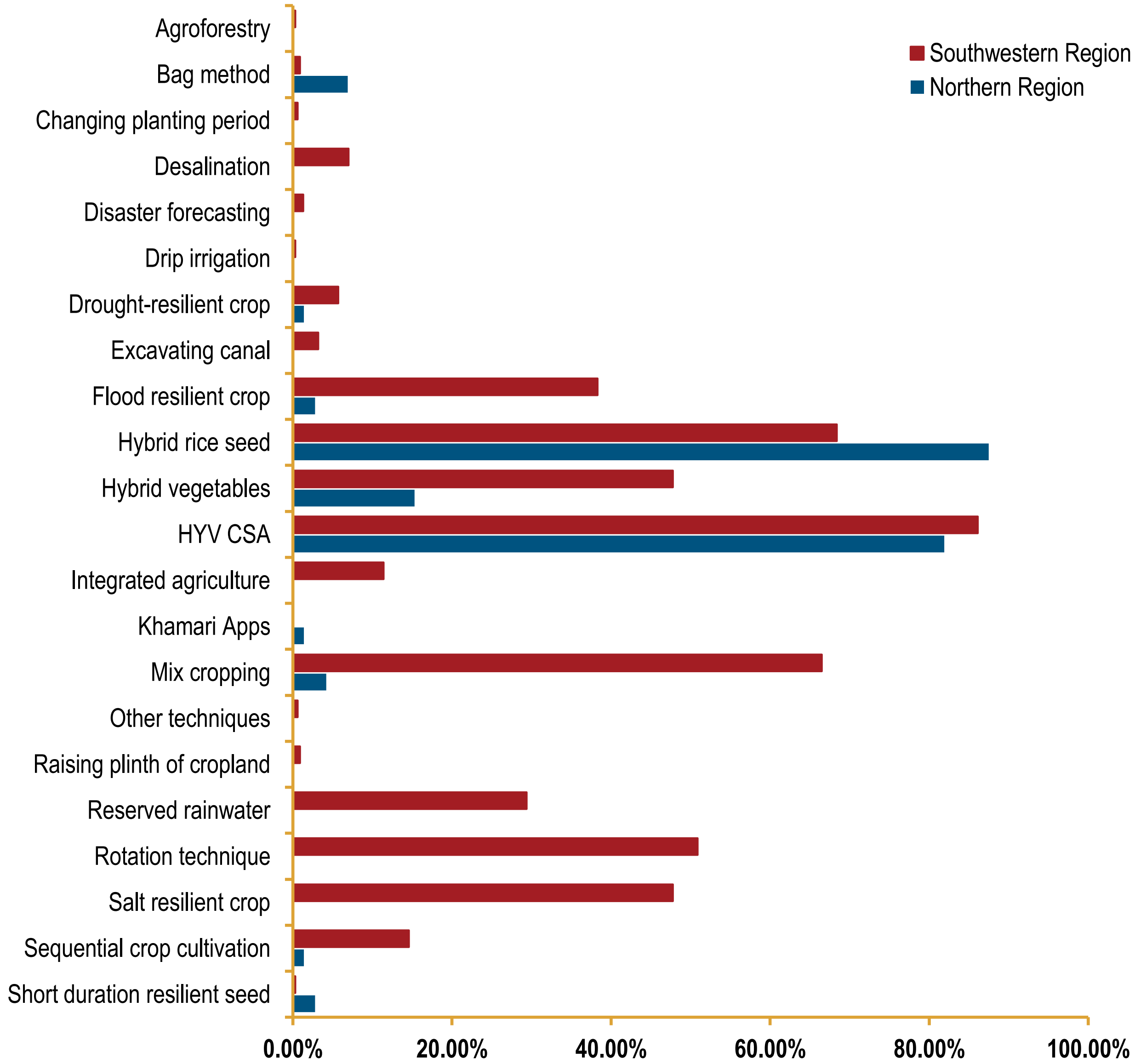

Fig. 30. Adoption Rate of Climate Adaptive Farming

6.3.16.1 Northern Region

- **HYV CSA (High Yielding Variety Climate-Smart Agriculture)**: 81.9% of farmers in the northern region use high-yielding climate-smart varieties, demonstrating a strong preference for varieties that are resilient to changing climate conditions.
- **Hybrid Rice Seed**: 87.5% of farmers in the northern region adopt hybrid rice seeds, reflecting a high emphasis on improving productivity and resilience to adverse weather conditions.
- **Hybrid Vegetables:** 15.3% of farmers in the region use hybrid vegetable seeds, highlighting a growing trend in diversifying farming systems for higher returns.
- **Drought-Resilient Crops**: Only 1.4% of farmers use drought-resilient crops, which could indicate limited exposure to drought or reliance on other adaptive strategies.
- **Flood-Resilient Crops**: 2.8% of farmers in the northern region adopt flood-resilient crops, suggesting that flooding may be a less critical issue than in the southwestern region.
- **Sequential Crop Cultivation**: 1.4% use sequential crop cultivation, reflecting a less widespread adoption of this practice.
- **Rotation Technique**: 0.0% adoption of crop rotation techniques in the northern region highlights potential gaps in awareness or barriers to implementation.

- **Mix cropping**: 4.2% of farmers use mixed cropping systems, offering diversified and climate-resilient options for food production.
- **Bag Method**: 6.9% of farmers use the bag method, which helps in pest and nutrient management and protecting crops from extreme weather.
- **Reserved Rainwater**: 0.0% use of reserved rainwater indicates that rainwater harvesting may not be a common practice in the region.
- **Khamari Apps**: 1.4% use of Khamari Apps, which could be an indication of growing interest in technology for managing climate-related crop and plant nutrition management.

6.3.16.2 Southwestern Region

- **HYV CSA**: 86.1% of farmers in the southwestern region also heavily rely on high-yielding climate-smart varieties, showing a similar trend as the northern region.
- **Hybrid Rice Seed**: 68.4% adoption in the southwestern region, lower than in the northern region, possibly due to other regional priorities like salinity tolerance.
- **Hybrid Vegetables**: 47.8% of farmers in the southwestern region use hybrid vegetable varieties, significantly higher than in the northern region, reflecting diversification for increased productivity.
- **Drought-Resilient Crops**: 5.7% of farmers use drought-resilient crops, a relatively small percentage compared to other adaptive practices.
- **Flood-Resilient Crops**: 38.3% of farmers adopt flood-resilient crops, highlighting the region's vulnerability to flooding.
- **Salt-Resilient Crops**: 47.8% of farmers in the southwestern region use salt-resilient crops, reflecting the widespread challenge of salinity in the region.
- **Sequential Crop Cultivation**: 14.6% use sequential crop cultivation, emphasizing crop diversification to manage risk and improve resilience.
- **Rotation Technique**: 50.9% of farmers in the southwestern region practice crop rotation, indicating a significant adoption of this sustainable farming technique.
- **Mix cropping**: 66.5% of farmers use mixed cropping systems, which enhance resilience by reducing vulnerability to climate extremes and diversifying production.
- **Agroforestry**: 0.3% adoption of agroforestry indicates limited uptake of integrating trees with crops for enhanced environmental sustainability.
- **Integrated Agriculture**: 11.4% use integrated agriculture techniques, combining crops, livestock, and other farm activities to enhance sustainability and resilience.
- **Drip Irrigation**: 0.3% adoption of drip irrigation is very limited but suggests some interest in water-efficient practices.
- **Bag Method**: 0.9% of farmers use the bag method, mainly for pest control or weather-related challenges.
- **Reserved Rainwater**: 29.4% use of reserved rainwater reflects a practical adaptation to water scarcity in the region.
- **Changing Planting Period**: 0.6% of farmers have adjusted planting periods, which can help adapt to shifting rainfall patterns.
- **Desalination**: 7.0% use of desalination technology, important for addressing salinity, particularly in coastal areas of the southwestern region.
- **Excavating Canal**: 3.2% of farmers engage in canal excavation, which helps manage water flow and improve drainage systems.
- **Other Techniques**: 0.6% of farmers report using other unspecified climate-adaptive techniques.

6.3.16.3 Key Insights

- **HYV CSA and Hybrid Rice**: Both regions show high adoption rates of HYV CSA (81.9% in the northern region and 86.1% in the southwestern region) and Hybrid rice seeds (87.5% in the northern region and 68.4% in the southwestern region), indicating a shared focus on increasing productivity through improved varieties.

- **Flood and Salt Resilience**: The southwestern region faces more salinity and flooding challenges, with 38.3% of farmers adopting flood-resilient crops and 47.8% using salt-tolerant varieties. In contrast, the northern region shows minimal adoption of these techniques.
- **Crop Diversification**: Practices like mix cropping (66.5% in the southwestern region) and rotation techniques (50.9% in the southwestern region) are more prominent in the southwestern region as farmers diversify their cropping systems to enhance resilience to floods, drought, and salinity.
- **Water Management Practices**: The use of reserved rainwater (29.4%) and desalination (7.0%) in the southwestern region reflects a regional strategy to manage water resources effectively in the face of salinity and water scarcity.
- **Technology and Innovation**: The adoption of innovative tools like the Khamari Apps (1.4%) in the northern region and the Bag method (6.9% in the northern region) highlights the role of technology in climate adaptation.

> "No significant changes have been observed in farmers' seed demands to adapt to climate challenges. Farmers mainly collect hybrid seeds based on the season. They prefer drought-tolerant seeds the most."
>
> Nur Alam
> Seed Vendor, Bottola, Kurigram Sadar, Kurigram

6.4 Factors Hindering the Adoption of CSA Technologies in the Northern and Southwestern Regions

The adoption of Climate Smart Agriculture (CSA) technologies in northern and southwestern Bangladesh is constrained by numerous barriers, impeding their widespread implementation. These challenges span technical, socioeconomic, and institutional domains, significantly affecting farmers' ability to integrate CSA practices into their farming systems.

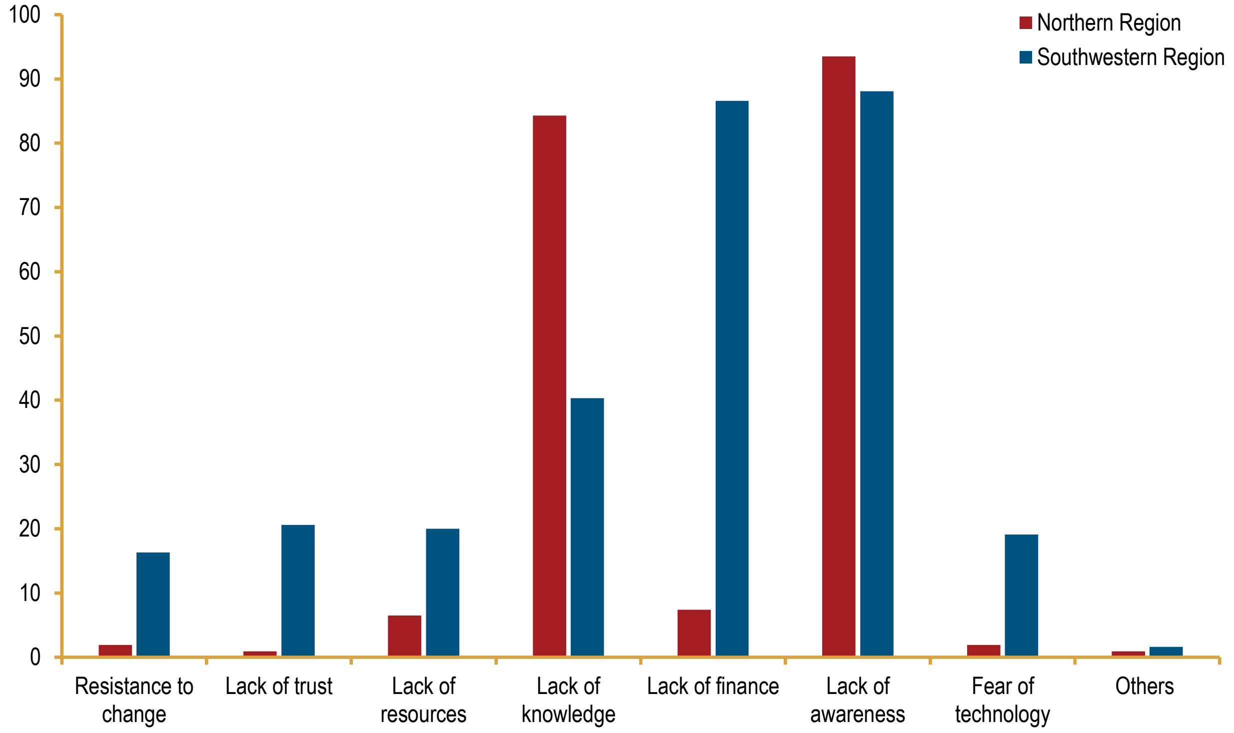

Fig. 31. *Factors Hindering the Adoption of CSA Technologies*

The adoption of Climate-Smart Agriculture (CSA) technologies faces significant barriers in both the Northern and Southwestern regions. In the Northern Region, lack of awareness (93.50%) and knowledge (84.30%) are the primary obstacles, highlighting the need for education and outreach (Fig. 31). Other barriers, such as lack of resources (6.50%), financial constraints (7.40%), and minimal resistance to change or fear of new technologies, are less critical. In the Southwestern Region, financial constraints (86.60%) and lack of awareness (88.10%) are the major challenges. Additional barriers, including lack of resources (20.00%), fear of new technologies (19.10%), and lack of trust (20.60%), reflect the region's infrastructural and economic limitations, along with higher resistance to change (16.30%).

In the Northern Region, prioritizing education and awareness programs can significantly enhance adoption rates by equipping farmers with the necessary knowledge and confidence to implement these practices. In the Southwestern Region, overcoming financial constraints and improving access to resources are essential to reduce dependency on traditional methods and encourage the use of CSA technologies.

Financial constraints are a significant barrier to CSA adoption, with 86.6% of farmers in the Southwestern Region citing it as a challenge, compared to 7.4% in the North. The key differences stem from:

6.4.1 Northern Region

In the Northern region, financial constraints are less severe due to lower environmental stress, as farmers primarily deal with drought, which is easier and cheaper to manage compared to salinity or cyclones[29]. Smaller-scale farming reduces input costs, while better access to loans and resources, such as drought-tolerant seeds, minimizes financial barriers. Additionally, proximity to markets and inputs helps farmers save on transportation costs, further alleviating financial challenges.

- Lower costs due to smaller-scale farming (Golam Rafiq, Islamkati, Satkhira).
- Monitored agricultural loans reduce over-borrowing (Ahmed Sharif, Koyra, Khulna).
- Preference for drought-tolerant seasonal hybrids reduces input costs (Nur Alam, Kurigram Sadar).

6.4.2 Southwestern Region

The Southwestern region faces significant financial challenges due to higher environmental stress, including salinity, cyclones, and flooding, which require costly inputs like saline-tolerant seeds and irrigation systems[30]. Limited access to modern machinery and infrastructure forces farmers to rely on expensive rentals. Poor market linkages and a lack of government support further exacerbate financial burdens, leaving farmers with fewer opportunities to invest in CSA technologies.

- Frequent replanting due to salinity damage increases expenses (Dulal, Morrelganj, Bagerhat).
- Dependence on rented equipment raises production costs (Farmer, Nishanbariya, Bagerhat).
- Farmers face unfair pricing, discouraging investments (Mizanur Rahman, Kapilmuni, Khulna).
- Subsidies are inaccessible or require unofficial payments (Alamin, Gazipara Mor, Khulna).

The barriers to adoption of CSA technologies,

Lack of Awareness

A significant barrier is the lack of awareness among farmers regarding the benefits of CSA technologies. The data shows that 93.5% of farmers in the north and 88.1% in the south cite this as a major obstacle, contributing to an overall rate of 89%. Limited exposure to CSA practices and benefits perpetuates reliance on traditional methods, creating resistance to adopting modern agricultural innovations. Insights from key informant interviews (KIIs) with NGO staff highlight that CSA technology adoption remains as low as 10% due to environmental challenges, economic barriers, salinity, lack of communication, and natural disasters like cyclones.

> "The adoption rate of CSA technologies is very low, around 10%. The main reasons are environmental challenges, economic constraints, salinity, poor communication infrastructure, and natural disasters like cyclones."
>
> Proshanto Mondol
> A field officer at Caritas, explained

Lack of Knowledge

A significant 51% of farmers overall reported a lack of knowledge as a barrier to adopting CSA technologies. This includes 84.3% in the northern region, compared to 40.3% in the southern region, highlighting regional disparities.

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[29] Sutradhar, R., Moniruzzaman, M., Chowdhury, F., & Rahman, A. (2015). A review of good adaptation practices: Lessons learned from NGOs and community-based organizations in Bangladesh. *Florida Institute of Technology*.

[30] Miah, M. G., Rahman, M. A., & Haque, A. (2020). Salinity intrusion and its impacts on agriculture in coastal Bangladesh. *International Journal of Agronomy and Agricultural Research*, 18(3), 45-53.

Farmers in the north face greater challenges in understanding the technical aspects of CSA technologies due to limited access to training, extension services, and informational resources. KII respondents also indicated that knowledge gaps persist due to insufficient training opportunities and weak extension services.

Financial Constraints

Financial limitations present another major hurdle, with 86.6% of farmers in the south and 7.4% in the north reporting this issue. Overall, 67% of farmers cite a lack of finance as a critical barrier, reflecting the high upfront costs associated with CSA technologies and limited access to credit or subsidies for smallholder farmers. This issue is further compounded by structural economic vulnerabilities and low profitability, as reported during KIIs.

Resource Limitations

Restricted access to essential resources, such as quality inputs, infrastructure, and training opportunities, was identified as a barrier by 6.5% of northern farmers and 20% of southern farmers, resulting in a total of 17%. This limitation hampers farmers' ability to effectively implement CSA technologies and realize their potential benefits. Environmental stressors like salinity and water scarcity exacerbate resource shortages, as highlighted in qualitative findings.

> "In our area, no government assistance is provided. To receive any government subsidy, a significant amount of money must be paid."
>
> Alamin
> Gazipara Mor, Ward 1, Koyra Sadar, Koyra, Khulna

Resistance to Change

Cultural and behavioral resistance to adopting new technologies affects 16.3% of farmers in the south, compared to only 1.9% in the north, contributing to an overall rate of 13%. This resistance often stems from a lack of understanding or trust in new practices. According to KIIs, farmers often prefer traditional methods over modern technologies due to skepticism and the fear of potential failure.

Fear of Unknown Technologies

Fear of unknown or untested technologies is a concern for 19.1% of southern farmers and 1.9% of northern farmers, amounting to 15% overall. This highlights the importance of demonstrations and community engagement in building farmer confidence. NGO staff mentioned that inadequate exposure to CSA technologies fuels this fear.

Lack of Trust

A lack of trust in CSA technologies or the institutions promoting them affects 20.6% of farmers in the south and 0.9% in the north, with a combined rate of 16%. This underscores the need for transparent and participatory approaches to encourage adoption. Trust issues also arise due to inconsistent governmental and institutional support, as emphasized in qualitative findings from the KIIs.

Other Barriers

A small percentage (**1% total**) identified other, unspecified barriers, which may include localized challenges or unique socio-economic factors.

6.5 Proposed Viable CSA Technologies, Practices, and Varieties for the Northern and Southwestern Regions

Table 3. Proposed Viable CSA Technologies, Practices, and Varieties for the Northern and Southwestern Regions

CSA technologies	Northwestern region	Reason behind the proposal	Southwestern region	Reason behind the proposal
Integrated Soil and Fertilizer Management	Urea deep placement (UDP)	Enhances nutrient uptake and reduces nitrogen loss in flood-prone soils.	Combination of organic and inorganic fertilizers	Addresses salinity-induced soil degradation and sustain fertility.
Conservation Agriculture	Zero tillage crop rotation and cover cropping	Minimizes soil disruption, prevents erosion and enhances nitrogen fixation.	Adapted conservation agriculture techniques, emphasizing crop rotation and diversification	Maintains soil health and resilience in saline conditions.
Integrated Nutrient Management (INM)	Organic inputs like vermicompost and trichocompost, balanced NPKS fertilizer application	Improves soil structure, microbial activity, and water retention in flood-affected areas.	Organic amendments paired with targeted chemical fertilizers	Counters salinity-induced soil degradation while ensuring balanced nutrient availability.
Irrigation and Water Management	Alternate Wetting and Drying (AWD) and furrow irrigation	Optimizes water use, conserves resources, and improves root health in flood-prone areas.	Fita pipes	Ensures precise irrigation and consistent moisture levels in saline-affected areas.
Crop Protection	Integrated Pest Management (IPM) using yellow sticky traps and pheromone traps	Provides sustainable pest control and reduces reliance on chemical pesticides.	Bio-pesticides and organic pesticides derived from natural sources	Protects crops while minimizing environmental impacts, supporting ecological balance.
CSA Agro-Machineries and Equipment	Power Tiller Operated Seeders (PTOS) and rice transplanters	Enhances planting efficiency and precision in flood-affected areas.	UDP applicators and Combined Harvesters	Streamlines operations, reduces labor, and minimizes post-harvest losses in challenging conditions
Salinity Adaptation Technologies	Not applicable in this region		Salt-tolerant crop varieties like BRRI dhan-67 and BRRI dhan-99	Maintains productivity in saline soils and supports food security.
Waterlogging Adaptation Technologies	Submergence-tolerant rice varieties like BRRI dhan-52 and BRRI dhan-78	Maintains yields under waterlogged conditions.	Drainage management systems	Alleviates prolonged water accumulation in saline-affected areas
Drought Adaptation Technologies	Drought-tolerant varieties like BINA dhan-14	Provides water-efficient crop options for water-scarce regions.	Heat-tolerant vegetable varieties and AWD technique	Optimizes water use and secures stable yields in water-scarce conditions.
Cost-Effective Technologies	Zero tillage and vermicomposting	Reduces operational costs and enhances soil fertility with low-cost solutions.	Bio-pesticides, fita pipes, and salt-tolerant varieties	Provides affordable solutions tailored to marginalized farmers' needs.

6.5.1 Cost-Effective CSA Technologies for Marginalized Farmers

6.5.1.1 Salinity-Prone Areas

Salt-tolerant rice varieties, such as BRRI dhan-67, are both affordable and locally accessible, making them highly compatible with the needs of small-scale farmers in saline-affected regions. Additionally, vermicomposting units, which utilize organic waste to create nutrient-rich compost, provide an economical method for enhancing soil fertility, aligning farmers with limited financial capacities.

6.5.1.2 Waterlogging-Prone Areas

Crops like BRRI dhan-52, designed for submergence tolerance, offer a practical and cost-efficient solution for farmers in flood-prone areas. Zero tillage further reduces operational expenses by eliminating the need for heavy tillage, conserving resources while maintaining productivity.

6.5.1.3 Drought-Prone Areas

The water-saving technique Alternate Wetting and Drying (AWD) is particularly cost-effective for smallholders, as it requires minimal equipment and achieves efficient water use. Meanwhile, drought-tolerant varieties, such as BINA dhan-14, offer farmers an economical path to secure stable yields in water-scarce conditions.

6.5.1.4 Mitigation Technologies across Regions

Affordable tools like fita pipes and furrow irrigation systems provide practical water management solutions that are accessible to marginalized farmers. Similarly, bio-pesticides and organic pesticides derived from natural sources offer low-cost and environmentally friendly alternatives to chemical pest control, reducing input costs and supporting sustainable farming practices. These CSA technologies and practices are aligned with Rogers' compatibility framework, as they address the socio-economic constraints of marginalized farmers. Their trialability ensures ease of experimentation, enabling gradual adoption and sustained benefits.

6.5.2 Inclusivity in CSA Technologies: Suitability for Women, Youth, and Persons with Disabilities

6.5.2.1 Attitudes

To ensure inclusivity, it is critical that CSA technologies are perceived as accessible and beneficial by women, youth, and persons with disabilities. Practices like vermicomposting or small-scale polyhouses provide manageable solutions that align with the physical and logistical capacities of these groups. For women, these technologies often allow them to engage in income-generating activities from home, reducing the burden of commuting or heavy labor. Youth, who are typically more adaptive to technology, find appeal in tools like mobile applications for agricultural management or lightweight equipment that introduce efficiency and innovation to farming practices. For persons with disabilities, tailored technologies, such as ergonomic tools or easily operable irrigation systems like fita pipes, ensure that farming becomes an inclusive activity.

6.5.2.2 Subjective Norms

Community and societal acceptance of CSA technologies are pivotal to ensuring inclusivity. Initiatives like women-led nurseries for producing salt-tolerant seedlings or youth-driven bio-pesticide production not only empower these groups economically but also shift societal perceptions about their roles in agriculture. By engaging in such activities, women and youth demonstrate their capacity to lead climate-smart agricultural practices, fostering a positive shift in community norms. For persons with disabilities, community support networks and inclusive policies play a critical role in creating opportunities to engage in agriculture. Peer-to-peer sharing of experiences and mentorship programs can further encourage these groups to participate in CSA practices actively.

> "Currently, CSA practices are beneficial for all community members, especially for people with disabilities, women, and youth."
>
> Sadequl Islam
> Ward 6, Holokhana, Kurigram (FGD 1)

6.5.2.3 Perceived Behavioral Control

Building the confidence and technical skills of marginalized groups is essential to overcome adoption barriers. Training programs specifically tailored to the needs of women, youth, and persons with disabilities can address the technical gaps. For example, hands-on training in bio-pesticide application, seedling management, or the operation of simple tools like rice transplanters can ensure that these groups feel capable and empowered to use CSA technologies. Capacity-building workshops that emphasize practical learning, coupled with follow-up support, ensure that these groups gain both the skills and the confidence needed to adopt CSA practices effectively.

6.5.2.4 External Factors

Policy and institutional support are critical enablers for inclusive adoption of CSA technologies. Governments and development agencies can introduce financial incentives such as subsidized access to lightweight machinery, low-interest loans, and grants specifically targeted at women, youth, and persons with disabilities. For example, ensuring that polyhouse materials or vermicomposting kits are affordable through subsidies can lower the barriers to entry. Additionally, market access mechanisms, such as cooperatives or digital platforms, can empower these groups to sell their produce or services, ensuring economic sustainability. Infrastructure improvements, such as creating accessible agricultural training centers, further contribute to inclusivity.

> "We have a person with a disability here who has only one hand. With that one hand, he cultivates various vegetables. A long time ago, he was provided with two sacks of 28-variety rice seeds through government support."
>
> Ibrahim
> Koyra Sadar, Khulna (FGD-3)

6.6 Proposed value chains and business models

6.6.1 Proposed value chain

6.6.1.1CSA Rice Seed Value Chain

Saline Tolerant and Short Duration in the Southern Region; Drought, Submergence Tolerant in the Northern Region

Southern Region (Saline Tolerant and Short Duration Variety):

- **Salinity Stress:** The region faces medium to high levels of soil salinity, making it difficult for conventional rice varieties cultivation.
- **Water Management:** Irrigation practices need to be optimized for saline water, which requires significant investment in infrastructure and technology.
- **Soil Degradation:** Over time, saline soils can lose fertility, requiring additional inputs (fertilizers, organic matter).
- **Access to Technology:** Limited availability of saline tolerant seed varieties.
- **Market Access:** Challenges in marketing saline-tolerant rice varieties.

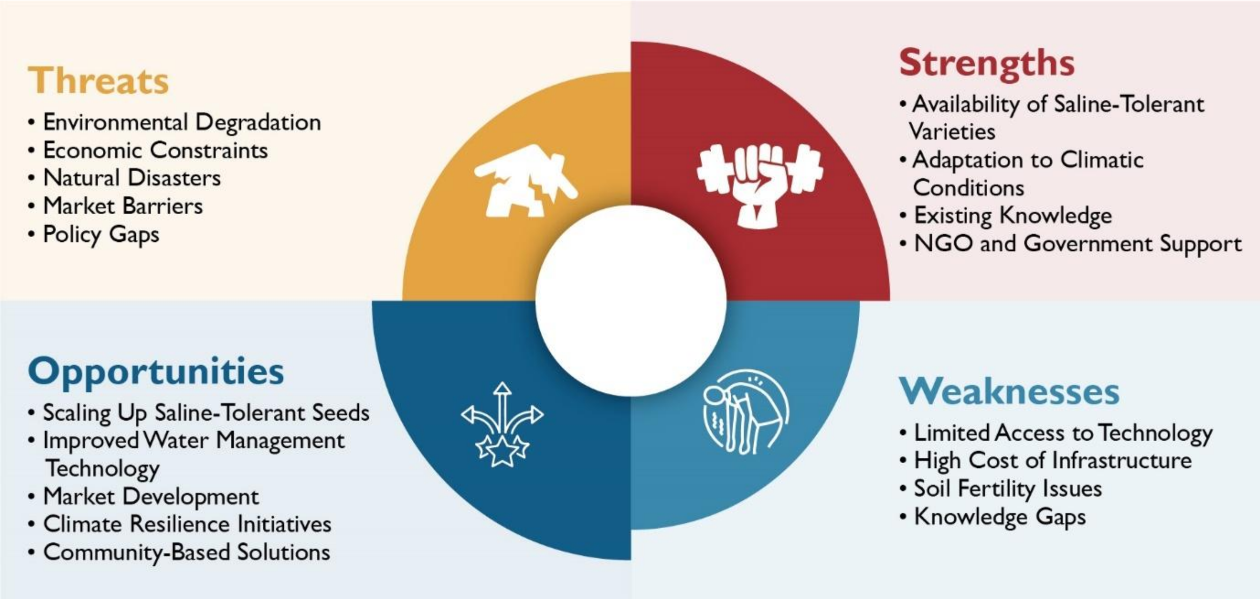

***Fig. 32:** SWOT Analysis*

Strengths

- **Availability of Saline-Tolerant Varieties:** The existence of climate-resilient crop varieties, such as saline-tolerant and drought-resistant seeds, provides a significant advantage. These varieties can withstand adverse climatic conditions, ensuring stable productivity even in challenging environments.
- **Adaptation to Climatic Conditions:** Farmers in the targeted regions are increasingly adopting practices suited to their environmental conditions, such as conservation agriculture and alternate wetting and drying (AWD). This adaptability supports the sustainability of the value chain.
- **Existing Knowledge:** Many farmers and local stakeholders possess traditional knowledge and experience in handling adverse conditions like salinity and flooding. This foundational understanding can be built upon to introduce modern agricultural practices and technologies.
- **NGO and Government Support:** Continuous assistance from NGOs, government bodies like the Department of Agricultural Extension (DAE), and other stakeholders provide technical guidance, resources and policy backing for the value chain's development.

Weaknesses

- **Limited Access to Technology:** Smallholder farmers often face barriers in accessing advanced agricultural tools, irrigation systems, and CSA technologies, limiting their capacity to implement efficient farming practices.
- **High Cost of Infrastructure:** Infrastructure development for irrigation, drainage systems, and storage facilities often requires substantial investment, which can be prohibitive for marginalized farmers.
- **Soil Fertility Issues:** Soil degradation caused by salinity, waterlogging, and overuse of chemical fertilizers poses a significant challenge to maintaining long-term agricultural productivity.
- **Knowledge Gaps:** While some farmers have traditional knowledge, there is often a lack of awareness and training regarding advanced CSA technologies, pest management practices, and integrated soil management strategies.

Opportunities

- **Scaling Up Saline-Tolerant Seeds:** Expanding the use of saline-tolerant crop varieties like BRRI dhan-67 and BRRI dhan-99 can enhance agricultural resilience and productivity across affected regions.
- **Improved Water Management Technology:** Technologies like fita pipes, AWD, and efficient irrigation systems can be scaled to improve water conservation and mitigate the effects of waterlogging and salinity.
- **Market Development:** Creating robust market linkages for CSA products, such as salt-tolerant crops and organic produce, can enhance economic opportunities for farmers and improve the value chain's sustainability.
- **Climate Resilience Initiatives:** Partnerships with NGOs and government initiatives focused on climate adaptation can provide resources, training, and infrastructure to strengthen the value chain against climate shocks.
- **Community-Based Solutions:** Promoting community-driven approaches, such as cooperative farming and shared resources for irrigation and pest management, can foster collective resilience and reduce individual costs.

Threats

- **Environmental Degradation:** Accelerated salinity intrusion, soil erosion, and loss of biodiversity could undermine agricultural productivity and the overall value chain.
- **Economic Constraints:** Limited financial capacity among smallholder farmers restricts investment in advanced CSA technologies, fertilizers, and infrastructure improvements.
- **Natural Disasters:** Frequent cyclones, storm surges, and floods pose a continuous threat to agricultural activities, disrupting the value chain and affecting livelihoods.
- **Market Barriers:** Farmers often face challenges accessing lucrative markets due to inadequate transportation, high logistical costs, and lack of competitive pricing for CSA products.
- **Policy Gaps:** Inconsistent or absent policies on climate-resilient agriculture, subsidies for CSA technologies, and support for marginalized farmers hinder the large-scale adoption of value chain improvements.

Northern Region (Drought and Submergence Tolerant Variety):

- **Climate Variability:** Unpredictable rainfall patterns and prolonged droughts may limit the effectiveness of drought-tolerant varieties.
- **Water Availability:** Limited irrigation resources for dry rice cultivation can affect yields.
- **Soil Fertility:** Drought-prone areas have poor soil fertility, requiring enhanced soil management techniques.
- **Farmer Awareness:** Farmers are unfamiliar with new drought-tolerant and submergence-tolerant varieties, affecting adoption rates.

6.6.1.2 CSA Seedlings Value Chain (Both Regions)

- **Quality Control:** Ensuring high-quality seedlings that can be produced by using the plastic seedling tray for using by rice transplants can be a challenge due to the lack of standardized production and handling methods.
- **Infrastructural Issues:** Poor infrastructure for transporting and storing seedlings, leading to loss of quality.

- **Access to Inputs:** Limited access to high-quality CSA seeds, fertilizers, and other inputs needed for healthy seedling production.
- **Pest and Disease Control:** Seedlings are vulnerable to pests and diseases, which can reduce their viability and success in the field.
- **Farmer Training:** Lack of knowledge about the best practices for seedling care and transplanting.

6.6.1.3 CSA Pulse and Oil Seeds Value Chains (Both Regions)

- **Market Volatility:** Prices for pulses and oilseeds can fluctuate, making it difficult for farmers to plan their production.
- **Water Management:** Pulses and oilseeds are water-sensitive, so irrigation issues (especially in the north) could hinder production.
- **Soil Fertility:** Both crops require nutrient-rich soils; northern regions is suffering from low fertility in dry lands.
- **Pests and Diseases:** Pulses are vulnerable to various pests and diseases, which could reduce yield if not managed properly.
- **Climate Variability:** Drought and unpredictable rainfall can have negative impacts on oilseeds, especially in the northern region.

6.6.1.4 Vegetable Value Chain (Pumpkin Value Chain for the North Region)

- **Climate:** Short growing seasons in the northern region may limit the potential for pumpkin cultivation. Additionally, temperatures may be too extreme for optimal growth.
- **Water Availability:** Insufficient rainfall and drought conditions can affect vegetable production.
- **Market Access:** Limited market access for niche crops like pumpkins.
- **Pest and Disease Management:** The northern region could face pest pressures (like red pumpkin beetle) that require specific control methods.
- **Seed Availability:** Limited availability of high-quality, region-specific drought tolerant pumpkin seeds.

6.6.1.5 Vermicompost Value Chain (Both Regions)

- **Awareness and Training:** Limited knowledge of farmers and awareness about the benefits of vermicomposting.
- **Raw Material Availability:** Sufficient organic waste for vermicomposting, specially cow dung, earthworm may not always be available, especially in the northern region.
- **Labor Intensity:** Vermicomposting is labor-intensive and may not appeal to women farmers without sufficient labor resources.
- **Quality Control:** Ensuring high-quality vermicompost requires proper management and attention to detail.
- **Market Demand:** Market for vermicompost may be limited, especially if synthetic fertilizers are more commonly used.

6.6.1.6 Guti Urea Value Chain (Both Regions)

- **Supply Chain Issues:** Limited availability and distribution networks for Guti Urea may limit adoption.
- **Awareness:** Farmers may not be aware of the benefits of Guti Urea as a slow-release fertilizer compared to prilled/normal urea.
- **Market Acceptance:** Conventional urea fertilizers may dominate the market, making it difficult for Guti urea to compete.

6.6.1.7Organic and Bio-Pesticides Value Chains (Both Regions)

- **Pest Resistance:** Organic and bio-pesticides may not be as effective as chemical alternatives, leading to pest resistance issues.
- **Cost and Availability:** Organic and bio- pesticides can be more expensive to produce or purchase, which may limit farmer adoption, especially for smallholder farmers.

- **Regulation:** Lack of regulatory frameworks or certification for organic and bio-pesticides may affect consumer confidence and market demand.
- **Awareness and Education:** Limited understanding of organic pest control methods and benefits among farmers, especially in the northern region.

6.6.1.8 CSA Machineries (Rice Transplanters, Combine Harvester) Value Chain (Both Regions)

- **Capital Investment:** High upfront costs for CSA machinery may be a barrier for smallholder farmers.
- **Mechanization Access:** In both regions, access to modern farming machinery may be limited due to financial and infrastructure constraints.
- **Skilled Labor:** There may be a shortage of skilled operator/mechanics to operate CSA machinery, particularly in the northern region.
- **Maintenance and Spare Parts:** Availability of spare parts and maintenance services for advanced machinery can be limited in targeted regions.

6.6.2 Common Constraints (for both regions)

Table 4. Common Constraints (for both regions)

Constraint	Intervention	Output	Outcome	Impact	Potential Partner
Access to finance	Introduce low-interest microcredit schemes through financial institutions and cooperatives.	Increased access to affordable credit for farmers.	Farmers can invest in CSA practices and inputs.	Enhanced agricultural productivity and resilience to climate change.	Banks, Microfinance Institutions (MFIs), NGOs, Government Financial Programs.
Market Linkages	Establish farmer cooperatives and digital platforms for direct market access.	Improved market access and better pricing for farmers' produce.	Stable income for farmers and reduced-price fluctuations.	Strengthened local and national agricultural markets, reducing uncertainties.	Local Cooperatives, E-commerce Platforms, Trade Associations, Ministry of Commerce.
Education and Extension Services	Strengthen agricultural extension services and conduct farmer training programs on CSA practices.	Farmers gain knowledge of CSA technologies and practices.	Increased adoption of CSA techniques, improving farm productivity.	Better-prepared farming communities that can adapt to climate variability.	Department of Agricultural Extension (DAE), NGOs, Universities, Agricultural Research Institutes
Infrastructure Deficiencies	Invest in road networks, storage facilities, and transportation solutions for rural areas.	Improved infrastructure for transportation and storage	Reduced post-harvest losses and efficient movement of goods and inputs	Enhanced supply chain efficiency and better income for farmers	Ministry of Roads and Highways, NGOs, Private Sector Logistics Providers, Development Partners
Climate Change	Promote CSA technologies like drought-tolerant crops, AWD, and integrated nutrient management (INM)	Adoption of climate-resilient agricultural practices	Farmers are better equipped to handle climate shocks and extreme weather	Sustainable agricultural systems that contribute to food security under changing climatic conditions	Climate Change Adaptation Programs, UN Agencies, Research Institutes, Local Government Authorities

6.6.3 Business Models: Opportunities for Scaling CSA Technologies in the Southwestern Region

Table 5. Business Models: Opportunities for Scaling CSA Technologies in the Southwestern Region

Business Model	Inputs	Production Process	Constraints	Other Relevant Factors
Group Approach/ Cooperative Model	Saline-tolerant seeds, financial resources, transportation facilities.	Formation of cooperatives, pooling resources, centralized production and distribution of saline-tolerant rice varieties to farmers.	Limited coordination among farmers, lack of leadership skills, transportation challenges.	Requires capacity-building workshops, support from local NGOs, and government backing for effective resource pooling.
CSA Seedling Production Model	Salt-tolerant seeds (e.g., BRRI dhan-67, 97, 99), nursery setup, water and soil testing kits, labor.	Women-led nurseries produce saline-tolerant seedlings (rice and vegetables), distribute seedlings to farmers, and promote adoption.	Limited access to initial capital, technical knowledge gaps, challenges in ensuring seed quality.	Encourages women's entrepreneurship, requires partnerships with BRRI, BINA, and agricultural extension services.
Eggplant Production Branding Model	Pheromone traps, sticky traps, mulching films, IPM tools, branding materials, and training programs.	Adoption of pest management practices (pheromone traps for BSFB, sticky traps for mites), use of mulching films, branding campaigns for regional and national markets.	Lack of branding expertise, inconsistent supply chain for branded products, pest management knowledge gaps.	Requires collaboration with agribusinesses, marketing firms, and government support to establish a sustainable branding initiative.
Women-Focused Vermicompost Model	Organic waste, vermicomposting units, packaging materials, and initial funding for setup.	Production of vermicompost using organic waste, packaging and selling to local farmers for soil fertility enhancement and reducing chemical dependency.	Inadequate technical knowledge of vermicomposting, insufficient market demand for compost in some areas.	Promotes women's economic empowerment, requires capacity-building initiatives and linkage with agricultural input suppliers.
Contract Farming Model	Saline-tolerant seeds, agreements between farmers and agribusinesses, training for contract farmers.	Women's groups or smallholders produce CSA crops under contracts, ensuring stable pricing and market access, with guidance on farming practices provided by agribusinesses.	Risk of unfair contracts, lack of trust between farmers and companies, limited understanding of contract terms.	Requires transparent agreements, legal assistance for farmers, and monitoring mechanisms to ensure fair practices.
Local Service Provider (LSP) Model	CSA equipment (rice transplanters, AWD tools, soil testers), training materials, initial funding for LSP setup.	Youth and women are trained as LSPs to provide advisory services and equipment rentals for CSA practices, addressing local needs at the community level.	Lack of skilled trainers, financial barriers for LSP setup, limited awareness of CSA benefits.	Encourages youth engagement and community-based solutions, supported by agricultural extension services and NGOs.
Social Enterprise Model	Bio-pesticide production tools, training resources, youth engagement programs, and marketing strategies.	Establish social enterprises to produce and sell eco-friendly pest control solutions while training local youth in CSA practices.	Limited access to bio-pesticide production technology, inadequate demand	Reinforces sustainable agriculture and youth skill development; requires partnerships with local NGOs and agricultural institutions.

Business Model	Inputs	Production Process	Constraints	Other Relevant Factors
			generation for eco-friendly solutions.	
Digital Marketplace Model	Digital platforms, mobile devices, internet connectivity, logistics support for deliveries.	Youth and women entrepreneurs market and sell CSA products (vermicompost, safe vegetables, seeds) online, overcoming physical market constraints.	Limited digital literacy, connectivity issues in remote areas, logistics inefficiencies for product delivery.	Promotes technological innovation and market accessibility; partnerships with e-commerce platforms and telecom providers are essential.
Sales Corner Model	Space in local markets, CSA products (vegetables, seeds, compost), branding and display materials.	Women, youth, and persons with disabilities showcase and sell safe food and CSA products in local haats and bazaars, promoting sustainable food practices.	Lack of access to prime market locations, competition with non-CSA products, limited visibility.	Requires local government support for setting up market stalls, community-based promotion, and branding campaigns.
Women/Persons with Disabilities Outlet Model	CSA inputs (seeds, compost, pest control materials), initial funding, training on store management.	Establish outlets managed by women and persons with disabilities to ensure CSA inputs' availability in underserved areas, fostering inclusivity and entrepreneurship.	Limited business management skills, low initial capital, and challenges in ensuring consistent input supply.	Empowers marginalized groups and improves CSA adoption in remote areas; partnerships with NGOs, local governments, and input suppliers are critical.

6.6.4 Business Models: Opportunities for Scaling CSA Technologies in the Northern Region

Table 6. Business Models: Opportunities for Scaling CSA Technologies in the Northern Region

Model	Inputs	Process	Constraints	Benefits
Pit Method Pumpkin Cultivation	Sandy char lands, seeds, compost	Create pits, plant seeds, irrigate, manage pests	Seasonal water availability, poor soil	Utilizes char lands, improves food security and income.
Contract Farming	Seeds, training, contracts	Grow crops as per contracts, sell to agribusiness	Farmer coordination, market reliance	Fair pricing, steady markets, women's participation.
Women-Focused Vermicompost	Organic waste, bins, earthworms	Produce compost, process, and package for sale	Limited waste access, low awareness	Women's income, reduced chemical use, improved soil
Plastic Tray & Rice Transplanters	Trays, rice seedlings	Produce uniform seedlings for mechanized farming	High initial cost, market linkage	Promotes mechanization, fosters entrepreneurship
Floating Gardens	Bamboo, organic matter, seeds	Build floating beds, grow vegetables	Seasonal flooding, input availability	Income, food in flood-prone areas, climate resilience.
Sales Corner	Safe vegetables, stalls	Market vegetables in local haats and bazaars	Limited branding, market fluctuations	Visibility for marginalized groups, safe food promotion.
Digital Marketplace	Mobile platforms, CSA products	Connect producers with urban consumers through apps	Digital literacy, logistics	Enhances market access, youth entrepreneurship.
Local Service Provider (LSP)	Training, CSA equipment	Provide advisory services and CSA tools to farmers	Limited training access	Boosts CSA adoption, youth and women empowerment
Women-Led Outlets	CSA inputs, shop spaces	Sell CSA seeds, vermicompost, and plant protection materials	Limited supply chain, initial setup cost	Empowers women, ensures rural input availability

6.7 Comprehensive Guidelines and Suitable Interventions for implementing the CSA Technologies and Practices in the Targeted Regions

To address finding barriers, several market-driven solutions and interventions were identified. These can be implemented through private, government sector collaboration and targeted community people engagement, particularly involving youth, women, and persons with disabilities.

6.7.1 Capacity Building Farmers on CSA Technologies

- ✓ Facilitate crop-specific training and hands-on demonstrations on CSA technologies and practices, addressing:
    - Salinity management in the southern zone.
    - Drought and waterlogging issues in the northern zone.
    - Fertilizer management
    - Water and irrigation management
    - Guti Urea application and requirement
    - Insect and disease control through IMP and bio-pesticides
    - CSA machineries utilization techniques
- ✓ Collaborate with the Department of Agricultural Extension (DAE) and private companies to strengthen training delivery and CSA technologies
- ✓ A details training modules need to develop for effectively increase the capacity (knowledge and skills on CSA Technology) of the targeted community people
- ✓ Organize farmers' exposure visits to observe the success of CSA technologies within the working zones.
- ✓ Knowledge and skills development on using the Khamari Apps/ Mobile Apps to optimize crop-specific fertilizer and crop selection, reduce production costs, and enhance crop yields with the help of DAE and SRDI personnel.

6.7.2 CSA Technology Demonstration Plot Establishment

The theme for this initiative is *"Seeing is Believing."* Establishing CSA (Climate-Smart Agriculture) technology demonstrations will serve as an effective way to showcase the benefits of CSA technologies to community farmers. By observing the success and impact of these technologies, targeted farmers will be encouraged to adopt them in upcoming seasons. This approach enables the community to witness firsthand the benefits of CSA varietals, fertilizers, irrigation systems, Integrated Pest Management (IPM), and CSA machinery. To ensure the success of these demonstrations, collaboration with the Department of Agricultural Extension (DAE) and private seed/input dealers is essential, as it will help strengthen the program's outreach and impact.

Key Implementation Steps of Demonstrations:

- **Develop a Demonstration Protocol:** A structured protocol should be created to effectively organize and manage the demonstrations.
- **Showcase Key Growth Stages:** Demonstrations should highlight different stages of crop growth, such as planting, tillering, and ripening, to provide a comprehensive understanding of the technologies.
- **Organize Farmers' Field Days:** Field days should be arranged to demonstrate the technologies in action, inviting relevant stakeholders, including farmers, extension officers, and private sector staff.
- **Analyze Results:** Results from the demonstration plots should be analyzed and compared with traditional farming practices to showcase the benefits of CSA practices to participants.
- **Install Informative Signboards:** Signboards with relevant CSA technology information should be placed in the demonstration plots to enhance visibility and provide ongoing education to visitors and farmers.

6.7.3 Enhancing CSA Input Accessibility

- Improve farmers' access to high-quality CSA seed varieties developed by research institutions like BRRI, BARI, and BINA (refer to the CSA seed variety list).
- Promote seed priming and treatment to enhance germination rates, reduce seed-borne diseases, and lower production costs.
- Promote the use of biopesticide tools, such as sticky traps and pheromone traps, by engaging youth, women, and persons with disabilities in their distribution channels.
- Promote vermicompost/trichocompost among the community through involvement DAE and private entrepreneurs.

6.7.4 Promoting Climate-Smart Practices

- Encourage the use of balanced fertilizers (NPKS + manure and micronutrients) and IPM methods to restore soil health, retain moisture, and address salinity issues.
- Promote Alternate Wetting and Drying (AWD) irrigation for boro rice cultivation to conserve water.
- Introduce crop rotation with legume/pulse crops (e.g., lentils, mung beans) to improve soil fertility status.
- Promote the perching in the crop field for controlling the insects

6.7.5 Mechanization and Equipment Support

- Facilitate access to CSA machinery, including seeders, rice transplanters, combine harvesters, and reapers, to improve efficiency and reduce losses
- Develop linkages with machine service providers (MSPs) to offer CSA equipment on a rental basis at the community level.
- Develop machine operators to operate the machine and mechanics for maintenance of the machinery

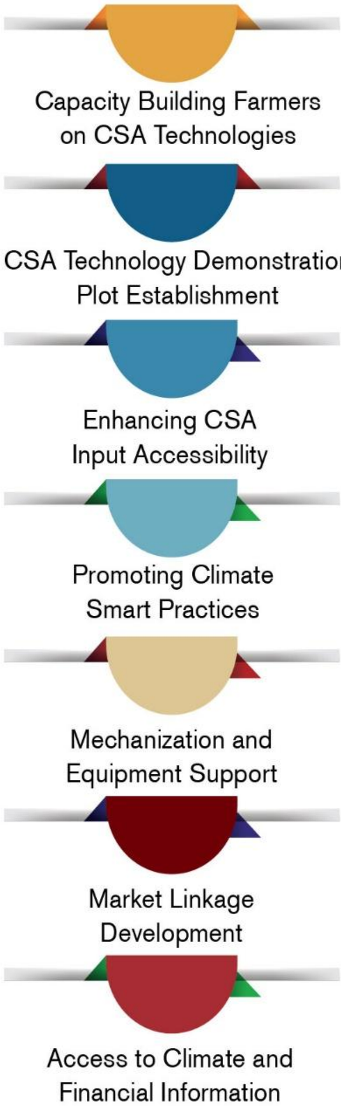

Fig. 33: CSA Implementation Strategies

- Work collaborates with DAE and private machine selling companies such as Alim Industries and Janata Engineering, Metal and ACI etc.

6.7.6 Market Linkage Development

- Strengthen commercial relationships with buyers and processors to establish stable procurement arrangements and encourage investments in farmer productivity.
- Foster partnerships between farmers and local service providers (LSPs) or machine service providers for improved access to CSA services.

> "Loans are provided to farmers carefully, ensuring they do not borrow more than they need. Discussions are held with them to provide loans according to their convenience. Agricultural loans are monitored, and no excess amounts are provided."
>
> Ahmed Sharif
> Ward 1, Koyra Upazila, Koyra, Khulna

6.7.7 Access to Climate and Financial Information

- Provide timely weather forecasts and early warning systems to enable farmers to implement preventive measures.
- Expand access to formal banking services and financial products tailored for CSA investments, particularly for CSA equipment procurement.

7.

Recommendation

Area	Key Recommendation
Farmers in Kurigram, a flood-prone northern region, face frequent waterlogging, leading to crop losses and low productivity.	▪ Promote floating vegetable beds and flood-resilient farming practices. ▪ Strengthen seed distribution networks for flood-tolerant varieties like BINA dhan 11 and BRRI dhan 52. ▪ Conduct training programs on water management techniques.
Farmers in Khulna, Satkhira, and Bagerhat face increasing salinity intrusion, reducing soil fertility and access to clean water.	▪ Ensure access to saline-tolerant seed varieties like BRRI dhan 97, 99, and BINA dhan 8, 10. ▪ Develop community seed banks and strengthen supply chains for bio-pesticides and organic fertilizers. ▪ Promote water conservation technologies such as drip irrigation and rainwater harvesting.
Knowledge gaps and lack of training hinder farmers in both regions from adopting CSA practices effectively.	▪ Organize Farmer Field Schools and demonstration plots for underutilized varieties like BRRI dhan 56, 57, and 98. ▪ Partner with NGOs, agricultural offices, and private organizations to build awareness and technical capacity.
Financial constraints prevent marginalized farmers, particularly women, from investing in CSA inputs and technologies.	▪ Provide targeted subsidies and low-interest loans for CSA tools and resilient seeds. ▪ Establish microfinance schemes and revolving funds focused on women and marginalized groups.
Gender disparities limit women farmers' participation in decision-making and access to resources. Weak extension services fail to deliver timely support and advice to farmers in remote areas.	▪ Conduct women-centric training programs on CSA tools and techniques. ▪ Promote women-led enterprises like vermicomposting and seedling nurseries. ▪ Ensure equitable access to inputs and financial support. ▪ Deploy mobile advisory units to provide real-time guidance on CSA practices. ▪ Develop partnerships with research institutions for timely delivery of seeds and tools.
Limited digital tools and technologies prevent effective planning and market access.	▪ Utilize mobile apps like the Khamari App for crop selection, weather updates, and market prices. ▪ Create online marketplaces to connect farmers with urban markets. ▪ Use geospatial technology to identify high-risk areas and plan interventions.
Farmers from Buraburi, Kurigram, emphasized the need for better tools and training.	▪ Provide region-specific training on drought-tolerant and saline-resilient crops. ▪ Equip farmers with modern agro-machinery and technical skills to enhance productivity.
Farmers in Satkhira and Khulna highlighted the importance of diversification for better resilience.	▪ Encourage mixed/intercropping systems and diversification with crops like pumpkin, maize, sesame, and quinoa.

8.

Conclusion

The Climate Smart Agriculture (CSA) study sheds light on the urgent need to address the multifaceted challenges posed by climate change to Bangladesh's agriculture sector. Agriculture remains a cornerstone of the nation's economy and livelihoods, yet it is increasingly threatened by adverse climatic impacts. This study highlights the distinct vulnerabilities faced by the northern and southwestern regions, where recurrent flooding in the north and salinity intrusion in the southwest undermine agricultural productivity and food security. These vulnerabilities demand context-specific, sustainable solutions that not only address immediate challenges but also lay the groundwork for long-term resilience and environmental sustainability.

Through its detailed findings, the study emphasizes the potential of CSA technologies and practices in transforming the agricultural landscape of these regions. Innovations such as drought-tolerant and saline-resistant crop varieties offer farmers viable tools to combat climatic extremes while maintaining productivity. Techniques like integrated nutrient management and precision irrigation enhance soil health, water efficiency, and crop resilience. Conservation agriculture practices, including zero tillage, crop rotation, and cover cropping, not only improve soil fertility and productivity but also contribute to broader environmental conservation goals by reducing greenhouse gas emissions and mitigating soil erosion. Furthermore, advancements in agro-machinery, such as Power Tiller Operated Seeders (PTOS), rice transplanters, and combined harvesters, provide scalable solutions for improving efficiency and reducing labor intensity. However, the study also underscores the barriers impeding the widespread adoption of these technologies. Lack of awareness about the benefits of CSA practices remains a significant obstacle, compounded by insufficient training and limited access to critical resources. Financial constraints, particularly among smallholder farmers, hinder their ability to invest in advanced technologies and resilient seed varieties. Gender disparities further exacerbate these challenges, as women—who play a vital role in agriculture—often face restricted access to training, resources, and decision-making opportunities. Institutional inefficiencies, such as inadequate extension services and policy gaps, also undermine efforts to scale CSA initiatives effectively.

To address these barriers, the study outlines actionable recommendations that advocate for a multifaceted and inclusive approach. Strengthening seed distribution networks, especially for flood-tolerant and saline-resistant varieties, is critical to ensuring farmers' timely access to essential inputs. Expanding capacity-building programs, including farmer field schools and community-based training initiatives, can enhance farmers' technical knowledge and confidence in adopting CSA practices. Financial support mechanisms, such as subsidies, microfinance schemes, and targeted grants, can alleviate the economic burden on farmers and encourage greater participation. Additionally, leveraging digital solutions such as mobile apps and geospatial technologies can enhance decision-making, improve market access, and streamline the dissemination of CSA-related information. Encouraging gender-inclusive strategies, including targeted programs for women farmers, is crucial to ensuring equitable participation in CSA initiatives. Strengthened institutional support, such as robust extension services and community-led cooperatives, can provide the necessary infrastructure for implementing CSA at scale.

9.

Annexures

9.1 CSA Rice Seed Varieties Developed by Research Organization (BRRI and BINA)

Name of the Variety	Recommend season for cultivation	CSA Features/ Character	Zn mg/Kg	Protein mg/kg	Salinity Ds/m2	Ave. Yield T/Ha
BRRI Dhan 99	Boro	Salt Tolerant		7.9	14 seedling stage but all stage 8-10	5.4
BRRI Dhan 97	Boro	Salt Tolerant		8.6	14 seedling stage but all stage 8-10	4.94
BRRI Dhan 67	Boro	Salt Tolerant			12-14 seedling stage. 8 All stage	5.7
BRRI Dhan 36	Boro	Cold tolerant				5.5
BINA 10	Boro	Salt Tolerant			Tillering to Maturity 8-10 and seedling stage 12-14	5.7
BINA 8	Boro	Salt Tolerant			Tillering to Maturity 10-12 and seedling stage 12-14	5.5
BRRI Dhan 108	Boro, lifespan:150 days	Drought & Bacterial Blight tolerant		8.8		8.7
BRRI Dhan 107	Boro Lifespan: 148 days	Drought & Bacterial Blight tolerant		10.02		8.19
BRRI Dhan 102	Boro, Lifespan 150 days	Drought & Bacterial Blight tolerant, Zn fortified	25.5	7.4		8.2
BRRI Dhan 101	Boro, Lifespan: 142 days	Drought & Bacterial Blight tolerant	18-22	9.8		7.72
BRRI Dhan 84	Boro	Zn fortified	27.6			7.1
BINA 20	T. Aman	Zn fortified	26.5			5.5
BRRI Dhan 91	T. Aman	Flood/Submergence tolerant				3.5
BRRI Dhan 111	T. Aman	Flood/Submergence tolerant				4.2
BRRI Dhan 103	T Aman; Plant Height 125 cm	Short Duration, Rainfed, Lifespan 128-133 days				6.2-8.0

Name of the Variety	Recommend season for cultivation	CSA Features/ Character	Zn mg/Kg	Protein mg/kg	Salinity Ds/m2	Ave. Yield T/Ha
BRRI Dhan 87	T. Aman, Plant height: 122 cm	Short Duration Lifespan 127 days				6.5
BRRI Dhan 79	T. Aman; Lifespan 135-160 days	Submergence Tolerant 21 days				4.0-5.0
BRRI Dhan 78	T. Aman, Height 122 cm	Salt & submergence				6.0
BRRI Dhan 71	T. Aman, Lifespan 114-117 days	Drought Tolerant, short duration				4.0 in drought condition, Normal condition 5-6 ton
BRRI Dhan 57. Rice Like Minikit	T. Aman	Drought Tolerant, short lifespan 100-105 days				4.5
BRRI Dhan 52	T. Aman	Submergence Tolerant				5.5
BRRI Dhan 53	T. Aman	Submergence and Salt tolerant/Photo-insensitive, Lifespan 125 days		8.5	Reproductive stage 8 suitable for Gher Satkhira	4.5-5.0
BR Dhan 23, Plant height 120cm	T Aman	Late planting variety, Photosensitive, after flood suitable, lifespan 150 days				5.5
BINA 7	T. Aman	Short duration lifespan 107 days				4.8
BINA 11	T. Aman	Submergence				4.5-5.0
BINA 12	T.Aman	Submergence				4.0-4.5
BINA 15	T. Aman	Short duration				5.8
BINA 16	T Aman	Short duration				5.5
BINA 17	T. Aman	Short duration				7.0
BINA 22	T. Aman	Short duration/ year-round can cultivate				6.5
BINA 23	T. Aman	Short duration/ year-round can cultivate				6.0
BRRI Dhan 27	Aus	Suitable for Barishal Region				4.0
BRRI Dhan 55	Aus & Boro	Salt, Drought & Cool Tolerant				5.0
BRRI Dhan 82	T. Aus	Short Duration (102 days)				4.7
BRRI Dhan 83	Broadcast Aus	Drought Tolerant & Short Duration (103 days)				3.8
BRRI Dhan 85	T. Aus	Submergence & Short Duration (107 days)				4.5
BRRI Dhan 98	T Aus	Short Duration, Drought tolerant				5.8

Name of the Variety	Recommend season for cultivation	CSA Features/ Character	Zn mg/Kg	Protein mg/kg	Salinity Ds/m2	Ave. Yield T/Ha
BINA 19	T Aus	Drought tolerant and short duration				
BINA 11	T. Aman	Submergence				
BINA 12	T.Aman	Submergence				
BINA 26	T. Aman	Suitable for all AEZ except Saline Districts. BLB Resistance		9.4		6.5
BINA 16	T. Aman Short Duration 100-108 days	All over the country				5.5
BINA 17 (80-95 cm), Compare with Sharna	T Aman, Lifespan:112-118 days	Drought Tolerant 30% less irrigation required				6.8

9.2 Lentils CSA Varieties Developed by BARI and BINA

Sl	Name of Variety	Climate features	Yield t/ha
1	BARI masur 6	Short duration (105--110 days)	2.2-2.3
2	BARI masur 7	Short duration (110-115 days)	1.8-2.3
3	BARI masur 8	Short duration (110-115 days)	1.8-2.0
4	BARI masur 9	Short duration (85-90 days)	1.1-1.5
5	BINA masur 5	Short duration (99-102 days)	2.15
6	BINA masur 7	Short duration (110-112 days)	2.2-2.4
7	BINA masur 8	Short duration (95-100 days)	2.4
8	BINA masur 9	Short duration (99-100 days)	2.3

9.3 Mungbean CSA Varieties Developed by BARI and BINA

Sl	Name of Variety	Climate features	Yield t/ha
1	BARI Mungbean-5	Short duration (55-60 days)	1.40-1.45
2	BARI Mungbean-6	Short duration (55-60 days)	1.5-1.6
3	BINA Mungbean-5	Short duration (70-80 days)	2.0
4	BINA Mungbean-6	Short duration (64-68 days)	1.5
5	BINA Mungbean -7	Short duration (70-74 days)	1.8
6	BINA Mungbean-8	Short duration (64-67 days)	2.0
7	BU Mungbean-4	Short duration (55-60 days)	1.8-2.0

9.4 Mustard CSA Varieties Developed by BARI and BINA

Sl	Name of Variety	Climate features	Yield t/ha
1	BARI Sarisha 9	Short duration (80-85 days)	1.4-2.0
2	BARI Sarisha 12	Short duration (90-95 days)	1.5-2.0

Sl	Name of Variety	Climate features	Yield t/ha
3	BARI Sarisha 14	Short duration (85-90 days)	1.5-2.1
4	BARI Sarisha 15	Short duration (90-110 days)	1.6-2.0
5	BARI Sarisha 16	Saline tolerant (105-110 days)	1.2-1.5
6	BARI Sarisha 17	Short duration (95-100 days)	1.5-1.8
7	BINA Sarisha 4	Waterlogged tolerant (95-100 days)	1.7-2.20
8	BINA Sarisha 9	Short duration (95-100 days)	1.6-2.1

9.5 Sesame CSA Varieties Developed by BARI and BINA

Sl #	Name of Variety	Climate features	Yield t/ha
1	BARI T2 Black	Short duration (90-100 days)	0.9-1.0
2	BARI T3 Brown	Short duration (85-90 days)	1.0-1.10
3	BARI T4 Brown	Short duration (80-95 days)	1.2-1.4
4	BARI T6 Black	Short duration (85-90 days)	1.0-1.1
5	BINA T2 Black	Waterlogged tolerant (95 days)	1.2-1.5
6	BINA T3 Brown	Resistant root rot disease (90-95 days)	1.5-1.8
7	BINA T 4 Black	Short duration (85-100 days)	1.4-1.8

9.6 Sunflower CSA Varieties Developed by Advanta Seeds

Sl	Name of Variety	Climate features	Yield t/ha
1	Hysun-33 (BRAC)	Short duration (100-110 days)	2.0-2.1
2	Hysun-36 (ACI)	Short duration (100-110 days)	2.0-2.2
3	BARI Surjamukhi-3	Short duration (100-110 days)	1.7-1.8

9.7 Climate-smart Vegetable Varieties Marketed by Private Seed Company

Sl	Name of the vegetable	Variety Name	Climate Features
1	Tomato	Mintu Super	Heat tolerant
		Mintu	Heat tolerant
		Unayan	Heat tolerant
		BARI 4, 8	Heat tolerant
		Roma VF	Heat tolerant
		Pusha Robi	Heat tolerant
2	Bitter gourd	Tia	Short duration and high yielding
		Papia	Short duration and high yielding
		Lima	Short duration and high yielding
		Bulbuli	Short duration and high yielding
		Badsha	Short duration and high yielding
		Banoropa	Short duration and high yielding
		Niharika	Short duration and high yielding

Sl	Name of the vegetable	Variety Name	Climate Features
		Chitra	Short duration and high yielding
		Green-Arrow	Short duration and high yielding
3	Bottle gourd hybrid	Martina	Short duration and heat tolerant
		Diana	Short duration
		Barsha	Short duration
		Tafsi	Short duration
		Green Diamond	Short duration
		Moyna	Short duration
4	Brinjal Hybrids	Laboni	Heat tolerant
		Sraboni	Heat tolerant
		Banani	Heat tolerant
		Parthib	Heat tolerant
		Kajla	Heat tolerant
		Shingnath	Heat tolerant
		Eva	Short duration and high yielding
		Purple King	Short duration and high yielding
5	Cabbage Hybrid	Nova	Short duration and high yielding
		Summar Star	Heat tolerant
6	Cauliflower Hybrid	Snow White	Heat tolerant
		Ninja	Heat tolerant
7	Pumpkin Hybrid	Suprima	Heat tolerant
		Sweety	Heat tolerant
		Dream Gold	Heat tolerant
		Solid Gold	Heat tolerant
		Chita	Heat tolerant
8	Cucumber Hybrid	Maynamoti	Heat tolerant
		Janata	Short duration
		Popular	Short duration
		577 Mollika	Heat tolerant
		Sumrin	Short duration
		Alavi	Short duration
		Kashinda	Short duration
		Green King	Short duration
		Sheila	Short duration
		Baromashi	Short duration
9	Snake gourd hybrid	Surma	Heat tolerant
		Padma	Heat tolerant
		Dhaka Green	Heat tolerant
		Tista	Heat tolerant
		Turag	Heat tolerant

Sl	Name of the vegetable	Variety Name	Climate Features
10	Country Bean	IPSA 1	Heat tolerant, early variey
		IPSA 2	Heat tolerant, early variety
		BARI Shim 1	Heat tolerant, early variey
		BARI Shim 2	Heat tolerant, early variety
		BARI Shim 3	Heat tolerant, early variey
		Goal Hadda	Heat tolerant, early variety

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