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Adaptation to Climate Smart Agriculture in Flood-prone Central Bangladesh

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Abstract
The adaptation of climate-smart technology for agriculture in flood-prone area of Bangladesh, specifically in Arjuna Union, Bhuapur Upazila, Tangail district is selected for this study. The objectives were to assess the level of climate-smart adaptation among farmers, identify challenges they face in implementing climate-smart agriculture, and propose solutions to these challenges. Data was collected through questionnaire surveys, focus group discussions, and interviews with key informants from a sample of 90 farmers randomly selected from 900 households in the study area.

The study found that farmers had a good understanding of adaptation, mitigation, and climate-smart agriculture, with a medium level of adaptation being common. Various climate-smart techniques such as zero tillage, minimum tillage, direct seeding, crop residue burning, and agroforestry showed moderate to high levels of adaptation. Drip irrigation and mulching had higher levels of adaptation compared to other irrigation systems. Weather-smart agriculture practices such as agro-met advisory, weather forecasts, early warning systems, crop insurance, and early crops harvesting had low levels of adaptation.

There was also limited knowledge and training in crop advisory meetings and capacity-building for smart agriculture among farmers. There is a knowledge gap on climate-smart agriculture among farmers. The labour shortage is also a great challenge for farmers to adopt climate-smart agriculture practices. To address the challenges in climate-smart agriculture, a comprehensive approach is needed. Training programs and extension services can enhance technical capacity. Raising awareness of farmers about the benefits of climate-smart agriculture can help to overcome barriers and promote adoption.

Keywords: Climate-Smart Agriculture, Adaptation, Crop Advisory, Questionnaire Surveys, Focus Group Discussions

Introduction
Bangladesh is a disaster-prone country and it is frequently affected by flood, drought, and tropical cyclones. Bangladesh is likely to be one of the most vulnerable countries of the world in the event of climate change. It is unequivocal that human influence has warmed the atmosphere, land, and ocean. Global surface temperature in the first two decades of the 21st century (2001-2020) was 0.99°C higher than 1850-1900. The global mean sea level increased by 0.20 meters between 1901 and 2018.

The average rate of sea level rise was 1.3 millimeters (mm) per year between 1901 and 1971, increasing to 01.9 mm per year between 1971 and 2006 and further increasing to 3.7 mm per year between 2006 and 2018. The average temperature increased of Bangladesh by about 1°C in May and 0.5°C in November during 1985-1998, and saline water intruded about 100 km or more inland from the Bay of Bengal by the coastal rivers during the dry season. The observed climatic data from 1971 to 2002 indicates that the temperature is increasing in the monsoon season (June, July and August) [1,2].

The average monsoon's maximum and minimum temperature show an increasing trend annually at the rate of 0.05°C and 0.03°C respectively. Floods are one of the usual disasters of Bangladesh which occur almost every year due to the extreme rainfall and upstream water. It mostly affects the buildings, normal livelihoods, and sewerage systems, sometimes even damages the power transmission, etc. Floods cause massive suffering and hardships for the poor people. The roads and crop fields go underwater [3].

The shortage of clean water and drinking of flood water results in various waterborne diseases and a lot of people die without proper treatment and medicine relief. To prevent the massive loss because of floods, people should take enough precautions to minimize the effects of floods. Climate-smart technologies assist in minimizing the loss of assets and crops that occur by flood. Climate change has already significantly impacted agriculture and is expected to further impact directly and indirectly on food production. Increase in mean temperature, changes in rainfall patterns, increased variability both in temperature and rain patterns, changes in water availability, frequency and intensity of extreme events, sea level rise and salinization, perturbations in ecosystems, etc. will have profound impacts on agriculture, forestry and fisheries [4,5].

The agriculture sector has to produce more food and it will be certainly impacted by climate change. As an integral part of the economy, it has also been called upon to contribute to mitigating climate change. The main direct sources of GHG emissions in the agricultural sector are not only carbon dioxide. Agriculture is a source of nitrous oxide, accounting for 58 percent of total emissions, mostly by soils and through the application of fertilizers, and methane, accounting for 47 percent of total emissions, essentially from livestock and rice cultivation. These emissions are dependent on natural processes and agricultural practices, which makes them more difficult to control and measure [6].

Climate-smart agriculture (CSA) is not a new agricultural system, nor is it a set of practices. It is a new approach, a way to guide the needed changes in agricultural systems, given the necessity to jointly address food security and climate change. The concept of climate-smart agriculture was introduced in 2010 by the Food and Agriculture Organization (FAO) of the United Nations to face climate change in the agricultural sector (FAO, 2010). It is an integrated approach to farming to address the problems of climate change in the farming system. It can help improve crop yields for enhance food security by using environmentally friendly techniques [7-9].

Climate-smart agriculture (CSA) shares sustainable development and green economy objectives and guiding principles. It aims also for food security and contributes to preserving natural resources. As such, it has close links with the concept of sustainable intensification, which has been fully developed by FAO for crop production and is now being extended to other sectors and a food chain approach [10].

Methodology

Study Area

In this study central Bangladesh including the Arjuna Union in Bhuapur Upazila, Tangail district, considered as the study area. The study took place in Bhuapur Upazila in Tangail district, situated at 24.4583°N and 89.8667°E. Bhuapur is bordered by Gopalpur and Sarishabari Upazila to the north, Kalihati Upazila to the south, Gopalpur and Ghatail Upazila to the east, and the Jamuna River to the west. According to the 2011 Bangladesh census, Bhuapur Upazila had 46,412 households and a population of 189,913. The literacy rate in Bhuapur was 43.84% for individuals aged 7 and above, lower than the national average of 51.8%, with a sex ratio of 1,059 females per 1,000 males. This area is prone to flooding. Bhuapur Upazila is the central of Bangladesh, covering an area of 225 sq. km.

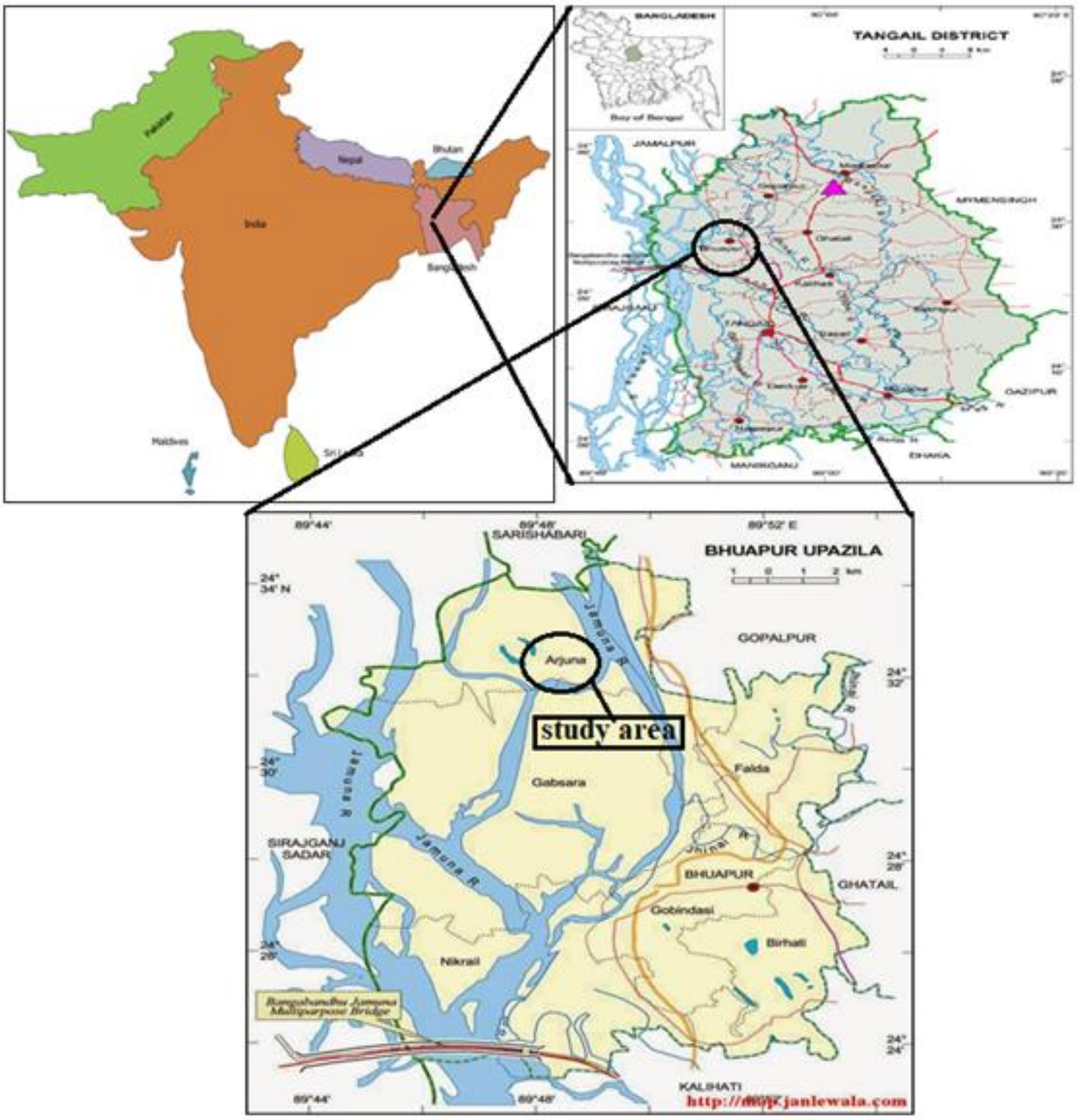

Figure 1: Shows the Map of Study Area

Methods of Data Collection

The study involved collecting both primary and secondary data.

Primary Data

The primary data was collected from the flood-affected farmers by using a structured interview schedule having open and closed form of questions.

Interview Schedule Preparation

The interview schedule was prepared in alignment with the study objectives. It was organized in a systematic manner to facilitate a clear understanding for the respondents and ensure consistent and structured information gathering.

Collection of Qualitative Data

Qualitative data was gathered through Focus Group Discussions (FGDs) using a semi-structured checklist. The participants included farmers, extension workers, and local elites. Two FGDs were conducted in May 2024, with one session in each village and twelve participants in each group. The researcher facilitated the FGDs. The information obtained from the FGDs was used to interpret the study results.

Qualitative data was also collected through Key Informant Interviews (KIIs) using a semi-structured checklist. The key informants were experts from government and non-government organizations, local extension workers, local elites, and members of local elected public bodies with experience in climate variability and change. Two KII was conducted in May 2024 to gather information on adaptation to climate-smart agriculture.

Time and Procedure of Data Collection

The researcher collected primary data in April and May 2024 from the study area. Efforts were made to clearly communicate the study objectives to the respondents at the beginning of the interviews to ensure the information obtained was relevant and accurate. Building rapport with the respondents was a priority to encourage open and honest responses to the questionnaire. Additionally, any necessary clarification of questions was provided to the respondents.

Secondary Data

Secondary data for the study was gathered from various sources including publications on climate-smart adaptation from government, donor agencies, national and international journals, books, dissertations, abstracts, reports, non-government organizations, climate change networks, and research organizations at both national and international levels.

Data Processing

Following the completion of the field survey, all data gathered from the interview schedule were compiled and tabulated in accordance with the study's objectives. Each response in the interview schedule was assigned a numerical code value, and local units of measurement were standardized. The responses to the interview questions were then transferred to a master sheet for easier tabulation. Tabulations and cross-tabulations were conducted using categories created by the investigator. The collected data were analyzed based on the study's objectives, and coded data were inputted into a computer for statistical analysis using the MS Excel program.

Sampling Procedure

A multi-stage sampling procedure was used to select the sample for the study. Initially, central Bangladesh was chosen as the study area due to its high vulnerability to severe floods. Among the districts in central Bangladesh (Sirajganj, Manikganj, and Tangail), Tangail was selected as it is the most flood-prone district. Within Tangail, the Bhuapur upazila was chosen due to its susceptibility to floods and climate-related issues compared to other upazilas.

Arjuna Union from one municipality and six Unions from Bhuapur Upazila were purposely selected. From Arjuna Union, two villages were chosen using purposely sampling - one village located in the countryside near the embankment and one village situated along the riverside of the Jamuna River. The total number of selected villages was two, with a combined total of 890 households (4,450 individuals).

Sample size 89 was determined by using the formula of Yamane (1967). The formula was:

$$n = \frac{N}{1 + N(e^2)}$$

$= 890/1+ 890\ (0.10^2 \text{ or } 10\%)$

$= 890/9.9 = 88.89 = 90$

Where,
n = Sample size
N = Population size
e = Level of precision (0.10 or .10%).

An updated list of climatic events impacting farmers in the study villages was obtained from the relevant Union Parishad, the lowest level of local government in Bangladesh.

Result and Discussion

Extent of Adaptation to Climate-Smart Agriculture

Climate-smart agriculture (CSA) represents an approach to transforming and reorienting agricultural systems to support food security under the new realities of climate change. The extent of adaptation to CSA can be evaluated through various dimensions: policy adoption, technological innovations, farmer practices, and regional implementations. An overview of the current state of climate-smart agriculture adaptation is given below:

The data presented in Table 3.1 shows that the understanding of weather was 51 as medium, 14 as low, 10 as very low, 3 as high, 8 as very high, and 4 persons as none out of a total of 90 respondents. The data presented in Table 3.1 also shows that the understanding of climate was 48 as medium, 8 as low, 2 as very low, 13 as high, 4 as very high, and 15 as none. In contrast, the understanding of climate change was 38 as medium, 3 as low, 5 as very low, 5 as high, 3 as very high, and 36 as none. However, the understanding of adaptation, mitigation, and climate-smart agriculture was higher as the medium extent of adaptation than the other drivers. Climate-smart agriculture information has been graphically presented in Figure 3.1 as well.

Table 3.1: Climate-Smart Agriculture Information

Climate-Smart Agriculture Information						
extent of adaptation	Understanding of weather	Understanding of climate	Understanding of climate change	Understanding of Adaptation	Understanding of mitigation	Understanding of climate-smart agriculture
Very low	10	2	5	5	2	1
Low	14	8	3	11	3	7
Medium	51	48	38	15	72	3
High	3	13	5	8	5	1
Very high	8	4	3	5	7	5
None	4	15	36	46	1	73
Total	**90**	**90**	**90**	**90**	**90**	**90**

Source: Field survey, 2024

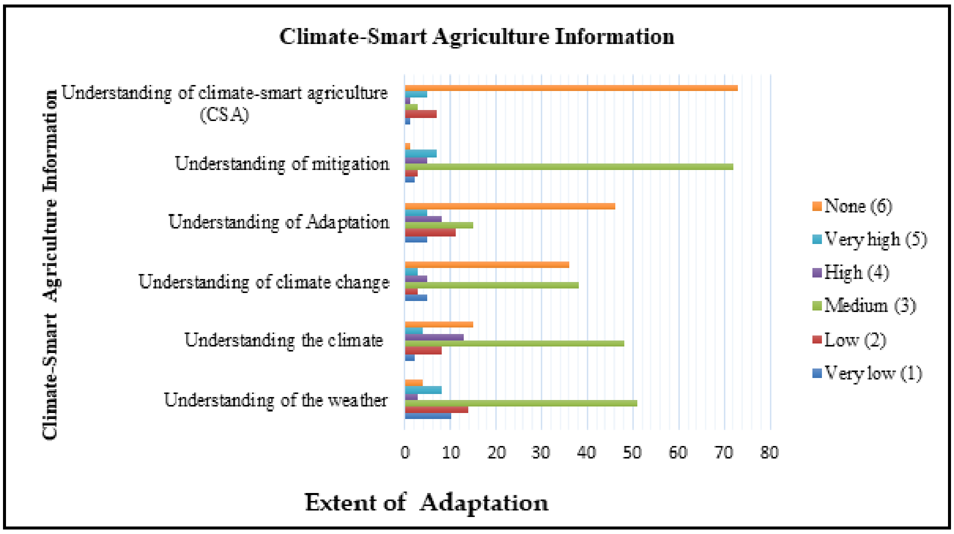

Figure 3.1: Climate-Smart Agriculture Information

The data in Table 3.2 shows that the carbon-smart agriculture of the respondents in practicing zero/no-tillage, dribbling/minimum tillage, strip tillage, direct seeding, burning of crop residues and agroforestry were observed to have medium, low, and high levels of adaptation, respectively. The cultivation of crops in strip tillage was observed to have a lower extent of adaptation among other adaptation techniques.

Carbon-Smart Agriculture						
Extent of adaptation	Cultivate crops in zero/no-tillage	Cultivate crops in dribbling/minimum tillage	Cultivate crops in strip tillage	Cultivate crops in direct seeding	Cultivate crops by burning of crop residues	Agroforestry
Very low	6	5	1	2	2	0
Low	12	18	17	13	13	12
Medium	22	28	12	48	27	9
High	26	17	5	12	37	67
Very high	11	5	0	4	6	2
None	13	17	55	11	5	0
Total	**90**	**90**	**90**	**90**	**90**	**90**

Source: Field survey, 2024

Table 3.2: Carbon-Smart Agriculture

The carbon-smart agriculture of the respondents in practicing zero/no-tillage, dribbling/minimum tillage, strip tillage, direct seeding, burning of crop residues and agroforestry has also been graphically presented in Figure 3.2.

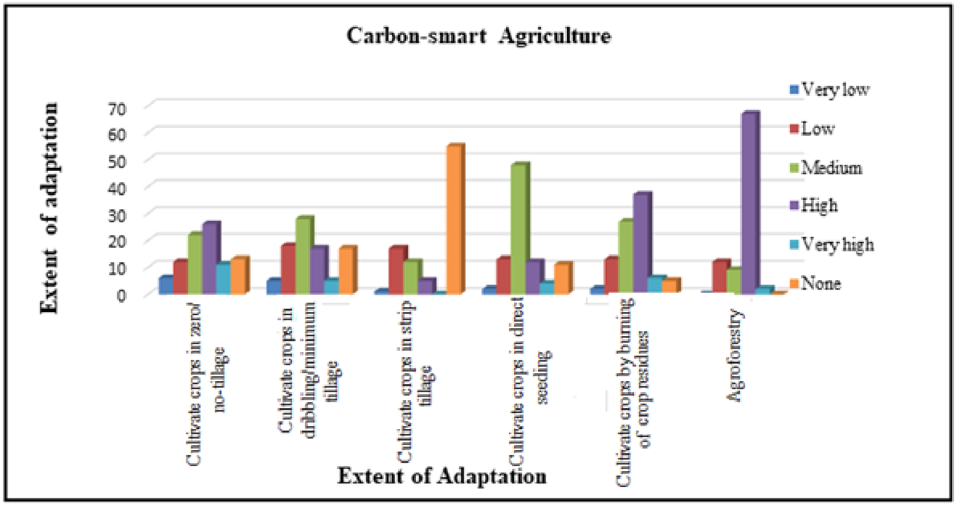

Figure 3.2: Carbon-Smart Agriculture

The data presented in Table 3.3 show that the nutrient/nitrogen-smart agriculture of the respondents in practicing urea in deep placement, green manure, farmyard compost, vermicomposting, leaf colour chart, bio-pesticide, and integrated pest management was observed to range from zero to very low and very high levels of adaptation. The use of a leaf colour chart was observed to have a lower (zero) extent of adaptation among other adaptation techniques. The nutrient/ nitrogen-smart agriculture of practicing urea in deep placement, green manure, farmyard compost, vermicomposting, leaf colour chart, bio-pesticide, and integrated pest management have been graphically presented in Figure 3.3 as well.

Nutrient/Nitrogen-Smart Agriculture								
Extent of adaptation	Use urea in deep placement	Use green manure	Use farmyard compost	Use vermin/ earthworm compost	Use Leaf Color Chart (LCC) for balanced fertilizer application	Insect control by bio-pesticide	Insect control by integrated pest management (IPM)	Other, if any
Very low	3	7	3	2	0	1	2	
Low	7	5	5	7	0	5	5	
Medium	26	4	47	0	0	26	26	
High	5	1	20	0	0	6	0	
Very high	0	0	10	0	0	0	0	
None	74	73	5	81	90	52	56	
Total	**89**	**90**	**90**	**90**	**90**	**90**	**89**	

Source: Field survey, 2024

Table 3.3: Natrient/Nitrogen-Smat Agriculture

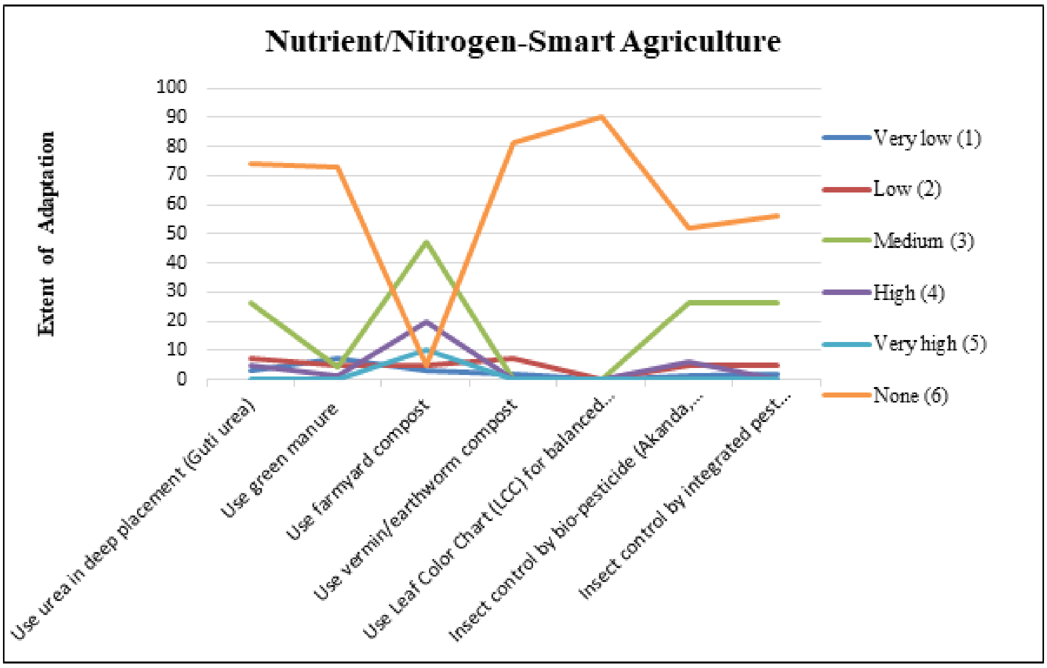

Figure 3.3: Natrient/Nitrogen-Smat Agriculture

The information presented in Table 3.4 shows that the water-smart agriculture of the respondents in practicing drip irrigation systems, mulching, alternative wetting and drying irrigation systems, and buried pipeline irrigation systems was observed to range from zero to very low and very high levels of adaptation. The use of alternative wetting and drying irrigation systems and buried pipeline irrigation systems were observed to have a lower (zero) extent of adaptation among other adaptation techniques.

Water-Smart Agriculture								
Extent of adaptation	Drip irrigation system	Mulching	Alternative wetting and drying irrigation	Buried pipeline irrigation	Rainwater harvest system	Cultivation of low water-requirements crops	Construction of climate-resilient water infrastructure	Other, if any
Very low	5	3	0	0	19	0	0	
Low	7	6	0	0	2	0	3	
Medium	12	60	0	0	0	11	2	
High	0	5	0	0	0	0	0	
Very high	0	0	0	0	0	0	0	
None	66	16	90	90	69	79	85	
Total	**90**	**90**	**90**	**90**	**90**	**90**	**90**	

Source: Field survey, 2024

Table 3.4: Water-Smart Agriculture

The water-smart agriculture of the respondents in practicing drip irrigation systems, mulching, alternative wetting and drying irrigation systems, and buried pipeline irrigation systems have also been graphically presented in Figure 3.4.

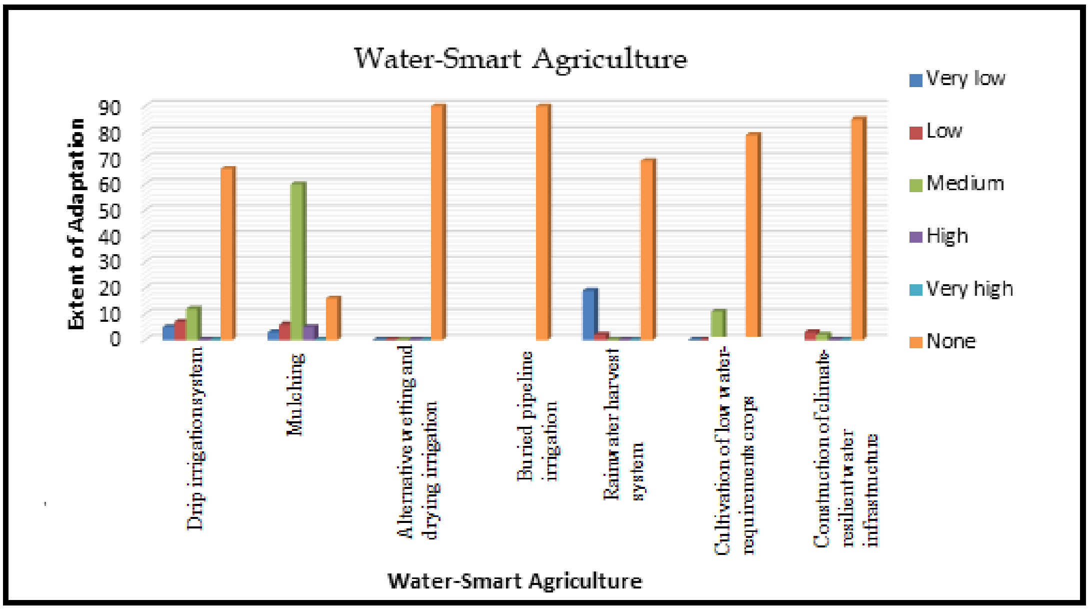

Figure 3.4: Water-Smart Agriculture

The data in Table 3.5 show that the weather-smart agriculture of the respondents in practicing agro-met advisory, season-wise weather forecast, weather early warning, index (weather)-based crop insurance, and before the disaster, early-maturity crop harvesting was observed from zero to very low, very high, and none levels of adaptation. The use of agro-met advisory and index-based (weather-based) crop insurance was observed to have a lower (zero) extent of adaptation.

Weather-Smart Agriculture							
Extent of adaptation	Agromet advisory	Season-wise weather forecast	Weather early warning	Index (weather) based crop insurance	Sowing/planting time adjustment	Before the disaster, early-maturity crop harvesting	Other, if any
Very low	0	1	1	0	3	0	
Low	0	1	2	0	17	6	
Medium	0	2	85	0	10	78	
High	0	0	2	0	5	6	
Very high	0	0	0	0	0	0	
None	90	86	0	90	55	0	
Total	**90**	**90**	**90**	**90**	**90**	**90**	

Source: Field survey, 2024

Table 3.5: Water-Smart Agriculture

The weather-smart agriculture of the respondents in practicing agro-met advisory, season-wise weather forecast, weather early warning, index (weather) based crop insurance, and before the disaster early-maturity crop harvesting have also been graphically presented in Figure 3.5.

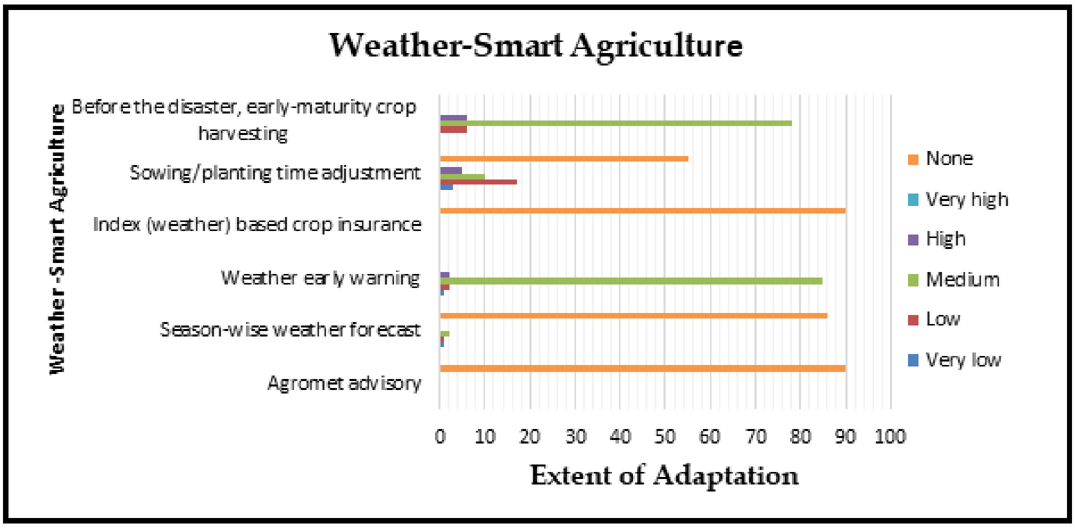

Figure 3.5: Water-Smart Agriculture

The data presented in Table 3.6 show that the knowledge-smart agriculture of the respondents in practicing crop advisory meetings (farmer-to-farmer meetings) and participating in capacity-building training were observed at zero to no levels of adaptation.

Knowledge-Smart Agriculture			
Extent of adaptation	Crop advisory meeting (Farmer-to-farmer meeting)	Participate capacity building training	Other, if any
Very low	0	4	
Low	1	5	
Medium	87	0	
High	2	0	
None	0	81	
Total	**90**	**90**	

Source: Field survey, 2024

Table 3.6: Knowledge-Smart Agriculture

The weather-smart agriculture of the respondents in practicing crop advisory meetings (farmer-to-farmer meetings) and participating in capacity-building training has also been graphically presented in

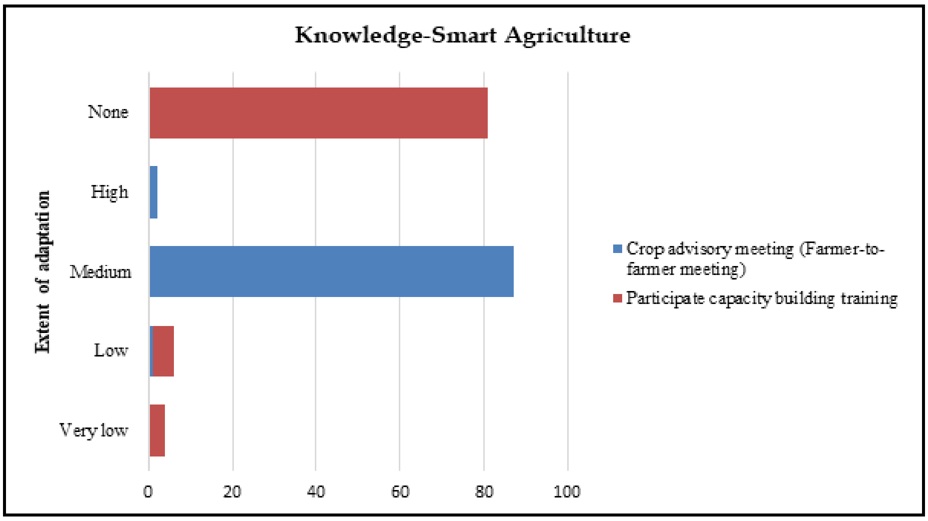

Figure 3.6: Knowledge-Smart Agriculture

Challenges Faced in Practicing Climate-Smart Agriculture

Climate-smart agriculture (CSA) faces a range of obstacles, such as financial constraints that make it difficult for smallholder farmers to access the necessary funds and credit to adopt CSA practices. Technical challenges also arise due to the need for specialized skills and knowledge to effectively implement advanced techniques. Institutional barriers, including a lack of policy support and collaboration among stakeholders, further hinder the uptake of CSA. Additionally, socio-cultural resistance to change and a lack of awareness about the benefits of CSA can limit its widespread adoption in Bangladesh.

The data presented in Table 3.7 shows that lack of technology and lack of financial support were reported by 23 and 60 respondents out of a total of 90, while 7 respondents reported that training was another challenge.

Challenges/Problems Faced in Climate-smart Agriculture			
Lack of technology	Lack of financial support	Other (Training)	Total
23	60	07	90

Table 3.7: Challenges/Problems Faced in Practices Climate-Smart Agriculture

The Challenges Faced in Practicing Climate-Smart Agriculture are Listed Below

• The significant knowledge dissemination gap on climate-smart agriculture (CSA) in Bangladesh is a major challenge to the effective adoption of CSA practices. This gap exists between local and national experts. It creates hinder in the dissemination of knowledge and best practices to farmers and other stakeholders.
• The flash floods and early monsoon occurrences in Bangladesh have caused significant losses to the agricultural sector, lives and livelihoods, making it challenging for farmers to adopt CSA practices.
• The lack of awareness and familiarity with the concept of climate-smart agriculture among farmers and local experts in Bangladesh hinders the adoption of CSA practices.
• The conversion of agricultural land to urban and industrial uses is a significant challenge for Bangladesh's agricultural sector, as it reduces the arable land for farming and increases the pressure on the remaining agricultural land.
• The unfavorable land-tenure system also leads to low-level technology uptake and limited adoption of CSA practices due to the predominantly small-scale farming structure.
• Inadequate management practices, such as the lack of irrigation and drainage systems lead to crop losses and reduce the resilience of agricultural systems to climate change.
• The participation of women in agriculture is limited, which hinders the adoption of climate-resilient practices.

Solutions to Address the Challenges in Practicing Climate-Smart Agriculture

Addressing the challenges in climate-smart agriculture requires a comprehensive approach. Financial solutions, such as microloans and subsidies, can provide farmers with the necessary funds to invest in CSA practices. Enhancing technical capacity through training programs and extension services helps farmers acquire the skills and knowledge required for effective implementation. Strengthening institutional frameworks and promoting collaboration among stakeholders, including government agencies, NGOs, and the private sector, can create a more supportive environment for CSA. Additionally, raising awareness and highlighting the benefits of CSA can help overcome socio-cultural barriers and promote widespread adoption. The data presented in Table 3.8 shows that the availability of technologies and financial support was reported by 23 and 60 respondents out of a total of 90, while 7 respondents reported that training was another solution for climate-smart agriculture.

Solution of Challenges to Climate-smart Agriculture			
Available technology	Available financial support	Other (Conduct training)	Total
23	60	07	90

Table 3.8: Solution of Challenges on Climate-Smart Agriculture

Below are Strategies to Overcome the Challenges in Climate-Smart Agriculture in Bangladesh

• Increase significant knowledge dissemination on climate-smart agriculture (CSA) in Bangladesh.
• Mechanization helps to reduce labour costs and increase efficiency in crop cultivation, making it more profitable for farmers.
• Implementation of water conservation techniques in all areas of Bangladesh significantly reduces water usage in rice cultivation and makes it more sustainable.
• The conduct of training for the farmers on CSA practices, climate change, and its impact on agriculture is crucial for their adoption of climate-resilient practices. The knowledge and skills are needed to adapt to climate change.

• Encouragement of sustainable urbanization and industrialization practices reduces the pressure on agricultural land and resources and allows more efficient use of the resources.
• Implementation of climate information and early warning systems assists farmers in preparing for and responding to climate-induced events such as floods and droughts etc.
• Encouragement of the participation of women enhances the adoption of climate-resilient practices and the development of the agricultural sector.
• Strengthening extension services such as use of mobile apps, SMS services, or community-based extension agents to disseminate information and support by providing farmers with access to climate information, technical assistance, and training on CSA practices.
• Conduction of extensive awareness campaigns and educational programs through workshops, training sessions, and community outreach programs to inform farmers about the benefits of CSA practices, such as increased crop yields, improved food security, and reduced vulnerability to climate change.
• Regularly monitor and evaluate the impact of CSA practices on farmers' livelihoods and the environment, which assists in identifying areas for improvement and ensures that CSA practices are effective and sustainable.

Results from Focus Group Discussions

The focus group discussions were conducted in two villages (Arjuna, and Kuthirboyra) of Arjuna Union under Bhuapur Upazila of Tangail district in May 2024. Focus group discussions (FGDs) on climate-smart agriculture (CSA) normally uncover a variety of perspectives from farmers, agricultural experts, and community stakeholders. Focus Group Discussions on CSA reveal that farmers generally have a basic understanding of climate-smart agriculture, but there is a shortage of knowledge levels regarding CSA practices. Challenges to the widespread adoption of CSA include economic constraints, limited knowledge, and institutional barriers. While CSA practices can improve resilience, there is a need for improved training, financial support, policy coherence, and community involvement to address these obstacles.

Key Findings from the Discussions are Outlined Below

Sl. #	A key area of discussion	Key findings
1.	Awareness and understanding of climate-smart agriculture	Many farmers have a basic understanding of climate-smart agriculture (CSA) Farmers' awareness of CSA practices varies, with some familiar with specific techniques and others unfamiliar with the term climate-smart agriculture.
2.	Sources of information on climate-smart agriculture	Farmers acquire knowledge of CSA through NGOs and agricultural extension services. Media platforms like radio, TV, and mobile apps, etc. contribute to disseminating information on CSA.
3.	Adoption of CSA Practices	Farmers have begun adopting CSA techniques such as improved seed varieties, conservation agriculture, and integrated pest management. Farmers are gradually implementing water-saving technologies (drip irrigation, rainwater harvesting, etc.) and soil management practices (composting, mulching, etc.) in their fields. Agroforestry and mixed farming are also gaining popularity among farmers.
4.	Knowledge and training for climate-smart agriculture	Farmers lack sufficient knowledge and technical skills to effectively implement CSA practices. Access to reliable climate and agricultural information is also limited.

5.	Increased resilience	Climate-smart agriculture practices are acknowledged for enhancing the resilience of farming systems to climate variability and extreme events.
6.	Capacity building	Enhance training programs for farmers on CSA practices. Strengthening extension services and build the capacity of local agricultural extension service providersl.

Results from Key Informant Interviews

The Key Informant Interviews (KIIs) were conducted with the Upazila Agriculture Officer and NGO representative in Bhuapur Upazila of Tangail district in May 2024. Key Informant Interviews on climate-smart agriculture (CSA) indicate that experts possess a comprehensive understanding of CSA and acknowledge its capacity to improve agricultural resilience and productivity.

However, the widespread adoption of CSA is impeded by significant initial costs, inadequate financial resources, and a lack of extension services. Key informants stress the importance of enhancing capacity, increasing access to credit and insurance, and combining local knowledge with innovative approaches to effectively implement CSA. The findings of KIIs were mentioned in below matrix:

Sl. #	A key area of discussion	Key findings
1.	Communication to farmers	Efforts are made to increase farmer awareness through conduction of training programs, workshops, and extension services. There are challenges in effectively communicating complex CSA concepts to farmers, requiring simplified and context-specific messages.
2.	Current agricultural practices	Commonly adopted CSA practices include improved irrigation techniques, conservation tillage, and integrated pest management.
3.	Innovation and adaptation	Local innovations and traditional knowledge are integrated with CSA practices, such as community-based water management systems and Indigenous crop varieties.
4.	Challenges and barriers	High initial investment costs and limited financial resources are significant barriers to CSA adoption. Farmers lack access to credit and insurance schemes to mitigate risks associated with adopting new practices.
5.	Institutional and policy barriers	Inconsistent policies and lack of coordination between governmental agencies hinder widespread CSA implementation.
6.	Research and development	Invest in research is needed for locally adapted CSA technologies and practices.

Conclusions

Based on the study findings and their logical interpretations, the following conclusions were drawn

- Climate-Smart Agriculture (CSA) recognizes farmers as key agents of change, engaging farmers, understanding their needs, and building their capacity are essential for the success of CSA initiatives.
- Effective implementation of CSA requires robust knowledge dissemination and capacity building. Farmers need access to climate information services, extension services, and training in sustainable practices. Engaging local communities

and fostering participatory approaches ensure that CSA practices are context-specific and culturally appropriate.

• CSA is inherently multidisciplinary, involving aspects of agronomy, environmental science, economics, and social sciences. Collaboration among researchers, policymakers, farmers, and other stakeholders is essential for developing and implementing effective CSA strategies.

• Successful implementation of CSA requires building the capacity of farmers and raising awareness about sustainable practices. Extension services, training programs, and the dissemination of climate-smart technologies are essential.

• To mitigate the adverse effects of climate change, farmers have adopted various climate-smart agriculture (CSA) practices, including soil management, the use of decomposed manure, agroforestry, and different tillage methods. These practices have proven to enhance crop yields and income. By combining multiple strategies, farmers can maximize the benefits of addressing climate change impacts. Additionally, government and private sector support, particularly through subsidized inorganic fertilizers, play a crucial role in supporting farmers' efforts to adapt to climate change.

• Farmers' resilience can be further improved by implementing more CSA practices and receiving active support from the government and other stakeholders. However, challenges remain, such as limited dissemination of climate information for optimal planting timing, inadequate irrigation systems during dry seasons, and insufficient awareness about organic fertilizers and pest management. Addressing these issues can lead to improved planting patterns, increased agricultural productivity, and enhanced product quality without exacerbating environmental degradation caused by climate change. By becoming more resilient, farmers can better cope with and recover from climate-related stresses.

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Conflict of Interests

The authors declare no conflict of interest.

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