Impact of Salinity on Food Security in Southwest Coastal Bangladesh: Strategies for Adaptation Methods

by

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A thesis submitted to the

Department of Environmental Science and Management

in partial fulfillment for the degree of

MASTER OF SCIENCE IN CLMATE CHANGE AND DEVELOPMENT

Department of Environmental Science and Management
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Dhaka, Bangladesh

November, 2025

BOARD OF EXAMINERS

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Dr. Md. Jamal Uddin

Dedicated

to

*“**-My family-**”*

ACKNOWLEDGEMENTS

First and foremost, I would like to express my heartful gratitude to Almighty Allah for His boundless mercy, guidance, and blessings, which have enabled me to successfully complete this thesis.

I extend my deepest appreciation to my supervisor, Md Abdul Khaleque, PhD, Professor, Dept. of Environmental Science and Management, IUB, for his invaluable guidance, insightful feedback, and steadfast support throughout the course of this research. His expertise and encouragement have been instrumental in shaping the direction and depth of this work, and his mentorship has greatly enriched my academic journey.

I am sincerely thankful to Md Hafizur Rahman, PhD, Professor and Head and K Ayaz Rabbani, PhD, Associate Professor, Dept. of Environmental Science and Management, Independent University, Bangladesh (IUB) for their valuable suggestion, kind cooperation and guidance.

My sincere thanks also go to the Department of Environmental Science and Management, Independent University, Bangladesh (IUB), for offering a stimulating academic environment and the necessary facilities that facilitated the completion of this research.

I am thankful to Department of Agricultural Extension (DAE) and Ministry of Agriculture, Government of The People`s Republic of Bangladesh for granting permission to pursue the degree.

I am express my gratitude and gratefulness to the authority of COLOCAL project at IUB-ICCCAD for granting scholarship to pursue the degree.

I am deeply indebted to my mother Rawshan Ara begum, my wife Rina Akther, affectionate daughter Juma and beloved son Rafi for their unwavering support, patience, and belief in my abilities. Their encouragement has been a source of strength and motivation throughout this journey.

Finally, I would like to acknowledge the constant support, cooperation, and understanding of my friends whose encouragement helped me persevere through the challenges of this endeavor.

This thesis stands as a testament to the collective support and inspiration I have received from all these individuals, to whom I remain profoundly grateful.

IUB, Dhaka, Bangladesh The Author

November, 2025 **Dr. Md. Jamal Uddin**

ABSTRACT

Salinity intrusion is a major environmental threat in coastal Bangladesh, severely affecting food security and rural livelihoods. This study, conducted in four unions of Satkhira district—three saline-prone (Atulia, Burigoalini, Gabura) and one non-saline (Helatala)—assessed the socioeconomic status of farmers, the impacts of salinity on agriculture, and the adaptation strategies adopted. A mixed-methods approach was applied, combining 120 household surveys, 12 key informant interviews, and 8 focus group discussions supported by salinity testing and field observations. Quantitative data were processed in Microsoft Excel using frequency tables, percentages, and graphs, while qualitative findings were analyzed thematically.

Results showed clear socioeconomic contrasts between saline and non-saline areas. Male-headed households dominated across all unions (over 80%), though female participation was higher in Helatala (43.33%). Education levels were markedly higher in Helatala, where 63.33% of respondents had completed secondary or higher education, compared to only 26.67% in Burigoalini. Income analysis revealed that 60% of Helatala households earned above BDT 200,000 annually, while only 20% in Atulia and Burigoalini reached this level.

Salinity impacts were most severe in Gabura and Burigoalini, where 50% of respondents reported crop and vegetable damage and 40% reported irrigation water scarcity. Waterlogging affected 30% of respondents in Gabura, further intensifying yield losses.

Adaptation analysis indicated that salinity-tolerant crop varieties (86.67%) and adjusting planting time (90% in Gabura, 66.67% in Burigoalini) were the most widely adopted techniques. Crop diversification was practiced occasionally by 73–93% of respondents, while methods such as AWD, mini ponds, and zero tillage were adopted by 10–25%. Resource-intensive practices like raised pits, floating seed beds, and dike culture showed limited use, except in Helatala, where 45% practiced dike culture regularly.

The study concludes that although awareness of adaptive techniques is widespread, consistent adoption remains limited by financial, technical, and institutional barriers. Strengthened extension services and climate-smart interventions are essential to enhance agricultural resilience in salinity-affected coastal regions.

Keywords: *salinity intrusion, coastal agriculture, adaptation strategies, Bangladesh, climate resilience*

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Chapter 1

Introduction

1.1 Overview

In Bangladesh's coastal regions, soil salinization is an important issue that poses significant obstacles to agricultural output and makes it difficult to achieve the sustainable development goals (SDGs). Although the biophysical aspects of salinity are well known, the varying effects of salinity on agricultural productivity—particularly on various livelihoods that may be affected differently—have received less attention. The policymakers who must decide how to adapt are faced with ambiguity as a result of this diversity. This chapter introduces key background information on the salinization problem, and the statement of the research problem. This chapter also introduces the research approach that is followed to achievethe key research goals, and background information on the coastal areas of Bangladesh, with special attention to the study area

1.2 Background and rationale of the study

The study area encompasses three unions from Shyamnagar upazilla of Satkhira district Bangladesh. The coastal belt of Bangladesh consists of 19 districts, which cover 32% of the country and accommodate more than 35 million people (Haque, 2006). During 1973, salinity affected 83.3 million hectares of land; this was increased to 102 million hectares by the year 2000. After that, salinity affected a recorded 105.6 million hectares during 2009 (SRDI, 2010). Among these affected areas, around 2.5 million hectares of low-lying coastal lands represents 0.9 to 2.1 salinity level (SL) in Bangladesh (Iftekhar and Islam 2004). Over the last 35 years, salinity has increased around 26 percent in the coastal region of Bangladesh (Mahmuduzzamanet al. 2014). The coastal Ganges-Brahmaputra delta has seen a relatively rapid increase in groundwater salinity, river salinity, and soil salinity as a result of sea level rise, overextraction of groundwater, upstream diversion of surface water, and shrimp aquaculture (Dasgupta et al. 2014; Ahsan and SDRI Team 2010). Although rice production predominates in Bangladesh's coastal zone, shrimp aquaculture is quickly becoming a significant source of revenue in the study region (Chowdhury et al. 2011). Since the 1970s, increased international demand for shrimps, along with relatively high pricing for shrimp goods, has resulted in an increase in the conversion of conventional agriculture into shrimp farming ponds (Rahman et al. 2013). Furthermore, the salt tolerance of modern rice varieties ranges between 3 and 12 dS/m (for dry season Boro rice cultivars, it ranges between 6 and 12 dS/m), hence soil salinization may drive farmers to switch from agriculture to aquaculture. River salinity rose from 2 to 10 times between 1970 and 2010 (Hossain and Dearing 2013; Hossain et al. 2015), whereas soil salinity impacted 0.223 million hectares (26.7%) during the same time period. Salinity intrusion harmed about 450,000 acres of coastal land where soil salinity exceeded 8 dS/m (SRDI 2010). Given the above-mentioned salt tolerance of rice cultivars, this area is expected to be minimally productive unless effective irrigation and land management measures are implemented to reduce the impact of such soil salinity levels. Importantly, despite rising urbanization, poverty in this region remains primarily a rural problem, as it does in other regions of Bangladesh (World Bank 2011). (Planning Commission 2011). Given the south-west coastal region's climate change and environmental sensitivity, there is rising worry that families, particularly those from the poorest sectors of society, would need to adopt extra coping methods to minimize existing and anticipated food insecurity threats (Faisal and Parveen 2004).

Global environmental change poses complicated hazards to health and livelihoods, and one of the key effect pathways is food security. The research on climate change vulnerability connects rising temperatures, variable precipitation, ocean acidification, drought, and flooding to food insecurity and food system breakdown. (Field et al., 2014; Myers et al., 2017). However, less attention has been devoted to another environmental trend that has the potential to have a hidden but catastrophic influence on food production: growing salinity of land and water. Although other human factors influence salinity, the Intergovernmental Panel on Climate Change (IPCC) reports with high confidence that landward intrusion of saltwater is increasing and is a climate change-sensitive trend that will result in salinization of groundwater, surface water, and soil resources, particularly in low-lying coastal areas, river deltas, and estuaries. (Oppenheimer et al., 2019; Wong et al., 2014). This happens gradually as a result of sea level rise, land subsidence, and changes in temperature and precipitation that alter aquifer recharge, as well as acutely as a result of storm surge and wave over-wash in the aftermath of extreme weather. (Cisneros et al., 2014; Cramer et al., 2014; Oppenheimer et al., 2019;, 2013; Wong et al., 2014). Saltwater intrusion, particularly at low elevations, can produce soil salinization, a primary source of soil deterioration that affects plant germination, biomass production, and yield. (Oppenheimer et al., 2019).

Bangladesh is a low-lying nation with a 440-mile coastline. Its coastal zone is divided into three regions: southwest, south-central, and southeast, with 62% of it below three meters above sea level (Nishat & Mukherjee, 2013). The districts of Satkhira, Khulna, and Bagerhat are located on the southwest coast, which borders India to the west and the Bay of Bengal to the south. Each district is further subdivided into sub-districts, which are further subdivided into unions, the lowest level of rural administration.

The salinity of the soil in Bangladesh's southwest coast varies according to season, year, and location (Sarwar & Islam, 2013). Saltwater is currently penetrating as far inland as 110 miles, infiltrating through rivers and channels, especially from January to June, when there is less rainfall and insufficient downstream flow of freshwater from the Ganges and its tributaries (Food and Agriculture Organization of the United Nations, 2009; Haque, 2006; Rahman et al., 2011a)

Bangladesh's 2017-2018 Demographic and Health Survey (DHS) (National Institute of Population Research and Training (NIPORT) and ICF International, 2020) reflects persistent nutrition and food security concerns. In rural Bangladesh, 33% of children under the age of five were stunted (short for their age), 8% were wasted (thin for their height), and 23% were underweight. For stunting, wasting, and underweight, the Khulna division reported prevalence rates of 26%, 8%, and 19%, respectively. Despite government and non-governmental organization (NGO) activities on nutrition and food security (Ishrat, 2013) and modest improvements in health indices over the last decade (Global Nutrition Report, 2020), nutritional status remains one of the country's most urgent issues.

Salinity has a significant influence on food production in Bangladesh's southwest coastal area, which is located in the core of the Ganges River Delta. Food security and overall well-being of the region's predominantly rural inhabitants are dependent on the capacity to manage land effectively. Bangladesh's coastal population works in commercial agriculture, including crops, horticulture, and fisheries, as well as subsistence household food production. Much of the region's arable soil becomes too salty to produce crops during the driest months of the year (apprx. January through May). (Rahman & Bhattacharya, 2014)

Climate change and human activities are both anticipated to worsen the region's salinity, with increasingly major effects for agricultural production and food security (Salehin et al., 2018). Due to its apparent profitability and appropriateness for salinity-affected locations, saltwater shrimp farming has quickly spread in the region in recent decades. However, this sort of aquaculture requires the intentional retention of saltwater via a system of sluice gates and embankments, which promotes additional salinization of land and water resources, underscoring the complexities of adapting agriculture to growing salinity (R. Rahman et al., 2014; Salehin et al., 2018). Government and non-governmental groups are experimenting with interventions to assist communities manage with soil and water salinity, including initiatives connected to freshwater infrastructure and improved agricultural methods and inputs, but the severity of the problem remains enormous. According to the Bangladesh government, between 2015 and 2030, $3 billion USD and $8 billion USD will be required for adaptation measures aimed specifically at "salinity intrusion and coastal protection" and "food security and livelihood and health protection (including water security)," respectively (Bangladesh Ministry of Environment and Forests, 2015).

1.3 Objective of the Study

With human and environmental effects causing salinity to rise, a greater knowledge of how to protect the food security of populations living in this climate-sensitive region is critical. Rather of focusing on a particular business or sector, more nuanced understanding about community-level experiences with salinity, its effects on family food security, and people' own appraisal of adaptation options is necessary. The general aim of this study is to examine local farmers' perspectives of growing dry season rice under an increasingly saline environment and their preferred adaptation strategies.

Considering the above reviewed facts and findings the study is designed to fulfill the following objectives-

I. To assess socioeconomic characteristics of farmers in coastal areas.
II. To find out impacts of salinity on agriculture and livelihoods.
III. To identify and analyze CSA adaptation strategies adopted.
IV. To recommend policy measures for climate resilience.

Chapter 2

Methodology

2.1 Study areas

Four locations comprise of three salinity prone unions viz. Gabura, Atulia and Burigualiny from Shyamnagar upazilla and one of non saline prone union viz. Helatola from Kolaroa upazilla of Satkhira district include 30 households, 3 Key Informant Interviews (KII) and 2 focus group discussions (FGDs) from each location. Thus a total number of 120 community participants, 12 Key Informant Interviews (KII) and 8 focus group discussions (FGDs) were conducted throughout the research period. Interview of NGO representatives and relevant government officials of three locations were conducted.

2.2 Study design

This was a mixed methods investigation, using a combination of qualitative research methods (in-depth interviews and focus groups discussions), participatory systematic data collection, field observations, and salinity testing. In-depth interviews (IDIs), Key Informant Interviews (KII) and focus group discussions (FGDs) - semi-structured, with guides developed in English and translated into Bangla. Systematic data collection consisted of participant rating and ranking exercises. Field observations - guided by a household inventory/questionnaire. All instruments were available upon request.

2.3 Data collection

Three components of data collection were done during the period from April, 2023 to, June, 2023. Community-level data collection in the southwest coastal region, salinity testing which accompanied community level data collection, and stakeholder-level data collection with government officials and NGOs in the study areas of Satkhira and Dhaka.

During data collection, consultation with supervisor to debrief, share observations, and supplement notes were taken during each data collection activity. Written consents were obtain from all participants and approval of the Institutional Review Board of competent institution, and the Research and Ethics Review Committees of the relevant institution was followed.

Community-level data collection: Data collection were selected purposively to achieve a balance between males and females, geographic spread across the sites, and coverage of occupations and roles within the community.

There were two rounds of community-level data collection, the first in May/June 2023 coinciding with hot season and the beginning of rainy season. 120 households across the four sites and conducted a structured visit consisting of: interviews with both a male and female household member, a questionnaire, and salinity testing of the household's garden soil and sources of water. Household interviews were covered the impacts of salinity on household food production and strategies for adapting, among other topics. Questionnaires were assess demographic characteristics and food production resources (land, gardens, ponds, livestock, etc.). Eight focus group discussions (FGDs) were conducted with other community members and interview of community 12 key informants across the four sites in May/June 2023. Among other activities, focus group participants' discussion on the impacts of salinity on food production, made seasonal calendars to depict trends in salinity and food production, and ranked and discussed adaptation strategies. Interviews with key informants focused on site history, salinity trends, and salinity impacts. During the second round of community-level data collection in October 2023, coinciding with mid-to-late rainy season, was revisit all recruited households and conducted a follow-up interview with one household member to update information. Interviewees also were participated in a rating exercise, whereby they were shown different pictures of factors cited in the literature or mentioned earlier by participants as a cause of salinity. Interviewees were asked about their awareness of the factor and the extent to which they believed it caused salinity.

Stakeholder-level data collection were taken place in May to June 2023. Interview of NGO and government representatives based in the southwest coastal region and Dhaka. The interviews entailed semi-structured discussion about impacts of salinity on agriculture and aquaculture and strategies for adapting, among other topics.

2.4 Data analysis

Salinity testing results were graphed and mapped. Household questionnaire results were tabulated. IDIs and FGDs were audio recorded, transcribed, and translated from Bangla to English. FGDs, community key informant interviews, and stakeholder (NGO and government) interviews were recorded. The mixed-methods approach provided both quantitative and qualitative insights into the socioeconomic conditions of farmers, the impacts of soil salinity, and the range of adaptation strategies employed to sustain agricultural livelihoods under changing environmental conditions.

The data analysis is based on Excel-driven tabulation and visualization, which represents results through percentages, charts, and graphs. These outputs not only highlighted differences between saline-prone and non-saline areas but also clarified the adoption patterns of adaptation strategies and their constraints.

Chapter 3

Results and Discussions

3.1 Socioeconomic characteristics of the farmers in the four different unions in the two coastal areas

Most of the socioeconomic and demographic characteristics viz. gender, age, education, family size, farm size and annual income of the farmers in the four different unions in the two coastal areas studied.

3.1.1 Gender Distribution of the respondents

Climate change-induced salinity has been a major issue in Bangladesh for years, and the impact is most evident among women residing in the coastal regions of the country. In this study Highest number of male farmers were interviewed in Burigoalini union (86.66%) followed by Gabura (80%) and Atulia (76.67%) and lowest in Helatala Union (56.67%) whereas female farmers vice versa (**Fig. 3.1**).

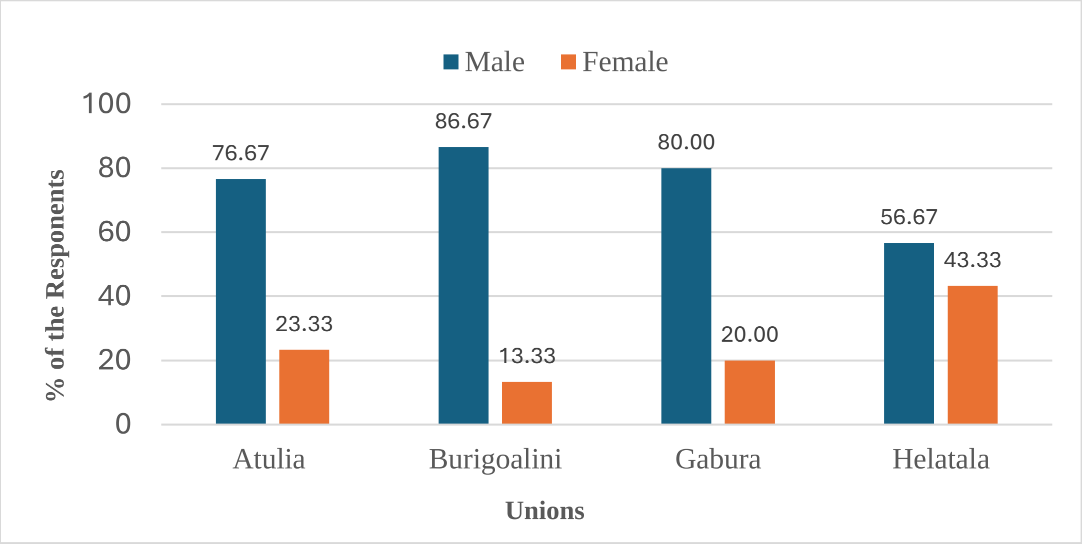

Figure 3.1 Status of Gender of respondents farmers in four different unions in the two coastal study areas

The findings indicate engagement of female in farm activities is limited in saline prone areas compare to non-saline areas. One of the key impacts of salinity is the reduction of the availability of drinking water and women need to go far from their house to fetch drinking water (Hossain et al., 2021). Consequently, the burden of work is increased, and women face challenges to perform their traditional household tasks effectively, for example, cooking, child-rearing, washing dishes, and clothes and elderly caring (Alston, 2015).

3.1.2 Age Groups of the respondents

With projected climate change and associated sea level rise, the existing problem of salinity in coastal Bangladesh will significantly increase and further worsen agrobiodiversity. This research aimed to examine the adverse effects of salinity on food security in climate-vulnerable coastal Bangladesh and to inform appropriate intervention strategies of adaptation and economic outcomes. In age groups engagement of respondents in agriculture is highest in Helatala (63.33%) followed by Burigoalainy (20%), Gabura (16.67%) and lowest in Atulia (13.3%) at age group 21 to 30 and lowest in Burigoalini (6.63%) at age group 31 to 40 (**Fig.3.2).**

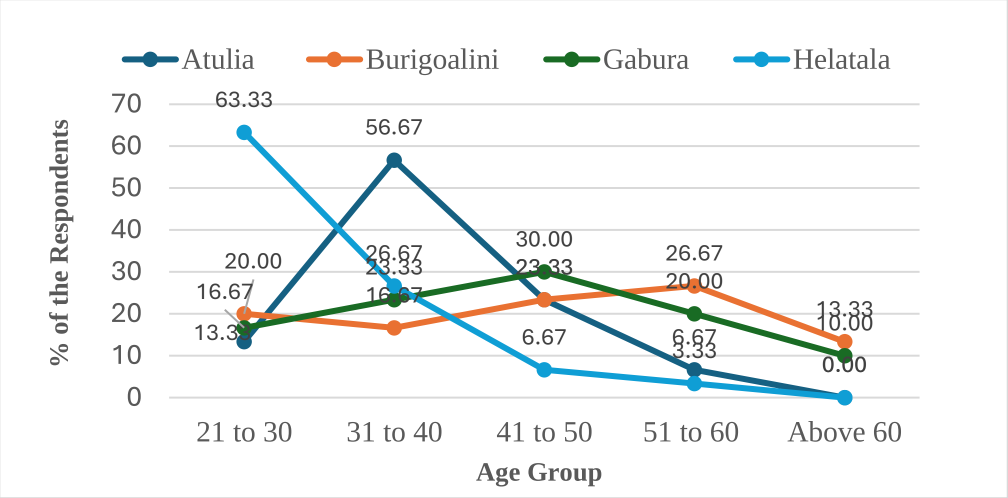

Figure 3.2 Age group of respondents farmers in four differnt unions in the two coastal study areas

The results indicate that engagement of youth farmers in farm activities is higher in non-saline areas compare to saline prone areas. Strategies like creating a positive outlook on rural life can be a good start. Evidence suggests that a positive outlook on the rural lifestyle can get young people interested in agricultural activities (Yazdanpanah et al. 2015).

3.1.3. Educational qualifications

The study areas are highly vulnerable to rapid onset of natural disasters like cyclones, storm surges and river flooding. Several major cyclones in the past fifteen years have inflicted significant damage to the school infrastructure, deteriorated basic school amenities and increased the dropout rate (Mallick et al., 2011). That is why educational qualifications differed significantly between the two different coastal study areas (**Fig.3.3).** Most of the respondents from saline prone areas found lower levels of education. Among the four groups of farmers, respondents from Helatala unions had the higher levels of educations (10% at SSC, 13.33% at HSC and 3.33% at Graduate) compare to the respondents from saline prone areas.

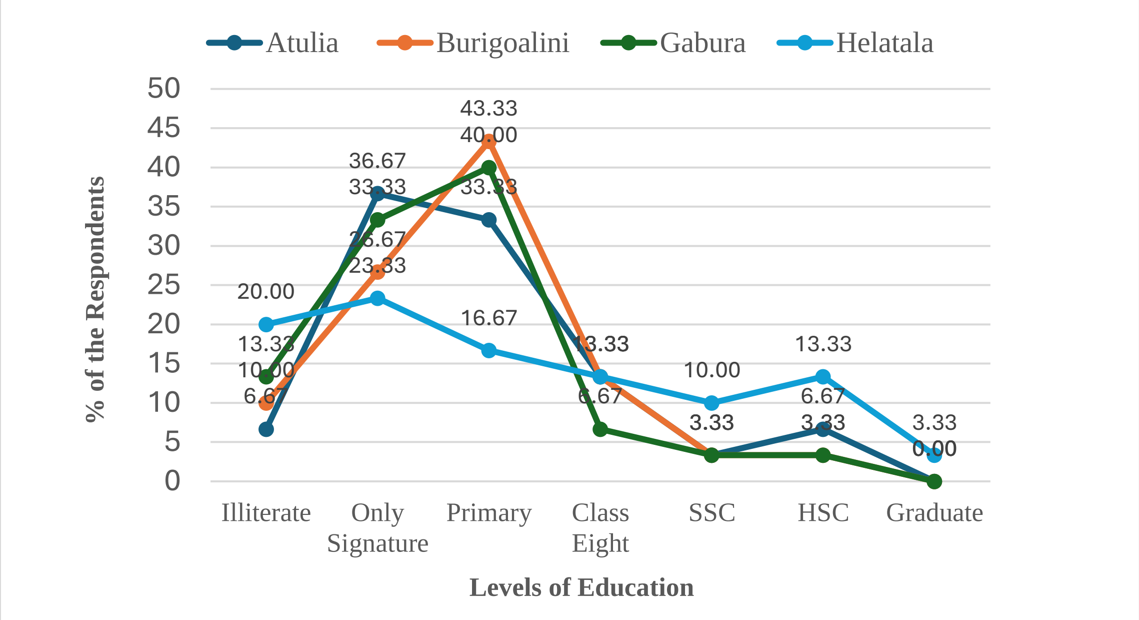

Figure 3.3 Level of education of respondents farmers in four differnt unions in the two coastal study areas

3.1.4 The family size of the respondents

The family size of the respondent farmers' in four different unions in the two coastal areas studied found that most of the respondents consists of 5 to 7 family members. Respondents in two location viz. Burigoalini(10%) and Atulia(6.67%) belongs to saline prone area consist of 8 to 10 family members(**Fig.3.4).** Bangladesh is densely populated, mostly poor, prone to major natural disasters, and uniquely vulnerable to the effects of climate change (Global Climate Risk, 2020; Shams & Shohel, 2016). The coastal rural communities must be given special attention because poverty has enveloped this population group, which lives in a vulnerable land with limited resources (Kabir *et* al., 2020). Increasing pressure of population on this area put more people at risk of suffering and economic losses due to disaster.

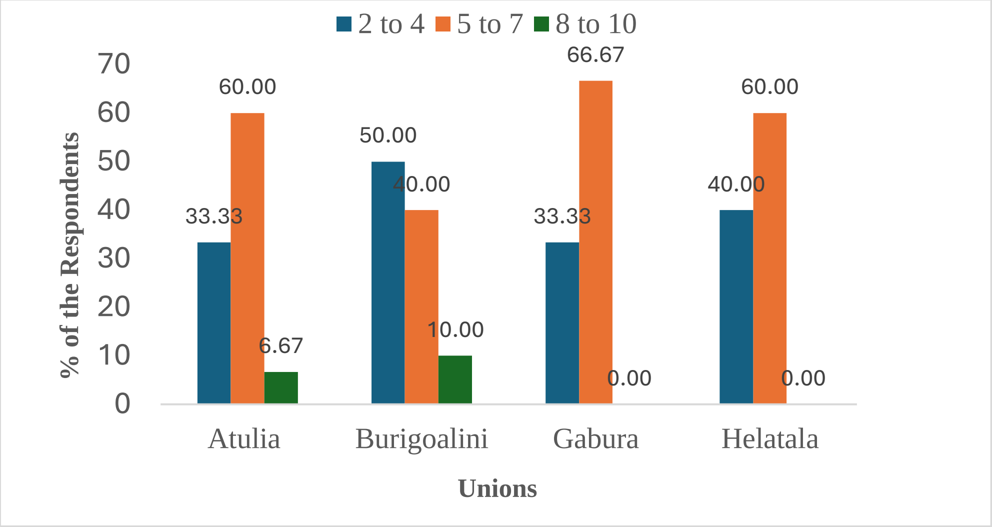

Figure 3.4 Family size of the respondents farmers in four differnt unions in the two coastal study areas

3.1.5. Farm size in the study area

Farm size refers to the physical area of land used for agricultural activities with a focus on the size of farms that are typically small and decreasing in Bangladesh. In this study number of the respondents based on total farm size were found higher having 51 – 100 decimal of land ownership in Burigoalini (50%), Helatala (46.67%) and Gabura (43.33%) unions in the two coastal study areas (**Fig.3.5**). The highest number of respondents belong to 101 to 150 decimals land ownership found in Atulia (43.33%) followed by Helatala (26.67%) and lowest in both Burigoalini and Gabura (23.33%). A few number of respondents belong to 151 to 200 decimals and more land ownership were found in four different unions in the two coastal areas.

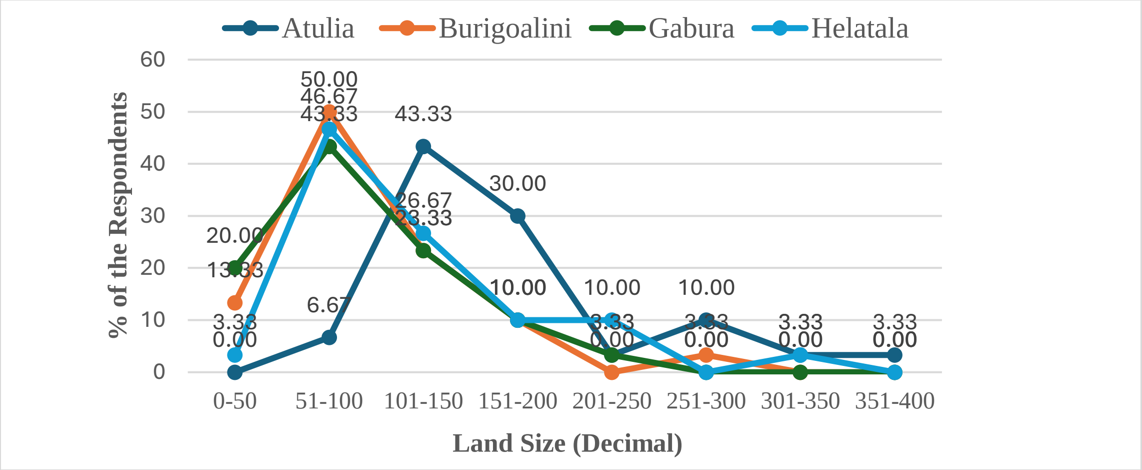

Figure 3.5 Farm size of the respondents farmers in four differnt unions in the two coastal study areas

Total cropland area of Bangladesh is 7.90 million ha and due to rapid population growth (1.37 percent per year (BBS 2011)), urbanization, industrialization and diversification of agriculture (redistribution of land between agricultural sub-sectors), per capita cropland has been decreasing over time. The cultivated area is at present 0.125 acre per person (Quasem 2011) which is accordance with the results of present study.

3.1.6. Annual income of the respondents

Annual income is the amount of income one receive each year and it is an important measure of financial stability and is often used to determine socio economic status. Salinity intrusion is a major issue in the South-east coastal region of Bangladesh. Around 53% of the coastal region is affected by different degrees of salinity (Nur et al., 2024). Increased salinity has several negative impacts on the livelihood of the people in this area. Therefore, the study aims to explore the socio-economic impacts of salinity on various aspects of livelihoods at four different unions in the two coastal study areas. Significant differences were found in annual income among the respondents four different unions in the two coastal areas (**Fig.3.6**).

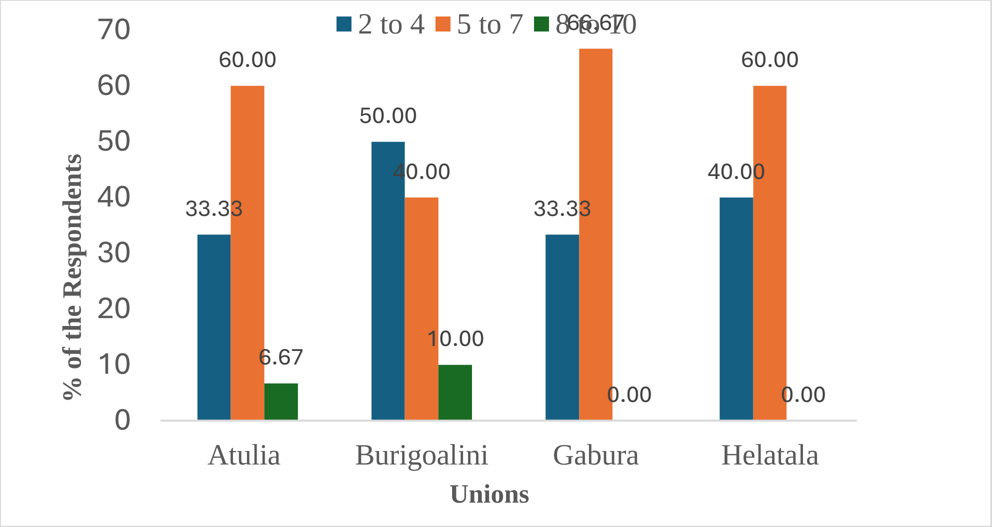

Figure 3.6 Family size of the respondents farmers in four differnt unions in the two coastal study areas

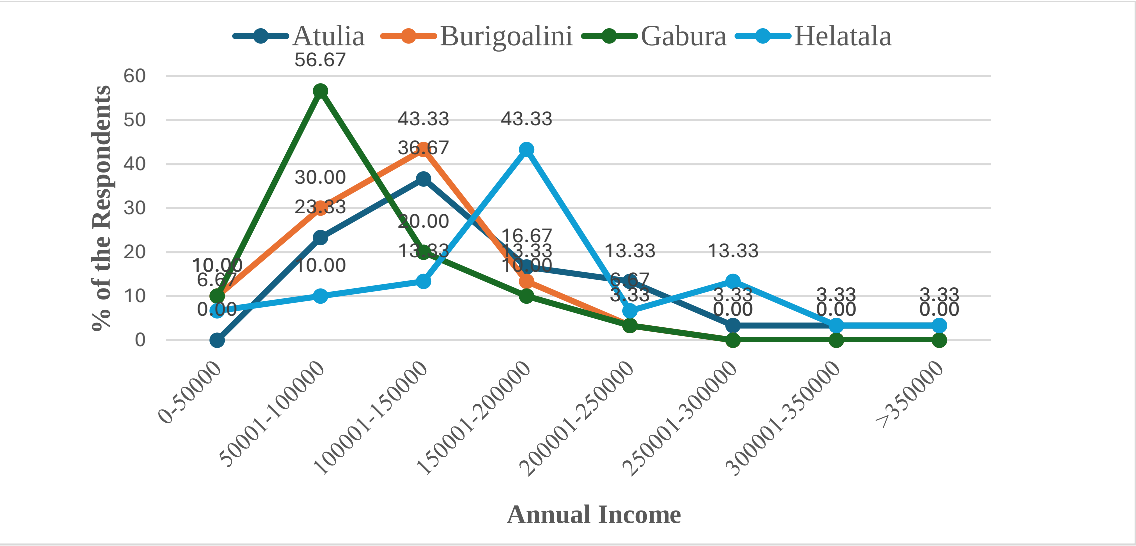

Figure 3.7 Annual income of the respondents farmers in four differnt unions in the two coastal study areas

The highest number of respondents having their annual income BDT 50000 to 100000 was found in Gabura (56.67%) followed by Burigoalini and Atulia and the lowest in Helatala (10%). Also the highest number of respondents having their annual income BDT 100001 to 150000 was found in Burigoalini (43.33%) followed by Atulia and Gabura and the lowest in Helatala (13.33%). The respondents having their annual income BDT 150001 to 200000 was found highest in Helatala (43.33%) followed by Atulia and Burigoalini and the lowest in Gabura (10.00%). The respondents having their annual income BDT 200001 to 250000 and above were found higher in non-saline area (Helatala) compare to three saline prone unions of in the coastal areas.

Soil salinity has emerged as a problem which is not only reducing the agricultural productivity (Ali, 2006; Sarwar and Khan, 2007), but also putting far reaching impacts on livelihood strategies of farmers. Both of the soil and water salinity have adverse effects on people’s living standard, daily life activities and socio-economic conditions (Haque and Saifuzzaman, 2003; Miah et al., 2004;).

3.1.7. Nature of participation in the local social organizations

Social participation can be defined as “a person's involvement in activities providing interactions with others in community life and in important shared spaces, evolving according to available time and resources, and based on the societal context and what individuals want and is meaningful to them”(Levasseur et.al.2010). Nature of participation of the farmers’ in the local organizations at four different unions in the two coastal areas studied found that most of the respondents have no participation in local organizations (**Fig. 3.8**). Some of the farmers are participate as an ordinary member in the local committees while a few acts as executive members NGO and Krishok Somobay Samity .

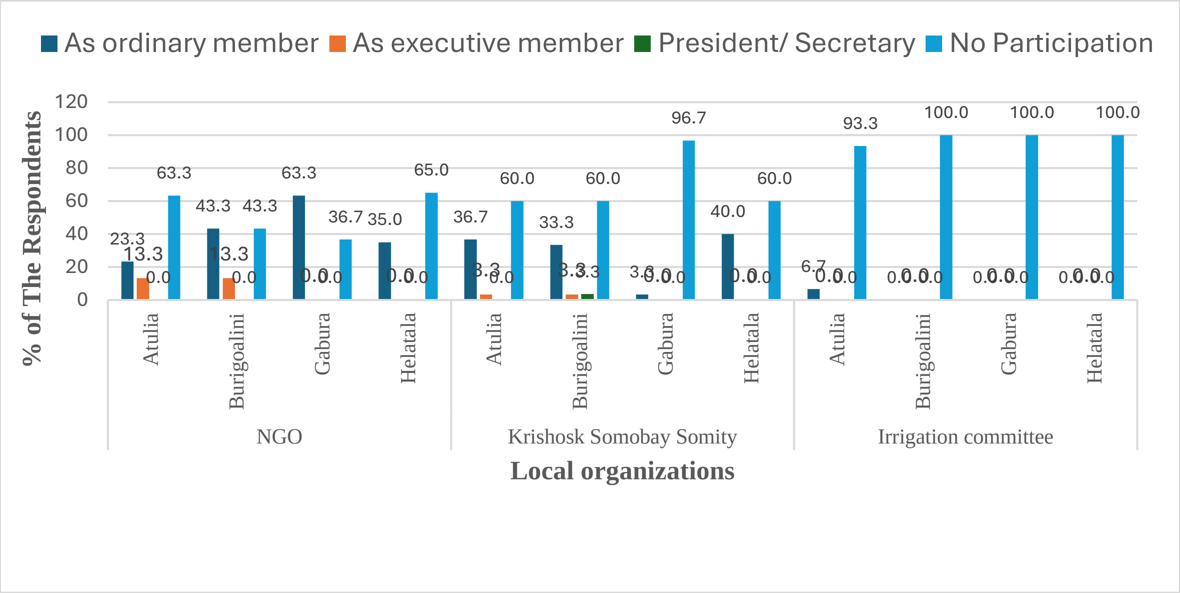

Figure 3.8 Nature of participation in the local organizations of the respondents farmers at four differnt unions in the two coastal study areas

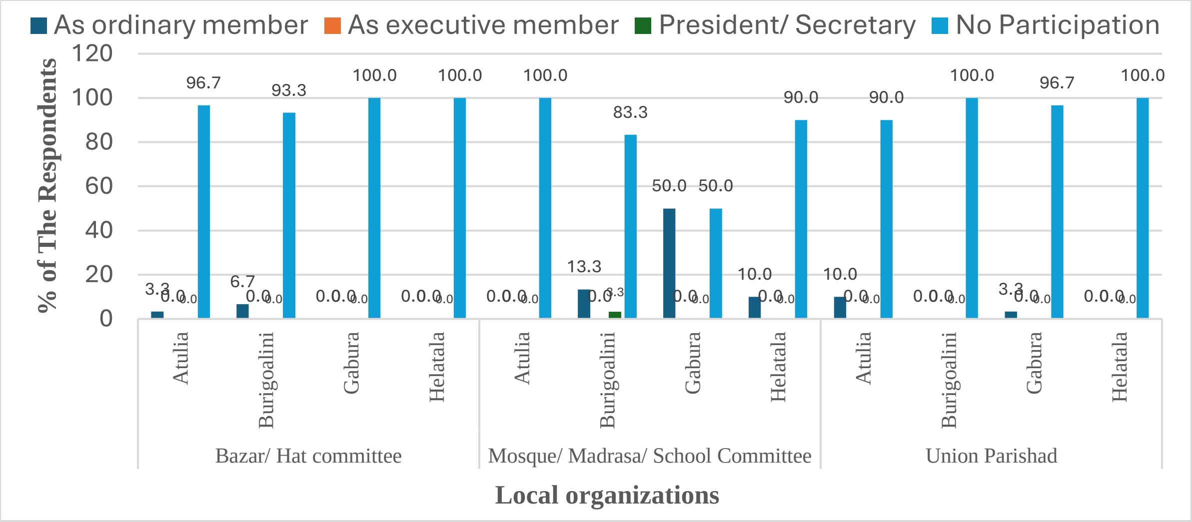

Figure 3.8.(Contd.) Nature of participation in the local organizations of the respondents farmers at four differnt unions in the two coastal study areas

3.1.8. Sources of information and farming advice of the farmers at four different unions in the two coastal areas

Sources of information and farming advice of the farmers at four different unions in the two coastal areas studied and found that most of the farmers obtain farming advice from the local sub-assistant agriculture officer, and to a lesser extent from local input dealers, neighboring farmers and mass media (**Fig.3.9)**. The highest number of respondents obtain agricultural advices from local SAAO in Helatala (56.67%) followed by Atulia (46.67%) and lowest in Gabura (30%). In saline prone areas, higher number of respondents obtain advices from local inputs dealers compare to non-saline area. In contrast, higher number of respondents obtain advices from mass media at non-saline area compare to saline prone areas.

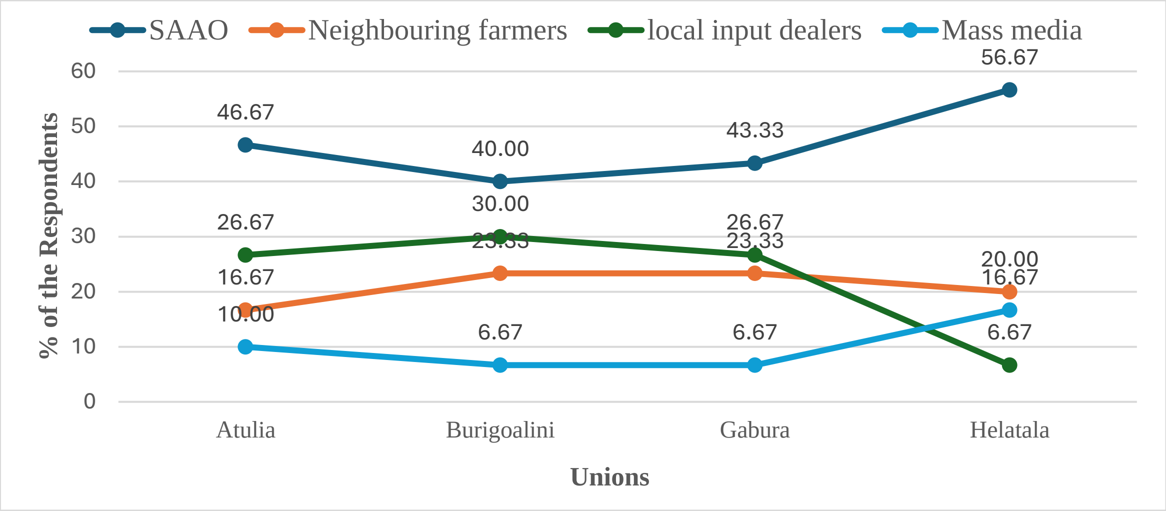

Figure 3.9 Sources of information and farming advice of the farmers at four different unions in the two coastal areas

3.2. Impacts of high salinity on the farming enterprise of the different unions

The perceived impacts of high salinity of the different unions in the coastal areas of Bangladesh were very much focused on their main enterprise, with most concerned about impacts on yield. For rice farmers, high salinity had negative consequences on yield, with reporting, "Scarcity of irrigation water, damage Crops and Vegetables fields, plant root spoilage, plants dry up, less heading, unfilled grain and lower yield".

3.2.1 Scarcity of Irrigation Water in the study areas

Salinity is a major issue for irrigation water in Bangladesh, threatening crop production and food security. Scarcity of Irrigation Water differed significantly between the two different coastal study areas (**Fig.3.10).** Most of the respondents from saline prone areas reported with high scarcity of irrigation water. Among the four unions highest respondents from Gabura unions reported with very high scarcity of irrigation water (66%) followed by Burigoalini (30%) and Atulia (20%) whereas none of the respondents from non-saline areas reported with very high scarcity of irrigation water .

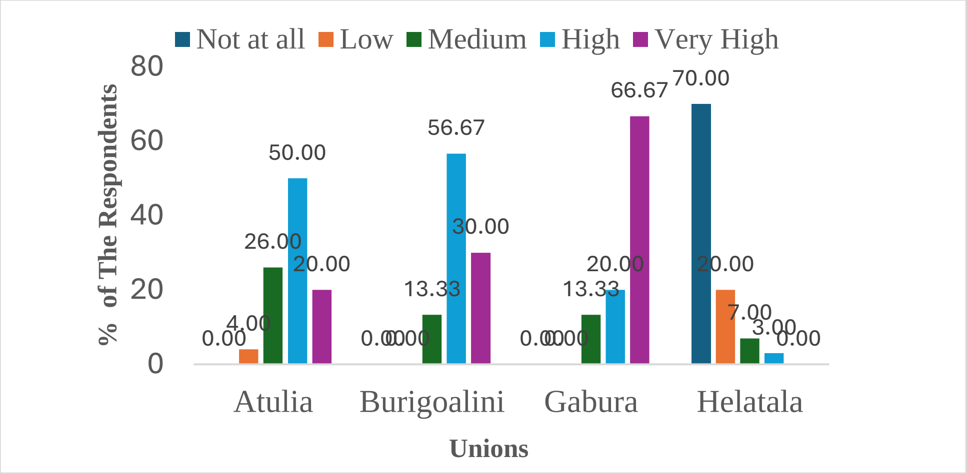

Figure 3.10 Scarcity of Irrigation Water at four different unions in the two coastal areas

Salinity becomes a major problem in south-west coastal region of Bangladesh, where irrigation water quality is highly affected by high levels of salinity, which is a source of irrigation salinity and it mainly results from rises in the groundwater table due to excessive irrigation and the lack of adequate drainage for leaching and removal of salts (Corwin et al., 2007). However, most rice lands in the coastal region of Bangladesh remain fallow in the dry season because surface water resources are saline and unsuitable for rice irrigation, while groundwater (GW) is not intensively utilized because of the fear of salt-water intrusion into coastal aquifers (Mondal et al., 2008).

3.2.2. Damage Crops and Vegetables fields in the study areas

In costal 70% area in our country are affected by saline soil (BBS, 2016). Vegetable cannot grow in this area particularly winter vegetables because all of winter vegetables are saline sensitive thus decrease cropping intensity with increased salinity environmental hazards in this area specially during rabi season is common phenomenon. As a result, salinity intrusion not only destructs crop yield but also causes a loss of total crop production on highly salt concentrated soil. Thus saline-prone coastal region had a drastic yield loss i.e. approximately average 20-40% in major crops (cereals, potato, pulses, oil seeds, vegetable, species and fruit crops). Salinity affects almost all aspects of plant development including germination, vegetative growth and reproductive development. Damage of Crops and Vegetables fields frequently occur in two different coastal study areas (**Fig.3.11**).

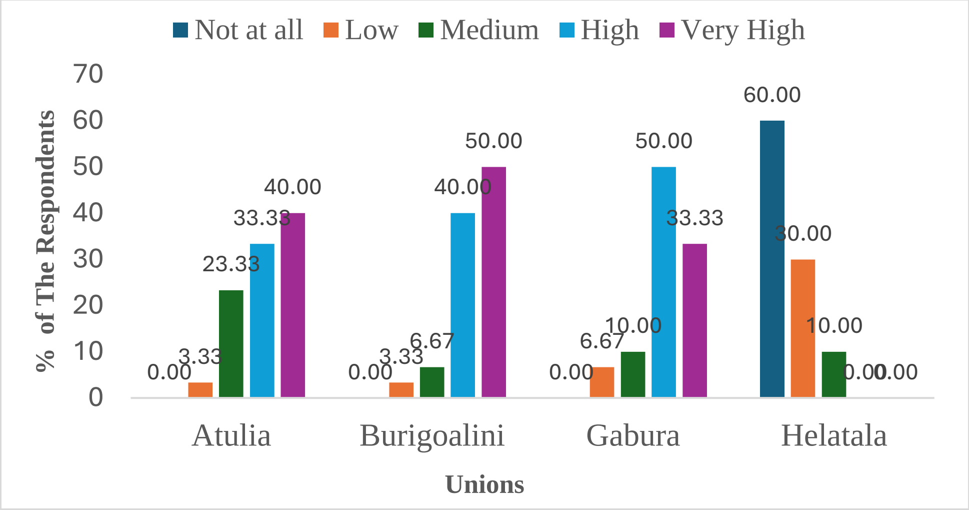

Figure 3.11 Damage Crops and Vegetables fields at four different unions in the two coastal areas

Most of the respondents from saline prone areas reported with high damage of crops and vegetables. Among the four unions highest respondents from burigoaliny unions reported with very high damage (50.00 %) followed by Atulia (40.00%) and Gabura (33.33%) whereas none of the respondents from non-saline areas reported with **Damage Crops and Vegetables fields**. Soil salinity imposes ion toxicity, osmotic stress, nutrient (N, Ca, K, P, Fe, Zn) deficiency and oxidative stress on plants, and thus limits water uptake from soil. Salinity effects are the results of complex interactions among morphological, physiological, and biochemical processes including seed germination, plant growth, and water and nutrient uptake (Akbarimoghaddam et al., 2011; Singh and Chatrath, 2001).

3.2.3. Root spoilage of crops in the study areas

High salinity may inhibit the root and shoot elongation due to slowing down the water uptake by the plant. In this study most of the respondents from saline prone areas reported with high **root spoilages of plant** due to salinity increase in soil (**Fig.3.12).** Among the four unions the highest respondents from Burigoalini unions reported with very high (20.00 %) root spoilage and respondents from Gabura unions reported with high (35.00%). A very few respondents (5.00%) from Helatala reported regarding low root spoilage compare to saline prone areas.

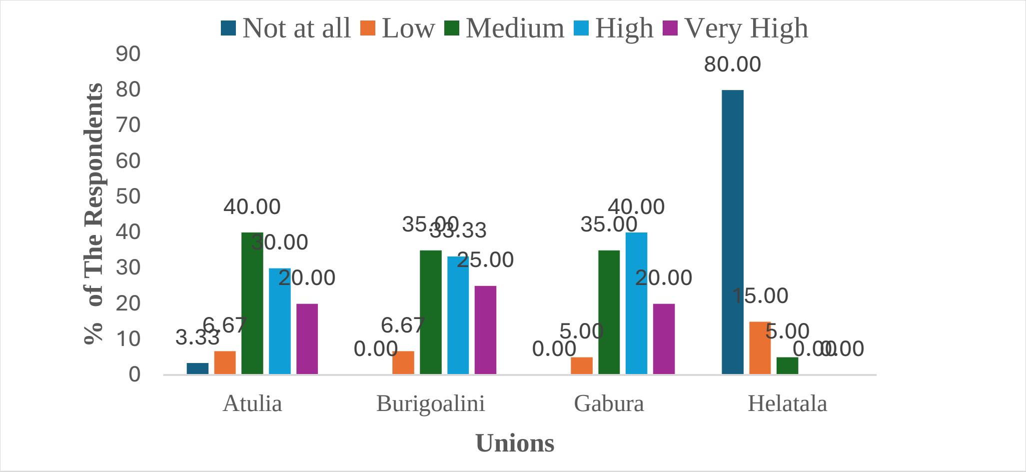

Figure 3.12 Root spoilage at four different unions in the two coastal areas

Salinity can rapidly inhibit the root growth and its capacity to water uptake and essential mineral nutrition from soil [Neumann, 1997]. The reduction in yield under saline condition was also due to reduced growth as a result of decreased water uptake, toxicity of sodium and chloride in the shoot cell as well as reduced photosynthesis [Juan *et*. al, 2005]. High concentrations of salt impose both osmotic and ionic stresses on the plants which lead to several morphological and physiological changes. High salt content, especially chloride and sodium sulphates, affects plant growth by modifying their morphological, anatomical and physiological traits (Muscolo *et*. al, 2006).

3.2.4. Plants dry up from the top and looks like straw

Symptoms of salt injury in plants resemble drought. Both conditions are characterized by water stress (wilting) and reduced growth. In this study most of the respondents from saline prone areas reported about plants dry up from the top and looks like straw with medium to very high extents due to salinity (Fig.3.13). Among the four unions the highest respondents (20.00 %) from Burigoalini union reported with very high extents of plants dry up from the top and looks like straw and the highest respondents (70.00%) from Gabura unions reported with medium extents. A very few respondents (10.00%) from Helatala reported regarding low extent and none of respondents reported with medium and above extents of plants dry up from the top and looks like straw compare to saline prone areas .

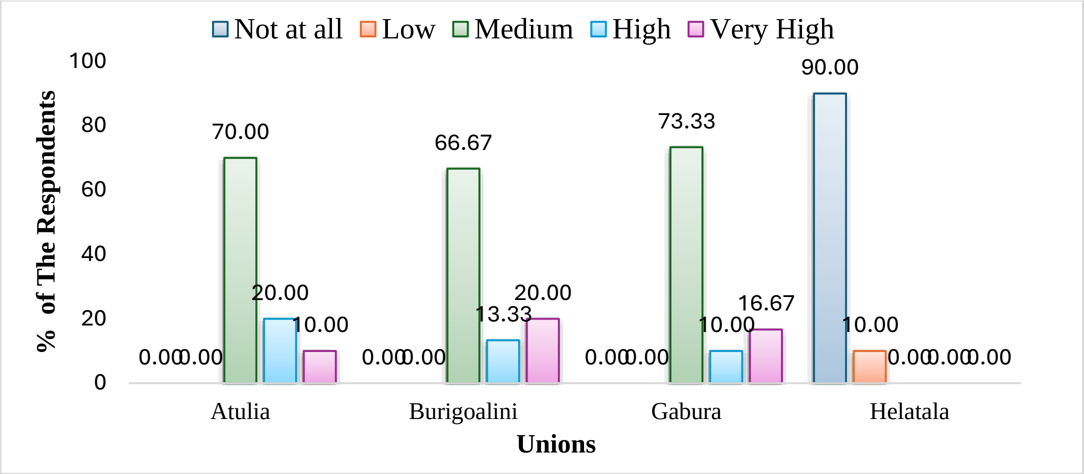

Figure 3.13 Plants dry up from the top and looks like straw at four different unions in the two coastal areas

Severe injury caused by prolonged exposure or high salinity results in stunted plants and tissue death due to osmotic effects that alters the water relations of the plant, and reduces the rate of cell expansion. This leads to a reduction in the rate of development of new roots, leaves and lateral shoots. The osmotic effect also reduces stomatal conductance, which leads to reduced photosynthesis. It also causes accelerated senescence of older leaves. Thus there are three somewhat independent processes being affected (i.e. new leaf formation, old leaf death and photosynthetic activity) that all contribute to a reduction in the net assimilation rate of the plant. Stunted growth and yellowed leaves are the first signs that salt has exceeded the amount a plant can tolerate. In broad-leafed species, the second stage involves leaves dying, followed by leaves dropping off (Munns, 1993).

3.2.5. Less heading, unfilled grains and Yield loss due to Salinity

This study has shown that the perceived effects of higher salinity during the reproductive stages of the rice plant (i.e. perceived as the most sensitive stages) (**Fig.3.14**) resulted in less heading (panicle extrusion) in rice and subsequently caused 'severe' yield reductions. Among the four unions the highest respondents (63.33 %) from Burigoalini union reported with 'very high' extents less heading, unfilled gain and yield loss and the highest respondents (76.67%) from Burigoalini unions reported with 'high' extents. A very few respondents (10.00%) from Helatala reported regarding low extent and none of respondents reported with medium and above extents of less heading, unfilled gain and yield loss compare to saline prone areas .

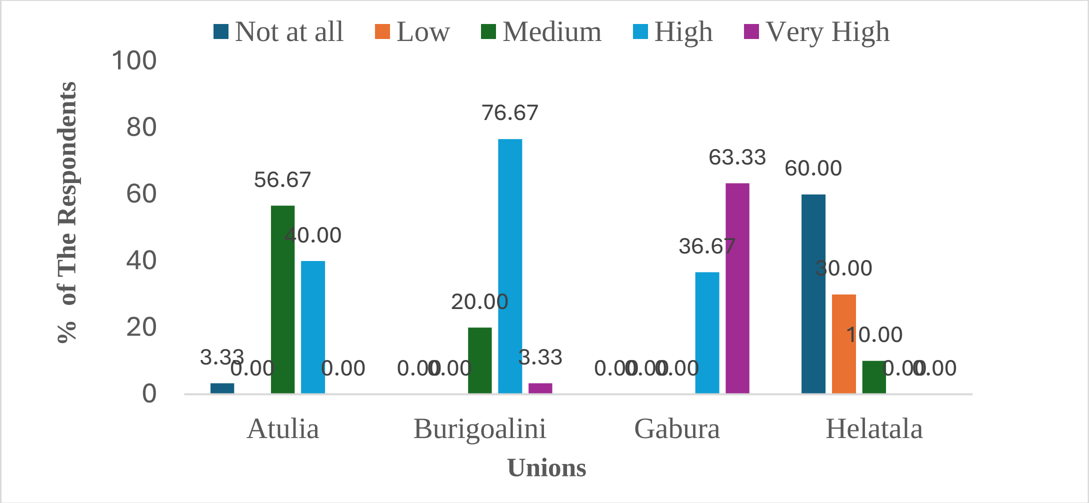

Figure 3.14 Less heading, unfilled gain and yield loss at four different unions in the two coastal areas

Farmers' perceptions in this study were confirmed to be consistent with agronomic research into salinity sensitive stages of rice. The adverse effect of salinity on rice crop at different stage was observed by Zeng et al. (2001) and they were exposed the rice crop to salinity at the time of seeding, first leaf, third leaf, panicle initiation (PI) and booting stages respectively. They point out that salinity stress before PI reduced shoot dry weight and grain yield. Yield of plants are closely associated with grain number and weakly associated with grain size. Hasanuzzaman et al. (2013) observed at high salinity stress grain number reduced at 31%, 22% in barley and wheat crop respectively and grain size reduced in both crops. Moreover, salinity stress at flowering stage also detrimental as like drought stress.

3.2.6. Water logging in the study areas

Water-logging is a pressing concern at the backdrop of climate change that becomes worsens for the people of southwest Bangladesh. Waterlogging occurs when there is too much water in a plant's root zone, which decreases the oxygen available to roots. Waterlogging can be a major constraint to plant growth and production and, under certain conditions, will cause plant death. The prolonged water-logging has caused significant displacement presenting humanitarian challenges in safe water supply, sanitation, shelter, food security, and employment opportunity.

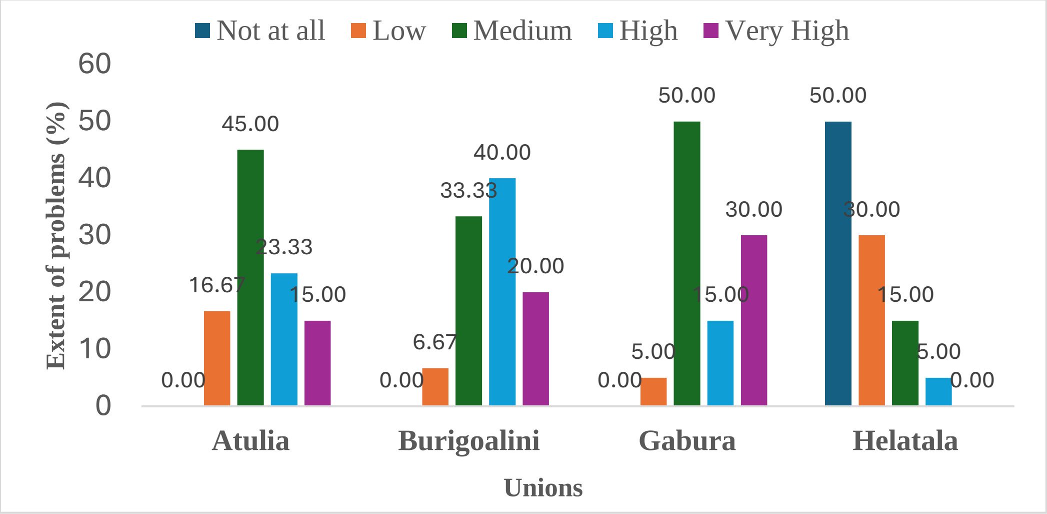

Figure 3.15 Water logging at four different unions in the two coastal areas

Damage of crops, water quality deterioration, inundated latrines, diseases and psychological and physical injuries are some frequently mentioned impacts due to waterlogging in the study areas and extent of waterlogging differed significantly between the two different coastal study areas (**Fig.3.15).** Most of the respondents from saline prone areas reported with high to medium extent of water logging. Among the four unions, the highest respondents (30%) from Gabura unions reported with `very high' water logging problem followed by Burigoalini (20%) and Atulia (15%). On the other hand the highest respondents (40%) from Burigoalini unions reported with `high' water logging problem followed by Atulia (23.33%) and Gabura (20%). None of the respondents from non-saline areas reported with very high water logging problem. Damage caused by a natural disaster, such as waterlogging, can push households into poverty and push already poor households further into the depths of the poverty cycle (Aawal, 2014).

3.3. Adaptation preferences to cope with expected high salinity

IPCC (2001) define adaptation as adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. Adaptations are the changes in structure or behavior of an organism that will allow the organism to survive in that habitat. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climatic change and variability (Lisa, 2007).

Common responses of plants to salinity exposure are an increase in solute concentration, for example, osmotic adjustment, changes to the cell wall elasticity, decrease in relative water content in the tissue, and increase in the percentage of water in the apoplast, which reduces salinity damages by maintaining ionic homeostasis and stimulate phytohormone signaling pathways, thereby balancing growth and stress tolerance to enhance their survival. However, Some of the widespread soil and land management techniques adopted in the saline areas of Bangladesh to cope with the salinity are mini-pond (khamar-pokor), sarjan method, usage of raised pit for year-round cropping, mulching (keeping land covered in winter and summer months), land leveling, pitcher (kolosh) irrigation to grow watermelon, dibbling method, zero tillage, AWD (alternate watering and drying), crop rotation, use of short duration crop varieties, dry seed bed, the addition of organic matter and cultivation of saline tolerant crop varieties, particularly rice.

Adaptation decisions to cope with salinization in the coastal areas of Bangladesh are becoming increasingly complicated as this problem not only exhibits spatial-temporal variations but also affects the coastal communities in diverse ways. This research addresses the differential perceptions of farmers to cope with salinity. The household interviews found significant differences in the adaptation preferences under expected high salinity among the different types of farmers in the two coastal areas of Bangladesh. The respondents' farmers placed the greatest emphasis on agronomic solutions for adaptation in high salinity, with referring to use of "Salinity tolerant crop, Sarjon method, Mulching, Mini pond, Zero tillage, Dry seed bed, Raised pit, AWD (alternate watering and drying), Crop rotation and Short duration crop varieties".

Adaptation preference mentioned by the farmers at four different unions in the two coastal areas to cope with expected high salinity are also found to align with the responses from the KII and FGD to the different organizations of the coastal areas. Among the coded references related to the adaptation options 43% from the agricultural extension department personnel, 9% of the coded reference are from Research Organization and 10% from the different NGO. The frequency query search result show that use of saline tolerant rice varieties and irrigation techniques were mentioned as the most preferred options to cope with expected high salinity by the organization also high represented in the same place. The specific options mentions by the agricultural extension staff were mostly agronomical technical option such as use of saline tolerant rice variety, Sarjon method, Mulching, Mini pond, Zero tillage, Dry seed bed, Raised pit, AWD (alternate watering and drying), Crop rotation and Short duration crop varieties

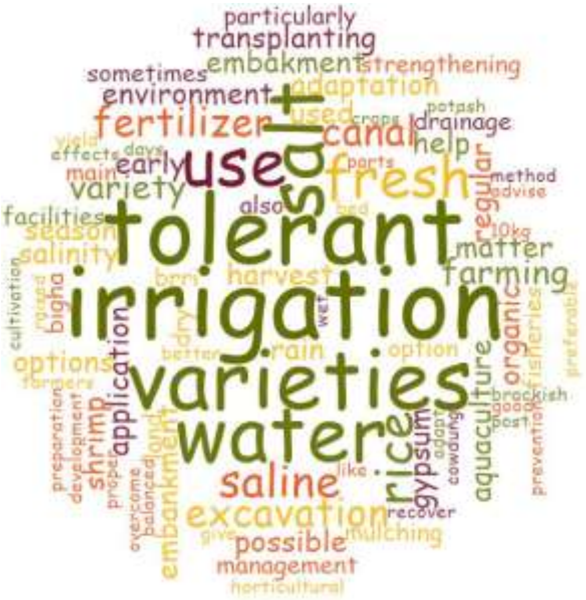

Figure 3.16 Adaptation options that emerged from the FGDs and KIIs

3.3.1. Use of Salinity tolerant crop varieties

Salinity is a major issue for irrigation water in Bangladesh, threatening crop production and food security. Extent of use of saline tolerant varieties differed between the two different coastal study areas (**Fig.3.17).** Most of the respondents from saline prone areas reported with frequently use of saline tolerant varieties. Among the four unions highest respondents from Burigoalini unions reported with frequent use of saline tolerant crops varieties (86.60%) followed by Gabura (46.0%) and Atulia (30.0%) whereas none of the respondents from non-saline areas reported with use of saline tolerant crops varieties. Saline-tolerant crops are used to help farmers to grow food in saline affected coastal areas that help farmers to improve their income and the nutritional diversity of their diets (Uddin and Fatema, 2016). Another findings prevailed that cultivation of saline tolerant rice in the dry season which have shown great potential to improve livelihood as well as climate change resilient farming system in the Mekong delta (Dang, 2020; Brennan et al., 2002)

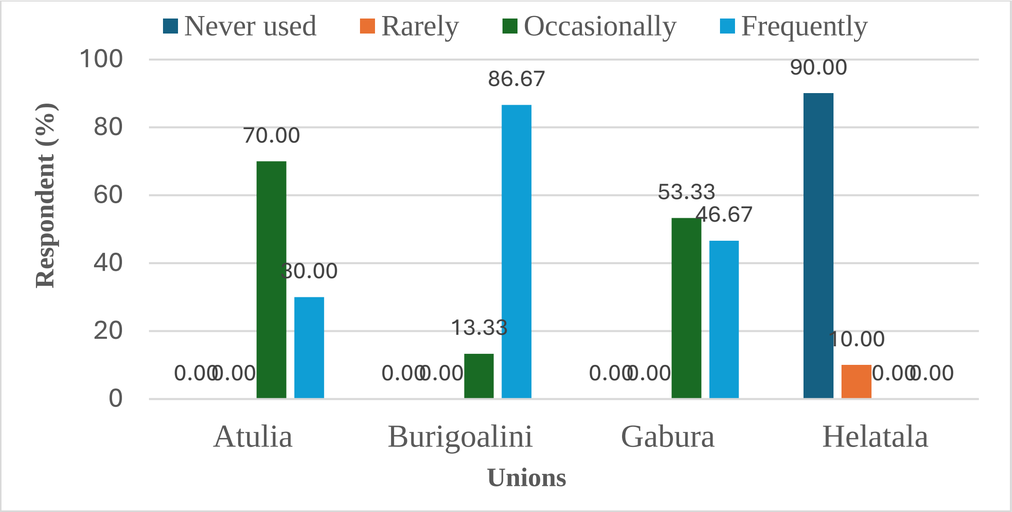

Figure 3.17 Use of Salinity tolerant crop varieties at four different unions in the two coastal areas

3.3.2. Use of Sarjon method

Sarjan technology – an alternate ditch and dikes proved a useful technology for coastal belt to cultivate crops throughout the year in changed climate. Through Sarjan technology, it is now possible to improve cropping intensity, diversify production and increase income. In order to avoid tidal water intrusion, farmers are making Sarjan by digging trench and raising land like ‘high beds’ to cultivate crops, fruits, vegetables throughout the year. Farm households in the coastal areas are using this technology and saving their cropland from tidal surges and salinity intrusion. Thus, they are now able to cultivate more crops, at least twice a year instead of single cultivation (Dhali et.al.,2014).

Figure 3.18 ***A demonstration plot using the sarjon technique***

The technology is attracting the coastal farm households of Bangladesh and becoming popular in the coastal area while farm households are establishing the technology in their own land and getting more food throughout the year and overcoming the adverse situation in changed climate. Extent of use of sarjan technique differed between the two different coastal study areas (**Fig.3.19**). Most of the respondents from saline prone areas reported with frequently use of sarjan technique. Among the four unions highest respondents from unions Gabura reported with frequent use of sarjan method (50.00%) followed by Burigoalini (40.0%) and Atulia (33.33%) whereas none of the respondents from non-saline areas reported with use of sarjan method.

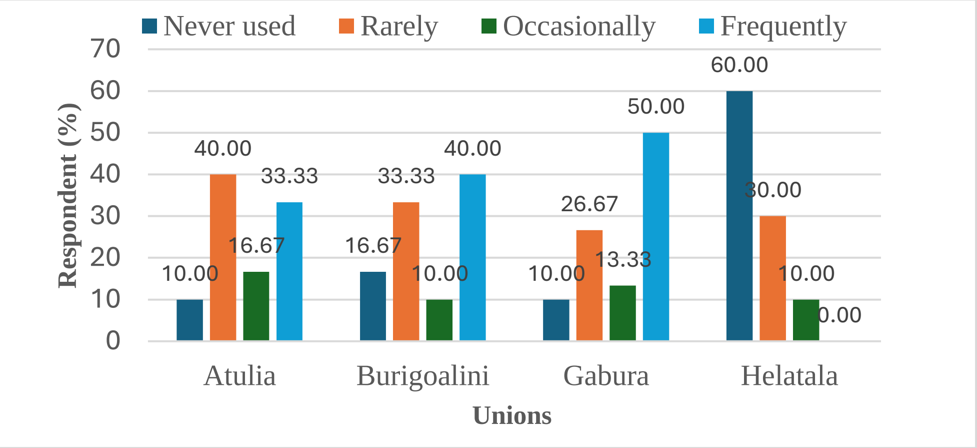

Figure 3.19 Use of Sarjon method at four different unions in the two coastal areas

3.3.3. Use of Mulching for adaptation

Mulching is a farming technique that involves covering the soil with a layer of organic material to improve soil quality and protect plants. In Bangladesh, mulching is used to grow vegetables and fruits, and to reduce cultivation cost. Mulching can reduce soil salinity by up to 73.7% in the topsoil and improve crop yields in saline areas. This is because plastic film mulching significantly increases top layer soil temperature in an early growth stage, reduces soil evaporation in the early stage, increases transpiration, accelerates plant growth and advances maturity.

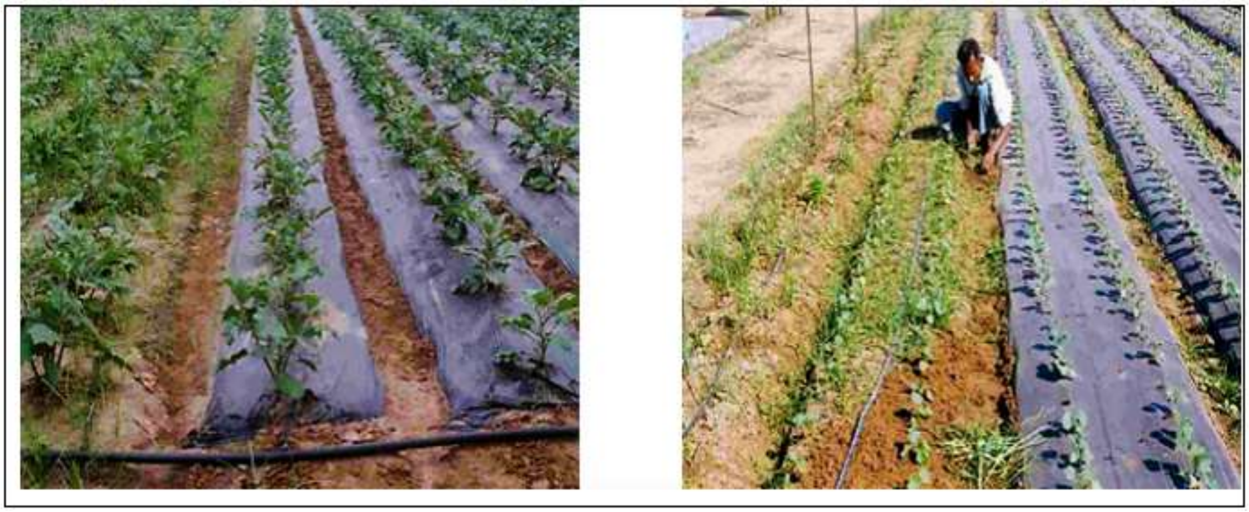

Figure 3.20 A demonstration plot using the Polythene mulch technique

Extent of use of mulching technique differed between the two different coastal study areas (**Fig.3.21**). Most of the respondents from nonsaline prone areas reported with frequently use of mulching technique. Among the four unions, highest respondents from unions Helatala reported with frequent use of mulching method (20.00%) followed by Gabura (10.0%) and Burigoalini (6.67%) whereas lowest respondents from Atulia union(3.33%) reported with use of mulching method.

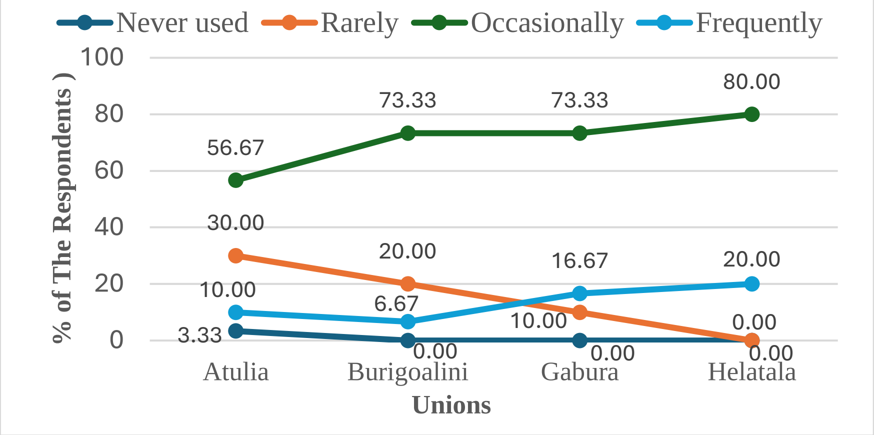

***Figure 3.21** Use of Mulching at four different unions in the two coastal areas*

Mulching with crop residues in raised beds planting system has previously been shown to have great potential to reduce soil salinity in salt-affected areas (Devkota, 2011). Polythene mulching along with convex or concave bed planting could be the powerful tool to manage saline soil. Because, polythene mulching significantly increased top layer soil temperature in early growth stage, reduced soil evaporation in the early stage and increase transpiration, accelerated plant growth and advanced maturity and help to reach higher yield and water use efficiency (Yang et al., 2018). Polythene mulching along with root zone irrigation can provide an alternative option to prevent the risk of soil salinization leading to land degradation and enhance crop productivity in the arid regions (Tan et al., 2017).

3.3.4. Digging of Mini pond in Saline area

Coastal saline soils vary widely in nature of salinity, depth of groundwater and its fluctuations along with seasonal variations in the salinity of surface water. Farmers cannot cultivate rice due to scarcity of fresh water for irrigation during the Boro season. Ground water near surface is saline and is not fit for irrigation. Groundwater from the deep aquifer at depth of 213 to 274 metres having salinity level below 0.5 dS per metre, which is suitable for irrigation but uneconomic due to high installation cost of deep tube well. Most of the areas in the coastal region remain fallow during

Rabi (dry) season. Few farmers cultivate pulses, potato, sweet potato, vegetables, oilseeds, groundnut and chilli using residual moisture in a limited scale in Rabi season.

An alternative source of water to be suitable for irrigation may be helpful in this regard. An attempt has been made by digging mini pond to use surface water for Rabi crop cultivation in the coastal area. Now a day rainwater harvesting in coastal saline areas using mini pond for irrigation is profitable for growing vegetable crops in Rabi season.

Figure 3.22 A demonstration plot using irrigation from the mini pond

Most respondents from saline-prone areas reported occasional use of mini pond technique compared to non-saline areas (Dhali et al., 2014).

Among the four unions, the highest percentage of respondents occasionally using mini ponds was reported from Burigoalini (86.67%), followed by Gabura (53.33%) and Atulia (53.33%), while the lowest was found in Helatala (45.00%) (Field Survey, 2023) (Fig.3.20 A).

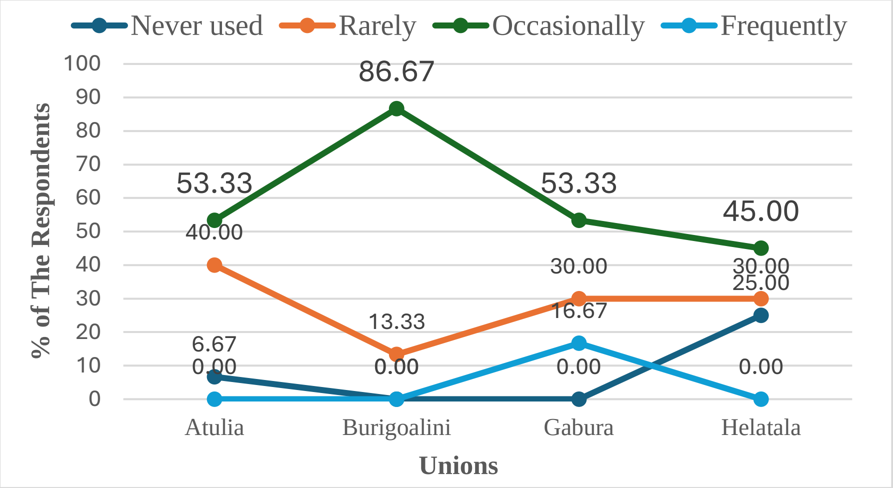

Figure 3.23 Use of Mini Pond at four different unions in the two coastal areas

In contrast, rare use of mini ponds was reported by 40.00% respondents in Atulia, while 13.33%

in Burigoalini, 16.67% in Gabura, and 30.00% in Helatala reported rarely using mini ponds (Field Survey, 2023).

The frequent use of mini ponds, however, was very minimal across all unions, with no significant percentage reported, showing that this practice is not yet fully established as a routine adaptation technique (Tan et al., 2017).

Additionally, never used category was highest in Helatala (25.00%), followed by Atulia (6.67%), while none reported in Burigoalini and Gabura (Field Survey, 2023).

This indicates that in saline-prone areas, farmers are more inclined to adopt mini pond irrigation occasionally as an adaptive measure compared to non-saline areas where a portion still has not adopted this technique (Yang et al., 2018).

The data imply that while mini ponds are recognized as a profitable method for rainwater harvesting and supplementary irrigation during the dry season (Devkota, 2011), their implementation remains occasional rather than frequent, suggesting potential for further promotion and technical support to make the practice more widespread and sustainable (Tan et al., 2017).

3.3.5. Zero Tillage Practice

Zero tillage (ZT), also known as no-till farming, is an agricultural practice in which the soil is not plowed before planting crops. Unlike traditional farming, where soil is tilled to prepare the seedbed, zero tillage leaves the soil undisturbed. This method involves planting seeds directly into undisturbed soil, with minimal soil disturbance.

The primary goal of zero tillage is to reduce soil erosion, conserve moisture, and improve soil health. By leaving the soil undisturbed, the natural structure of the soil is preserved, which helps maintain beneficial soil organisms and enhances water infiltration. This practice is particularly valuable in areas prone to soil degradation, such as coastal regions affected by salinity, where conventional tillage can exacerbate soil erosion and reduce soil fertility.

Zero tillage also offers environmental benefits, including carbon sequestration, where carbon dioxide from the atmosphere is stored in the soil, and a reduction in greenhouse gas emissions due to less energy required for tilling. The method is widely adopted in many parts of the world, particularly for crops like wheat, maize, and soybeans. In regions with saline soils, such as the coastal areas of Bangladesh, zero tillage can be a crucial tool in reducing soil salinity, improving soil health, and enhancing agricultural productivity.

By allowing the soil to retain its natural structure, zero tillage helps improve water retention, reduce evaporation, and enhance soil moisture levels. This, in turn, creates a more resilient farming system, especially in the face of climate change and water scarcity. Farmers can benefit from increased crop yields and reduced dependence on chemical fertilizers and irrigation, making zero tillage an important sustainable farming technique.

Figure 3.24 A demonstration plot using Zero tillage (ZT), also known as no-till farming

Extent of use of zero tillage technique differed between the two different coastal study areas (**Fig. 3.24** and **Fig. 3.25).**

Most respondents from saline-prone areas reported rare use of zero tillage technique compared to non-saline areas (Dhali et al., 2014).

Among the four unions, the highest percentage of respondents rarely using zero tillage was reported from Burigoalini (86.67%), followed by Gabura (53.33%) and Atulia (53.33%), while the lowest was found in Helatala (45.00%) .

In contrast, occasional use of zero tillage was reported by 40.00% respondents in Atulia, while 16.67% in Burigoalini, 16.67% in Gabura, and 30.00% in Helatala reported occasional use.

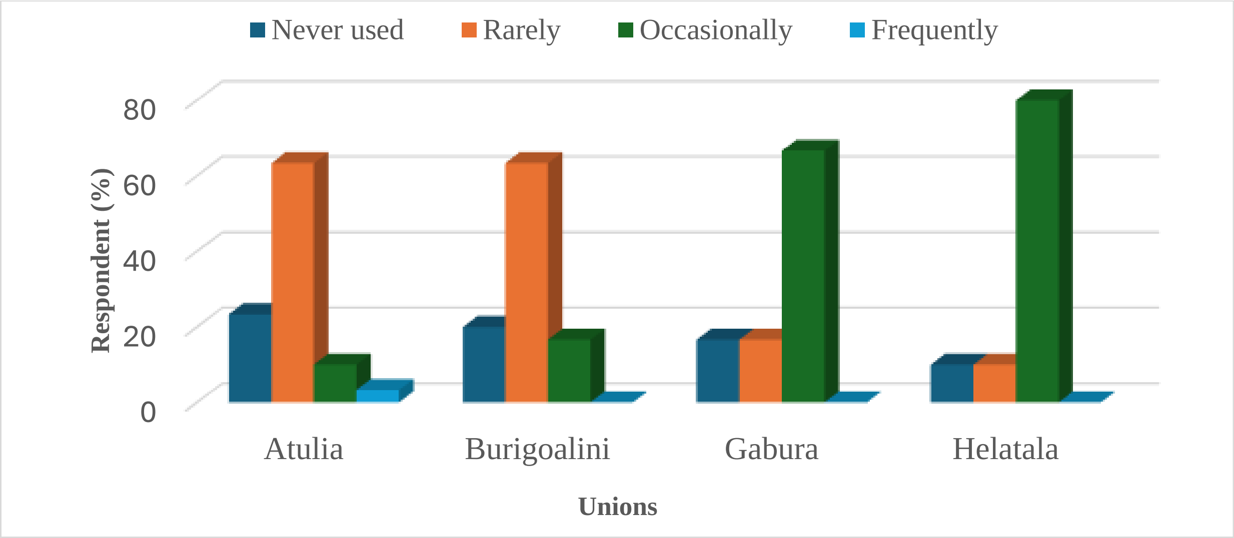

Figure 3.25 Use of Zero tillage at four different unions in the two coastal areas

The frequent use of zero tillage was reported at a minimal percentage, with the highest percentage found in Helatala (30.00%), indicating that this method is not commonly adopted as a regular practice (Tan et al., 2017).

Additionally, never used was most common in Atulia (63.33%), followed by Burigoalini (40.00%), and Gabura (30.00%). The data show that zero tillage is not widely used in the region, particularly in saline-prone areas, where farmers are more likely to report rare or occasional use of this technique. The adoption of zero tillage is somewhat limited due to a lack of familiarity with the technique and its effectiveness in improving crop yields in saline soils (Yang et al., 2018).

3.3.6. Alternate Wetting and Drying (AWD)

Alternate Wetting and Drying (AWD) is an irrigation method where rice fields are alternately flooded and allowed to dry during the growing season. This method helps to save water, reduce methane emissions, and increase the efficiency of water use in rice cultivation. It is particularly beneficial in regions where water scarcity or soil salinity is an issue, such as coastal areas affected by salinity.

The primary goal of AWD is to optimize water usage by reducing the amount of time the rice fields remain submerged in water. By implementing this technique, farmers can increase water use efficiency, improve soil health, and enhance crop productivity. AWD also helps reduce waterlogging and the negative impacts of continuous flooding, which can lead to soil degradation over time. In coastal regions with saline soils, AWD can contribute significantly to managing soil salinity by controlling the water table and preventing excessive salt accumulation.

Figure 3.26 A demonstration plot using Alternate Wetting and Drying (AWD)

Extent of use of AWD technique varied between the two coastal study areas (Fig. 3.22). Most respondents from non saline-prone areas reported occasional use of AWD compared to saline areas. Among the four unions, the highest percentage of respondents occasionally using AWD was reported from Helatala (25.00%), followed by Gabura (10.00%) and Burigoalini (10.00%), while the lowest was found in Atulia (3.33%) (**Table 1**).

In contrast, rare use of AWD was reported by 10.00% respondents in Atulia, 10.00% in Burigoalini, and 3.33% in Gabura, while 5.00% in Helatala .

Table 1 Use of AWD at four different unions in the two coastal areas

Extent of use	***Respondent (%) at four different unions***			
	Atulia	**Burigoalini**	**Gabura**	**Helatala**
Never used	96.67	90.00	86.67	25.00
Rarely	3.33	10.00	10.00	10.00
Occasionally	0.00	0.00	3.33	5.00
Frequently	0.00	0.00	0.00	60.00

The frequent use of AWD was reported at a minimal percentage in the study areas, indicating that the method has not yet been widely adopted as a regular practice in the coastal regions. However, there is potential for this technique to be more widely implemented as awareness about its benefits grows (Tan et al., 2017).

Additionally, never used was reported most commonly in Atulia (63.33%), followed by Burigoalini (40.00%) and Gabura (30.00%). The low adoption rates suggest that while AWD is recognized as a water-saving method, its full potential in saline-prone regions remains untapped due to limitations in awareness, access to technology, or other agricultural constraints (Yang et al., 2018).

3.3.7. Adaption of Raised Pit System

A raised pit system is a land management technique used to grow crops on elevated beds or pits that are built above the natural soil surface. This method is particularly beneficial in saline-prone coastal regions, where frequent waterlogging and salinity make conventional cultivation difficult. By planting crops on raised beds or pits, the root zone is kept above the saline water table, helping to reduce salt accumulation around the plant roots.

The main purpose of the raised pit system is to improve drainage, reduce waterlogging, and protect crops from salinity stress. It also helps in better aeration of the root zone and facilitates healthy plant growth. Farmers using this method often achieve better yields in salt-affected areas and during the rainy season when fields are prone to flooding. Raised pits can be combined with organic amendments to improve soil fertility and moisture retention, making them a sustainable option in vulnerable coastal regions.

Figure 3.27 ***A demonstration plot using Raised Pit System***

Extent of use of raised pit system varied between the four study unions (**Table 2**).

Most respondents reported rare use of raised pit systems across the unions. The highest percentage of respondents rarely using raised pits was observed in Gabura (66.67%), followed by Burigoalini (60.00%) and Atulia (53.33%), while the lowest was in Helatala (15.00%). In contrast, never used was reported most in Helatala (75.00%), followed by Atulia (30.00%) and Burigoalini (30.00%), while the lowest was in Gabura (23.33%). Occasional use of raised pits was consistent across the unions, with 10.00% of respondents in each area reporting occasional use.

Table 2 ***Use of Raised pit system at four different unions in the two coastal areas***

Extent of use	***Respondent (%) at four different unions***			
	Atulia	**Burigoalini**	**Gabura**	**Helatala**
Never used	30.00	30.00	23.33	75.00
Rarely	53.33	60.00	66.67	10.00
Occasionally	10.00	10.00	10.00	15.00
Frequently	6.67	0.00	0.00	0.00

Frequent use of raised pit systems was minimal, reported by 6.67% of respondents in Atulia, while no respondents reported frequent use in Burigoalini, Gabura, or Helatala .

These findings indicate that while the raised pit system is recognized as an effective adaptation technique in saline and flood-prone areas, its adoption remains limited. Awareness campaigns, demonstrations, and technical support could help expand its use in coastal Bangladesh, where it can play a vital role in improving soil conditions and crop productivity (Yang et al., 2018; Tan et al., 2017).

3.3.8. Adaption of Relay Cropping

Relay cropping is a farming practice where two or more crops are grown simultaneously or sequentially on the same land during the same growing season. The technique maximizes land use by allowing crops with complementary growth cycles to be cultivated in the same field. Relay cropping is particularly effective in regions with short growing seasons, or where water and land resources are limited, as it optimizes the utilization of available resources without depleting the soil.

The key benefits of relay cropping include improved soil fertility, higher crop productivity, and reduced soil erosion. This method can help farmers grow crops during off-seasons or in between main cropping periods, thereby increasing overall yields. Relay cropping can also help reduce pest buildup by diversifying the crops grown in the same field, which acts as a natural pest control.

Figure 3.28 A demonstration plot using Relay Cropping

The adoption of relay cropping showed significant variation across different unions, as illustrated in the **Fig. 3.29**. A substantial number of respondents from saline-prone areas reported limited use of relay cropping. The highest adoption rates were observed in Helatala (80.00%) and Gabura (76.67%), with a significant proportion of farmers practicing this method regularly. In Helatala, 10.00% of respondents reported frequent use, and 80.00% noted occasional use (Field Survey, 2023). However, Burigoalini (51.67%) and Atulia (46.67%) reported lower percentages of adoption, with most respondents indicating rare use. A notable proportion of respondents in these areas stated they rarely practiced relay cropping due to the challenges posed by soil salinity and limited access to necessary resources or technical knowledge (Dhali et al., 2014).

Never using relay cropping was most common in Gabura (23.33%) and Helatala (20.00%), indicating that some farmers in these regions may still prefer conventional methods or face logistical barriers to adopting relay cropping. Atulia and Burigoalini also showed considerable non-adoption rates, with 33.33% of respondents from Atulia reporting they had never used relay cropping .

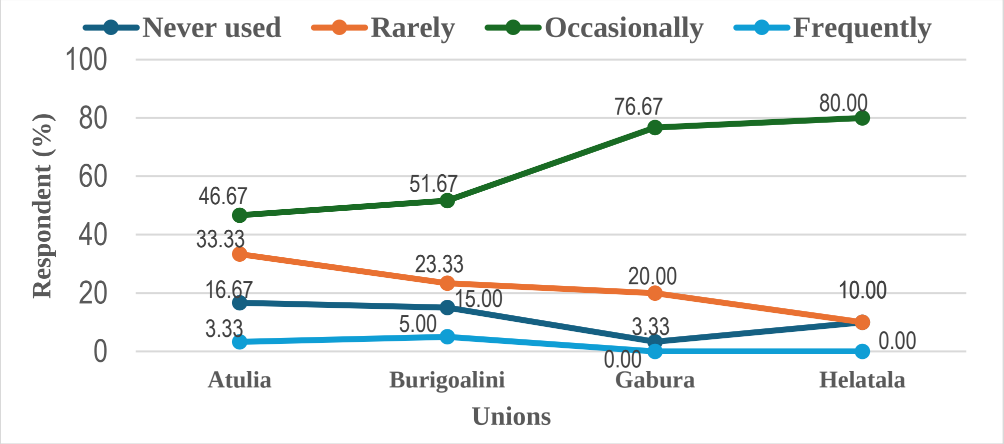

Figure 3.29 Use of Relay cropping at four different unions in the two coastal areas

While relay cropping shows great potential for enhancing land use efficiency, its widespread adoption is still limited by various factors such as lack of awareness, technical knowledge, and resource constraints. Promoting the benefits of this technique through farmer education and access to better agricultural practices could help improve adoption rates, especially in areas where land and water management are critical (Tan et al., 2017; Yang et al., 2018).

3.3.9. Adaption of Dry Seed Bed

The dry seed bed method is a technique where seeds are sown on dry, non-flooded land, typically before the onset of the monsoon or the rainy season. This method is used to reduce waterlogging, prevent salinity stress, and ensure better germination. It is especially effective in areas prone to flooding or salinization, where traditional paddy rice cultivation methods, which require constant flooding, may not be suitable.

By sowing seeds in dry soil, farmers can avoid excessive water, which may hinder seedling growth in saline or poorly drained soils. This technique also reduces water consumption and provides an alternative to flooded fields, thus improving water use efficiency. It has become a useful practice in areas affected by soil salinity and those that are subject to unpredictable water availability, like Bangladesh's coastal regions.

***Figure 3.30* A demonstration plot using Dry Seed Bed**

Data on the use of dry seed beds shows variation across the study areas (**Table 3**).

The majority of respondents from Atulia (60.00%) reported never using the dry seed bed method, indicating that traditional wetland rice farming is still prevalent there. This is likely due to the availability of water or lack of awareness about the benefits of dry seed bed methods (Field Survey, 2023). However, in Helatala and Gabura, 5.00% and 13.33% of the respondents respectively reported occasional use of the dry seed bed method, with frequent use reported by 10.00% in Helatala (Field Survey, 2023). Burigoalini showed non-adoption, with 46.67% of respondents saying they had never used the method. This shows that dry seed beds are still in their early stages of adoption across the study area, despite their potential to improve soil health and crop resilience.

***Table 3* Use of Dry seed bed at four different unions in the two coastal areas**

Extent of use	***Respondent (%) at four different unions***			
	Atulia	**Burigoalini**	**Gabura**	**Helatala**
Never used	60.00	46.67	70.00	85.00
Rarely	26.67	43.33	13.33	10.00
Occasionally	13.33	10.00	16.67	5.00
Frequently	0.00	0.00	0.00	0.00

The rare use of this method in areas like Gabura (13.33%) and Atulia (26.67%) suggests that some farmers may be experimenting with the practice, but it has not yet been widely adopted due to challenges in availability of appropriate resources, technical knowledge, or water management infrastructure.

In conclusion, while the dry seed bed technique shows promise, especially for managing water use and reducing salinity stress, its adoption remains limited in the study areas, with most farmers still relying on traditional practices. Encouraging its wider use through farmer education and access to technical support could help boost its adoption, particularly in areas suffering from salinity and water management issues.

3.3.10. Cultivation of Short duration crop varieties

Short duration crop varieties are cultivars that reach maturity faster than conventional crops. These varieties are particularly useful in areas with limited growing seasons or where climatic challenges like salinity, drought, or waterlogging shorten the planting window. By growing crops that mature earlier, farmers can avoid peak periods of salinity or flooding, harvest before adverse weather, and even fit in an additional crop within the same year.

Such varieties help improve cropping intensity, reduce the risk of total crop loss, and allow farmers to diversify their production. In coastal Bangladesh, where salinity and erratic rainfall often disrupt normal cultivation schedules, short duration varieties have proven to be a practical adaptation strategy.

Figure 3.31 A demonstration plot using Short duration crop varieties

From the study, it is clear that the use of short duration varieties differs widely among the four unions. A large portion of farmers in Burigoalini (83.33%) and Atulia (76.67%) reported occasional use, suggesting these areas are actively experimenting with shorter-season crops to cope with changing conditions **(Table 4).** Interestingly, Gabura shows a strong trend in frequent use, with 40.00% of respondents adopting short-duration crops on a regular basis. This reflects a growing confidence in the benefits of these varieties, likely due to their ability to produce reliable yields despite challenging conditions (Dhali et al., 2014).

In contrast, Helatala had a mixed pattern: 30.00% of respondents reported occasional use, while 65.00% indicated frequent use, making it the highest in terms of regular adoption among all four unions. This demonstrates that farmers in Helatala are more proactive in integrating these varieties into their cropping systems.

Table 4** **Use of of Short duration Crops varieties at four different unions in the two coastal areas

Extent of use	***Respondent (%) at four different unions***			
	Atulia	**Burigoalini**	**Gabura**	**Helatala**
Never used	6.67	0.00	0.00	5.00
Rarely	16.67	10.00	0.00	0.00
Occasionally	76.67	83.33	60.00	30.00
Frequently	0.00	6.67	40.00	65.00

Reports of rare use were relatively modest—16.67% in Atulia and 10.00% in Burigoalini—while never used was almost negligible across all locations, suggesting that awareness of these varieties is widespread, even if adoption rates vary.

Overall, the data show that short duration crop varieties are gaining traction, especially in Gabura and Helatala, where frequent use is higher. This indicates a positive shift toward resilient farming practices that help farmers adapt to salinity stress and limited water availability (Tan et al., 2017; Yang et al., 2018).

3.3.11. Adaption of Floating seed bed

Floating seed bed technology involves preparing seedbeds on water-tolerant floating platforms made of straw, water hyacinth, or other organic material. Seeds are sown on these raised floating beds, which float on the water surface. This practice is especially useful in areas with prolonged waterlogging or recurrent flooding, where conventional soil-based nurseries cannot be established. By using floating beds, farmers can produce healthy seedlings even during the monsoon season and transplant them once the water recedes.

This technique plays a key role in maintaining crop cycles under challenging conditions, reduces the risk of seedling loss, and enables timely sowing, which is critical in coastal regions prone to salinity and waterlogging.

Figure 3.32 A ***demonstration plot using Floating seed bed***

The use of floating seed beds is still limited in most study unions **(Table 5).** A significant portion of respondents reported never using this method, with the highest rates in Helatala (90.00%), followed by Gabura (76.67%) and Burigoalini (63.33%). Even in Atulia, where the adoption is slightly better, 33.33% of respondents said they had never used floating beds .

Those who do experiment with the technique mostly fall into the rare use category. Rare usage was noted by 43.33% of respondents in Atulia, 33.33% in Burigoalini, 23.33% in Gabura, and only 10.00% in Helatala. This pattern suggests that while farmers are aware of floating seed beds, many still rely on traditional practices or have not faced conditions severe enough to adopt them widely (Dhali et al., 2014).

***Table 5** Use of Floating seed bed at four different unions in the two coastal areas*

Extent of use	***Respondent (%) at four different unions***			
	Atulia	**Burigoalini**	**Gabura**	**Helatala**
Never used	33.33	63.33	76.67	90.00
Rarely	43.33	33.33	23.33	10.00
Occasionally	23.33	3.33	0.00	0.00
Frequently	0.00	0.00	0.00	0.00

Occasional use is minimal, reported by 23.33% in Atulia and a small fraction, 3.33%, in Burigoalini, while no respondents in Gabura or Helatala reported occasional use.

Frequent use was not reported in any of the unions, indicating that the technique remains underutilized, possibly due to a lack of materials, technical knowledge, or demonstration of long-term benefits (Tan et al., 2017; Yang et al., 2018).

Overall, while floating seed beds offer a resilient solution for seedling production under waterlogged conditions, their current adoption is low. With proper training and resource support, this method has strong potential to help farmers in flood-prone coastal regions maintain continuous production.

3.3.12. Adjusting planting time

Adjusting planting time refers to modifying the sowing or transplanting schedule of crops to align with favorable environmental conditions. In climate-vulnerable areas like coastal Bangladesh, this strategy helps farmers avoid peak periods of salinity, waterlogging, or drought. By shifting planting dates earlier or later, farmers can reduce risks from seasonal shocks and optimize yields. This technique is low-cost yet highly effective, especially in regions where timing mismatches between rainfall and planting can severely impact crop performance. Adjusting the planting calendar is also helpful in synchronizing crop cycles with available irrigation, minimizing exposure to extreme weather events.

According to the chart, frequent use of this method is noticeably high in most unions. Gabura leads with the highest rate of frequent adoption (90.00%), followed by Burigoalini (66.67%) and Helatala (20.00%). This indicates strong awareness among farmers about the value of strategic planting adjustments **(Fig.3.33).** Occasional users were most common in Atulia (76.67%) and Helatala (80.00%), where farmers may rely on this method seasonally or combine it with other practices. The occasional usage suggests these communities recognize the method's benefits but might not depend on it as a standalone adaptation (Dhali et al., 2014).

On the other hand, rare use was very low across all unions — only 20.00% in Atulia, 3.33% in Burigoalini, and 0% in Gabura and Helatala. Similarly, non-adoption (never used) was nearly negligible, with only 3.33% in Atulia and 0% in the remaining unions, reflecting strong overall acceptance of this method as a key resilience measure (Yang et al., 2018).

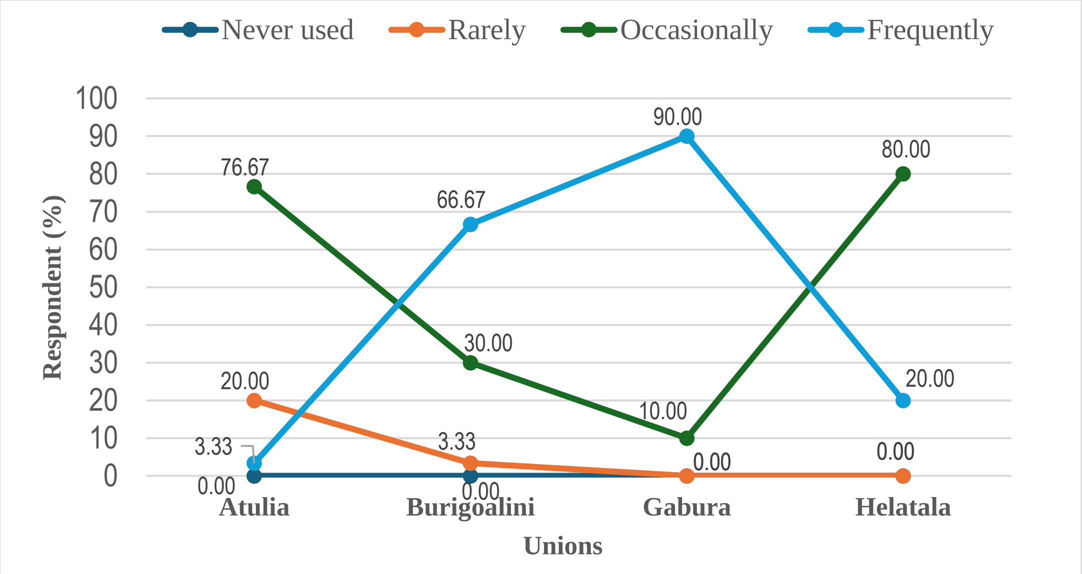

Figure 3.33 Use of Adjusting planting time at four different unions in the two coastal areas

These findings highlight adjusting planting time as one of the most widely adopted and consistently applied adaptive strategies across coastal regions. Its success lies in its simplicity, affordability, and high compatibility with other practices like saline-tolerant varieties or dry seed beds.

3.3.13. Crop Diversification practice

Crop diversification is the practice of growing a variety of crops on the same farm within a single year or over multiple seasons. It is a well-established method to minimize agricultural risks and enhance food security, especially in regions affected by climate variability, salinity, or market instability. This approach enables farmers to spread risk, improve soil health through nutrient rotation, and increase income stability by tapping into diverse market opportunities.

In coastal areas like Satkhira, where salinity intrusion and unpredictable rainfall pose challenges to monoculture farming, crop diversification helps build a more resilient agricultural system. By combining short-duration crops, legumes, vegetables, and salt-tolerant varieties, farmers can better utilize land, reduce dependency on single-crop income, and restore ecosystem balance.

Figure 3.34 ***A demonstration plot using Crop Diversification***

According to the chart, occasional adoption of crop diversification is dominant across all unions. The practice is universally applied in Helatala, where 100.00% of respondents reported using crop diversification on an occasional basis. Similarly, Burigoalini (93.33%), and both Atulia and Gabura (73.33%) also showed strong engagement in occasional usage. This indicates widespread acceptance of crop diversification as a key adaptation technique.

However, when it comes to frequent use, Gabura stands out with 26.67% of respondents adopting crop diversification regularly, suggesting that a notable segment of farmers in this union have fully integrated the method into their production cycles. In contrast, frequent usage in other unions is relatively low—10.00% in Atulia, and only 3.33% in Burigoalini, with Helatala having no respondents reporting frequent use.

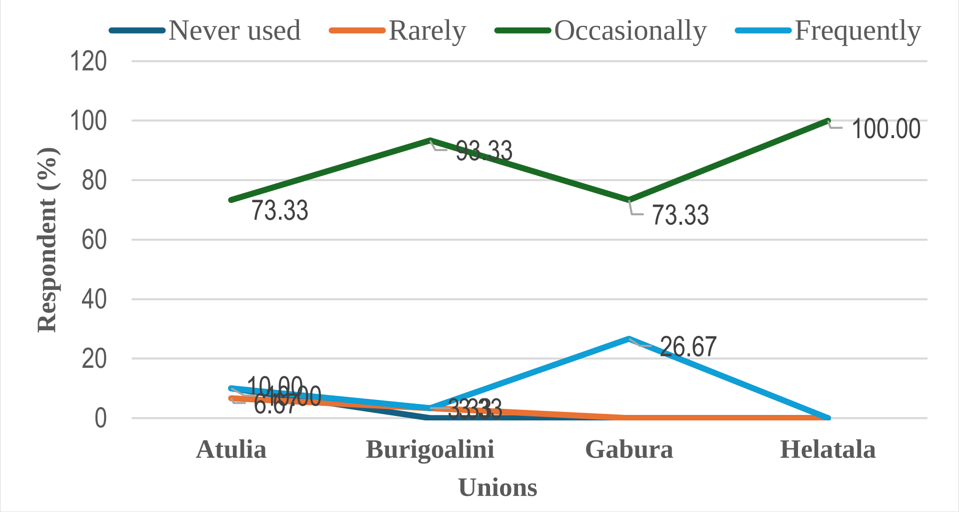

Figure 3.35 Use of Crops diversification at four different unions in the two coastal areas

Rare use was negligible across the board, with the highest being 6.67% in Atulia and just 3.33% in Burigoalini, implying that most farmers are beyond the trial phase and either practice it occasionally or not at all. Non-adoption was reported only in Atulia (10.00%), which may be due to localized constraints like limited landholding. These trends highlight crop diversification as one of the most consistently practiced adaptation strategies in the coastal regions studied. While frequent adoption still varies, its widespread occasional use signals a strong foundation that could be scaled up further through targeted extension services and market support (Tan et al., 2017; Yang et al., 2018).

3.3.14. Adaption of Dike Culture

Dike culture is an integrated farming technique practiced along the raised embankments or dikes of ponds, canals, or shrimp ghers. Farmers utilize these elevated soil strips to grow vegetables, spices, and fruits while the water bodies are used for aquaculture. This method not only ensures optimal use of available land but also creates an additional source of income and improves food security in saline-affected and flood-prone coastal areas.

Dike culture helps reduce dependence on monoculture farming and allows households to practice mixed farming, leading to more efficient use of nutrients and improved resilience to climate stressors. It is particularly effective in areas where horizontal expansion of farming land is not feasible due to waterlogging or shrimp-based aquaculture systems.

Figure 3.36 A ***demonstration plot using Dike Culture***

The survey data indicates that non-adoption of dike culture remains high in several unions. The majority of respondents in Burigoalini (86.67%), Atulia (80.00%), and Gabura (75.00%) reported never using the practice. This shows that despite its proven benefits, the technique is not yet widespread in these areas, likely due to salinity and structural limitations **(Fig.3.37).**

In contrast, Helatala demonstrates a more encouraging trend. 45.00% of respondents here reported frequent use, and an additional 10.00% used it occasionally, making it the most proactive area for adopting dike culture. This may be attributed to better exposure to integrated farming systems, absence of salinity and extension interventions (Dhali et al., 2014).

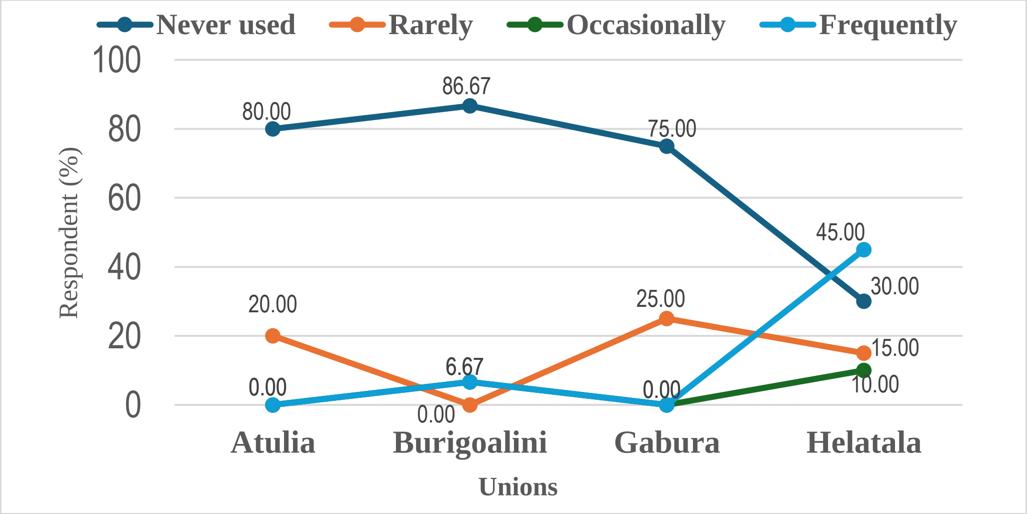

Figure 3.37 Use of Dike cultureat four different unions in the two coastal areas

As for rare use, Gabura (25.00%) leads, followed by Atulia (20.00%) and Helatala (15.00%), while only 6.67% in Burigoalini reported rare engagement. Occasional adoption was lowest across the board, with only Helatala (10.00%) recording this category.

These patterns highlight that while dike culture holds strong potential—especially when practiced alongside aquaculture—it remains underutilized in most unions. With greater training, demonstrations, and support for initial setup, this method could be scaled up as a sustainable, space-efficient solution for enhancing nutrition, income, and climate resilience in coastal farming communities (Yang et al., 2018; Tan et al., 2017).

Chapter 4

Conclusions

4.1 Introduction

This study assessed the socioeconomic characteristics of farming households and the adaptation strategies adopted to cope with salinity-induced stress across four unions—Atulia, Burigoalini, Gabura, and Helatala—located in two coastal zones of Bangladesh. The research aimed to examine how salinity impacts agricultural productivity, livelihood stability, and adaptive responses at the community level. This chapter synthesizes the major findings of the study, provides concluding remarks, and acknowledges the limitations of the research.

4.2 Conclusion

The major findings related to the socioeconomic and adaptive responses of farmers in saline and non-saline coastal areas of Bangladesh are summarized below:

- **Socioeconomic disparities:**
  The study revealed significant differences between saline-prone and non-saline areas. Farmers in Helatala (non-saline) demonstrated higher educational attainment, with 63.33% completing secondary or higher education, compared to only 26.67% in Burigoalini. Income levels were also notably higher in Helatala, where 60% of households earned above BDT 200,000 annually, in contrast to 20% in Atulia and Burigoalini. Non-saline areas also had greater youth participation and diversification of income sources.
- **Salinity-induced agricultural stress:**
  Farmers in saline-prone unions, particularly Gabura and Burigoalini, reported the most severe salinity impacts, including irrigation water scarcity (40%), crop and vegetable damage (50%), and yield reduction during the Rabi season. Waterlogging was found to exacerbate these challenges, particularly in Gabura, disrupting cropping patterns and household livelihoods.
- **Adoption of adaptive strategies:**
  Farmers employed a variety of techniques to mitigate salinity impacts. *Salinity-tolerant*

crop varieties were the most widely used (up to 86.67%), followed by *adjusting planting time* (90% in Gabura, 66.67% in Burigoalini) and *crop diversification* (73–93% occasional use). Practices such as *alternate wetting and drying (AWD)*, *zero tillage*, and *mini pond irrigation* were adopted occasionally (10–25%), while *raised pits*, *dry and floating seed beds*, and *dike culture* remained underutilized due to knowledge and resource constraints. Notably, *dike culture* was frequently practiced only in Helatala (45%).

- **Institutional and technical gaps:**
  Although awareness of adaptive measures is increasing, frequent and systematic adoption remains limited due to financial constraints, insufficient training, and inadequate institutional support. Strengthening agricultural extension services and promoting farmer-led adaptation programs were identified as key pathways to resilience.

In conclusion, salinity continues to be a dominant stressor influencing agricultural productivity and socioeconomic stability in coastal Bangladesh. Addressing these challenges through targeted capacity building, technology dissemination, and policy-level support is crucial to ensure sustainable agricultural development and improved livelihoods for coastal communities.

4.3 Recommendations

Based on the study findings, the following recommendations are proposed to enhance resilience and promote sustainable agricultural practices in coastal saline regions:

- **Strengthen agricultural extension services:**
  Expand and improve farmer outreach programs to provide technical guidance on climate-resilient and salinity-tolerant crop management practices through training, demonstration plots, and mobile advisory services.
- **Promote climate-smart technologies:**
  Encourage the adoption of water-efficient techniques such as alternate wetting and drying (AWD), zero tillage, and mini pond irrigation by ensuring access to affordable inputs, tools, and credit facilities.

- **Develop and distribute improved crop varieties:**
  Continue breeding and dissemination of short-duration and high-yielding salinity-tolerant crop varieties suitable for varying levels of soil salinity and seasonal constraints.
- **Enhance community water management systems:**
  Promote rainwater harvesting, canal re-excavation, and small-scale pond systems to ensure sustainable irrigation sources during the Rabi season.
- **Institutional and policy support:**
  Strengthen coordination among government agencies, NGOs, and local institutions to support adaptive capacity-building initiatives and ensure farmers have equitable access to resources, subsidies, and extension information.
- **Awareness and capacity building:**
  Conduct regular awareness campaigns and participatory workshops to increase farmers' understanding of the long-term benefits of sustainable adaptation strategies and resource management.

Implementation of these recommendations can substantially improve agricultural productivity, promote livelihood security, and enhance the overall resilience of coastal communities against salinity intrusion and climate change.

4.4 Limitations

The study was based on cross-sectional data collected from a single season, which may not fully capture inter-annual variability in salinity and adaptive practices. The sample size, while representative of the study area, limits broader generalization to all coastal regions. Moreover, resource constraints restricted the scope of biophysical measurements, such as soil and water salinity testing, to a few representative locations. Lastly, the study relied primarily on self-reported data, which may include minor recall bias or respondent subjectivity.

Despite these limitations, the findings provide valuable insights into the socioeconomic dynamics, salinity impacts, and adaptive responses in coastal farming systems of Bangladesh, serving as a basis for further policy and research interventions.

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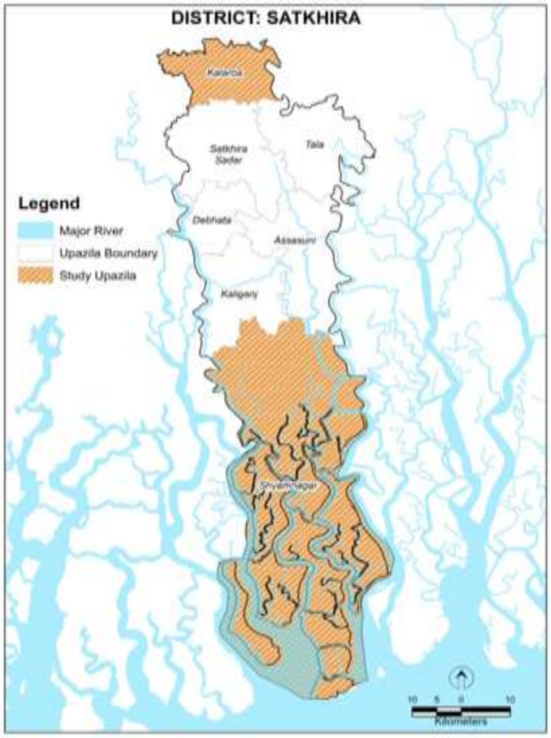
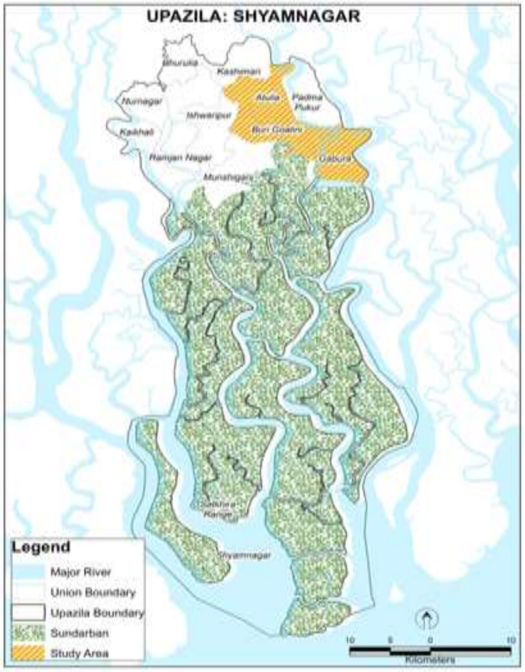
APPENDIX

APPENDIX A





Figures showing study area

APPENDIX B

Figures showing Research activities in study areas

APPENDIX C

An Interview Schedule on

"Impact of Salinity on Food Security in Southwest Coastal Bangladesh : Strategies for Adaptation Methods"

[This information will only be used in research purpose]

Sample No. Date of interview:

Name……………………………Father's/Husband's name:……………………........

Village……………………..Union…………………..Upazila…………………………

District……………………………..Mobile Number…………………………………..

1. Age

How old are you? ....Years

2. Gender

i = Male, ii = Female

3. Educational qualification

i = Illiterate, ii = Only signature, iii = Primary, iv = Class eight, v = SSC, vi = HSC, vii = Graduate viii = Post graduate

4. Family size

How many family members do you have?...........person/persons.

5. Farm size

Please furnish information about your farm size:

Sl. No.	Land type	Area	
		Local unit (Decimal)	Hectare
i.	Homestead area including pond		
ii.	Own land under own cultivation		
iii.	Land given to others as borga		
iv.	Land taken from others as borga		
v.	Land taken from others as lease		
	Total		

6. Annual income

Please mention your yearly family income from the following sources.

Items	Amount (Tk.)
Field crops	
Homestead crops	
Fruit trees	
Timber trees	
Livestock	
Fisheries	
Poultry	
Total	

7. Organizational participation

Please indicate the nature of participation in the following organizations:

Sl. No.	Name of the organization	No participation (0)	Nature of involvement with duration (Year)		
			As ordinary member (1)	As executive member (2)	President / Secretary
i.	Non-Government Organization (NGO)				
ii.	Krishok Samaboy Samity				
iii.	Bazar / Hat Committee				
iv.	Irrigation Committee				
v.	Mosque / Madrasa / School Committee				
vi.	Union Parishad				
vii.	Others (if any)				

8. **Do you have any participation in planning of adaptation technologies to reduce climate change hazards on crop production?**

i. Yes ii. No

9. **Use of adaptation technologies to reduce climate change hazards on crop production**

Please mention the extent of your use of the following adaptation technologies in the last three years (2020-2023) to climate change impacts by putting tick (✓) mark in appropriate column:

Sl. No.	Items of adaptation technologies	Never used (0)	Extent of use		
			Rarely (1)	Occasionally (2)	Frequently (3)
i.	Salinity tolerant crop varieties				
ii.	Sarjon method				
iii.	Mulching				
iv.	Mini pond				
v.	Zero tillage				
vi.	Alternate Wetting and Dry (AWD)				
vii.	Raised pit system				
viii.	Crop rotation				
ix.	Priming of seeds during sowing				
x.	Relay cropping				
xi.	Dry seed bed				
xii.	Short duration crop varieties				
xiii.	Floating seed bed				
xiv.	Adjusting planting time				
xv.	Crop diversification				

10. Do you have any idea about adaptation technology to climate change impacts on sustainable crop production

11. Yes ii. No

11. Where you have heard about climate change adaptation technology? Please tick mark (✓) **as many as you feel apply**

Radio	☐	friends / Family	☐
Television	☐	Television	☐
Internet	☐	Publications	☐
Journal	☐	School / College / University	☐
Government agencies	☐	Others	☐

12. Farming experience

How many years you are engaged with adaptation to climate change impacts on crop production?

Answer………… … (Years)

13. **Have you any idea about Crop Insurance as a major adaptation technology to climate change impacts on sustainable crop production**

12. Yes ii. No

14. **Benefit obtained by using adaptation technologies to climate change impacts on crop production: Please mention the extent of benefit obtained by you by using adaptation technologies to climate change impacts on crop production.**

Sl. No.	Items	Extent of benefit			
		Largely benefited (3)	Moderately benefited (2)	Less benefited (1)	Not at all (0)
	Social benefit				
i.	Development of organizational participation				
ii.	Increased interpersonal skill				
iii.	Development of leadership				
iv.	Increased social participation				
	Economic benefits				
v.	Annual income increased				
vi.	Production cost decreased				
	Technical benefits				
vii.	Improved capacity on new technology implementation				
viii.	Increased crop yield				
ix.	Increased cropping intensity				
x.	Increased crop production and productivity				
	Psychological benefits				
xi.	Positive mental state to adopt new adaptation technology				

15. **Ranked order of the adaptation technologies to climate change impacts on crop production:**

Adaptation Technologies	Importance of your farm				Rank
	High (1)	Medium (2)	Low (3)	No (4)	
Crop Insurance					
Salinity tolerant crop variety					
Sarjon method					
Mini pond					
Zero tillage					
Alternate Wetting and Dry (AWD)					
Raised pit system					
Mulching					
Priming of seeds during sowing					
Relay cropping					
Dry seed bed					
Short duration crop varieties					
Floating seed bed					
Adjusting planting time					
Crop rotation					

16. Which problems faced by you due to climate change impacts?

Sl. No.	Problems	Extent of problems				
		Very high (4)	High (3)	Medium (2)	Low (1)	Not at all (0)
i.	Scarcity of irrigation water					
ii.	Lack of quality seed					
iii.	Insect infestation					
iv.	Lack of proper water drainage system					
v.	Water logging in crop production time					
vi.	Lack of technological information and advice					
vii.	Lack of training					

Thank you for your kind co-operation.

Signature of the interviewer and date