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MORALITY BEFORE KNOWLEDGE

Assessing the effectiveness of climatic information services in reducing disaster loss and damage among marginal farmers

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ABSTRACT

Background: Climate change poses significant challenges to agricultural livelihoods in coastal Bangladesh, particularly for marginal farmers who are highly vulnerable to cyclones, salinity intrusion, irregular rainfall, and rising temperatures. This study assessed the effectiveness of climatic information services (CIS) in minimizing agricultural loss and damage among marginal farmers in Srirampur Union of Dumki Upazila, Patuakhali District, Bangladesh. **Methods**: A mixed-method approach was adopted using both primary and secondary data. Primary data were collected through structured questionnaire interviews with 100 marginal farmers selected through purposive sampling, while secondary data were obtained from relevant literature and published sources. **Findings:** The findings reveal that all respondents observed changes in weather patterns, only 12% were aware of climate change, and only 14% were aware of climatic information services. The study further found that 40% of respondents considered CIS inaccessible, while 60% reported that climatic information was unclear and difficult to understand. Only 8% of farmers fully relied on climatic information for farming decisions, and 32% reported changing farming practices based on climatic information. Furthermore, 95% of respondents experienced crop failure or yield losses due to climatic factors, while 53% perceived climatic information services as ineffective in minimizing loss and damage. The study identified major barriers to the effective utilization of CIS, including low awareness, poor digital access, lack of institutional support, inadequate training, and limited confidence in the reliability of climatic information. **Conclusion**: Based on these findings, the study recommends improving awareness programs, strengthening digital and institutional support systems, enhancing climate education, and developing farmer-friendly climatic information delivery mechanisms. **Novelty/Originality of this article:** This study provides empirical evidence that, despite widespread exposure to climate-related hazards, the utilization and perceived effectiveness of climatic information services among marginal farmers in Coastal Bangladesh remain low because of limited awareness, poor accessibility, inadequate institutional support, and low digital connectivity. The findings identify critical barriers that should be addressed to improve climate information delivery and strengthen farmers' adaptive capacity and resilience.

KEYWORDS: climatic information services (CIS); coastal Bangladesh; disaster risk reduction; marginal farmers; weather information.

1. Introduction

Climate change poses a significant challenge to agricultural systems worldwide,

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and Bangladesh is one of the countries most vulnerable to its adverse impacts on farming communities. In the coastal regions of Bangladesh, where a large proportion of small-scale farmers reside, the impacts of climate change are particularly severe. These areas frequently experience cyclones, floods, saline water intrusion, waterlogging, heavy rainfall, river erosion, storm surges, tidal surges, tornadoes, and droughts (Biswas et al., 2015a; Faisal et al., 2021; Saha et al., 2024; Faisal et al., 2024; Faisal et al., 2026). Such climatic hazards cause significant loss of life, damage to property, reduced agricultural productivity, and severe disruptions to livelihoods, particularly among marginal farmers who already face considerable resource constraints and reside in highly vulnerable coastal environments (Hoque et al., 2019; Saha et al., 2019; Faisal et al., 2025). Marginal farmers, characterized by small landholdings, low income, and limited access to modern agricultural technologies, are highly vulnerable to climate variability and extreme weather events. These challenges continuously threaten crop production, livestock, household income, and food security. As the frequency and intensity of climate-induced hazards continue to increase, identifying effective adaptation strategies for these vulnerable farming communities has become critically important (Biswas et al., 2015b; Warner et al., 2022).

In response to these challenges, the Government of Bangladesh, in collaboration with non-governmental organizations (NGOs) and international development agencies, has introduced various climatic information services (CIS). Climatic information services include the timely dissemination of weather forecasts, climate-related data, and agricultural advisory services aimed at supporting farmers in making informed decisions regarding agricultural practices, resource management, and disaster preparedness (Ouédraogo et al., 2018; Kumar et al., 2021). Several mobile applications have been developed to provide weather forecasts, agricultural advisories, and climate-related information directly to farmers' mobile phones. These applications are generally designed to be user-friendly and accessible in local languages, enabling farmers to receive real-time weather updates and location-specific recommendations related to their farming activities (Antwi-Agyei et al., 2021a). In addition, SMS-based climatic information platforms distribute weather alerts, crop advisories, and other relevant information directly to farmers through mobile text messaging services. This approach is particularly effective in rural areas with limited internet connectivity, allowing remote farming communities to access essential weather information (Friedman et al., 2022). Online climate information portals also serve as centralized platforms that provide access to historical weather data, forecasts, satellite imagery, and climate change projections. These platforms often include interactive tools that help farmers analyze weather conditions, plan agricultural activities, and make informed decisions regarding crop management and resource allocation (Harvey, 2019). Through these multiple communication channels, including traditional media, mobile applications, SMS services, websites, and community networks, climatic information services aim to provide timely, accurate, and relevant information to farmers, thereby reducing climate-related risks and enhancing adaptive capacity (Ouédraogo et al., 2018; Baffour-Ata et al., 2022).

Previous studies consistently demonstrate that climatic information services improve agricultural decision-making and strengthen farmers' resilience to climate variability. However, the reported effectiveness of these services varies considerably across geographical and socio-economic contexts. For example, Ouédraogo et al. (2018) and Antwi-Agyei et al. (2021a) found that timely and localized climate information significantly enhanced farmers' adaptation strategies in West Africa. Similarly, Friedman et al. (2022) emphasized that accessibility, communication quality, and institutional support are critical determinants of effective climate information utilization. In contrast, Baffour-Ata et al. (2022) and Hoque et al. (2019) identified limited literacy, poor infrastructure, weak extension services, and inadequate institutional capacity as major barriers preventing farmers from effectively utilizing climatic information. Collectively, these studies indicate that the success of climatic information services depends not only on information availability but also on the socio-economic, technological, and institutional environment in which farmers operate.

Although previous studies have substantially improved understanding of climate information dissemination and farmers' adaptation practices, three important research gaps remain. First, most existing studies focus primarily on climate information accessibility and adoption rather than evaluating its effectiveness in reducing agricultural loss and damage. Second, relatively few studies have simultaneously examined awareness, accessibility, reliability, trust, institutional support, and farmers' adaptive responses within a single analytical framework. Third, empirical evidence from the highly climate-vulnerable coastal regions of Bangladesh remains limited, despite these areas facing some of the country's greatest climate-related risks. This study addresses these gaps by providing an integrated assessment of the effectiveness of climatic information services and the socio-economic and institutional factors influencing their utilization among marginal farmers in coastal Bangladesh.

This study is conceptually guided by the IPCC Adaptive Capacity Framework, which emphasizes that access to climate information, knowledge, institutional support, technology, and financial resources are essential components of climate adaptation. Climatic information services enhance farmers' adaptive capacity by providing timely and reliable information that supports informed decision-making regarding crop management, disaster preparedness, and resource allocation. However, the effectiveness of these services depends not only on the availability of climate information but also on farmers' ability to access, understand, trust, and utilize that information within their socio-economic and institutional contexts.

This study seeks to address this research gap by critically assessing the effectiveness of climatic information services in practice. The study specifically examines how farmers access, interpret, and utilize climatic information in agricultural decision-making processes. Factors such as literacy levels, access to communication technologies, and the influence of indigenous knowledge systems are also considered in understanding the effectiveness of CIS utilization (Friedman et al., 2022; Ouédraogo et al., 2018). Furthermore, the study evaluates the extent to which climatic information services contribute to reducing agricultural losses and strengthening resilience among marginal farmers. This includes assessing changes in cropping patterns, adoption of climate-resilient agricultural practices, and improvements in disaster preparedness. By identifying both the strengths and limitations of existing climatic information services, the research aims to provide a comprehensive understanding of their practical effectiveness. The study also investigates the socio-economic and institutional factors influencing the successful utilization of climatic information services. These factors may either facilitate or hinder farmers' ability to adopt climate adaptation strategies. Understanding these dynamics is essential for designing more effective, inclusive, and context-specific interventions tailored to the needs of marginal farmers (Muema et al., 2018; Ouedraogo et al., 2022).

Marginal farmers in coastal Bangladesh are highly dependent on climate-sensitive sectors such as agriculture and fisheries, which are critical for national food security and rural livelihoods. Therefore, strengthening their adaptive capacity is essential not only for sustaining agricultural production but also for ensuring broader socio-economic stability (Warner et al., 2022). This study is particularly important because it provides an in-depth evaluation of the challenges faced by marginal farmers in climate-vulnerable coastal regions. By examining the utilization, effectiveness, and barriers associated with climatic information services, the research offers valuable insights into their practical relevance and limitations. Ultimately, the findings of this study are expected to support policymakers, development practitioners, and researchers in designing evidence-based strategies to improve the accessibility, reliability, and effectiveness of climatic information services for marginal farmers in coastal Bangladesh. Strengthening these services can significantly contribute to enhancing agricultural resilience, reducing climate-induced loss and damage, and promoting sustainable rural livelihoods in the face of ongoing climate change (Antwi-Agyei et al., 2021b; Baffour-Ata et al., 2022). Accordingly, this study addresses the following research questions: How effective are climatic information services in minimizing disaster-related agricultural loss and damage among marginal farmers in coastal Bangladesh? What

socio-economic, institutional, and technological barriers limit the effective utilization of climatic information services? What measures can improve the accessibility and effectiveness of climatic information services for marginal farmers? Therefore, the objectives of this study are to evaluate the effectiveness of climatic information services in minimizing disaster-related agricultural loss and damage among marginal farmers and to identify the barriers affecting the effective utilization of these services while proposing recommendations to improve their accessibility and effectiveness in coastal Bangladesh.

2. Methods

2.1 Study area

The study was conducted in Srirampur Union of Dumki Upazila, located in Patuakhali District in the coastal region of Bangladesh (Fig. 1). This area was selected due to its high exposure to climate-induced hazards such as cyclones, storm surges, flooding, and salinity intrusion. The region is predominantly characterized by smallholder agriculture, where most farmers are marginal, possessing limited land, financial resources, and access to modern agricultural technologies. As a result, they are highly dependent on climatic information services (CIS) to support agricultural decision-making. The selection of Srirampur Union provides a representative case for examining the effectiveness of CIS in climate-vulnerable coastal settings.

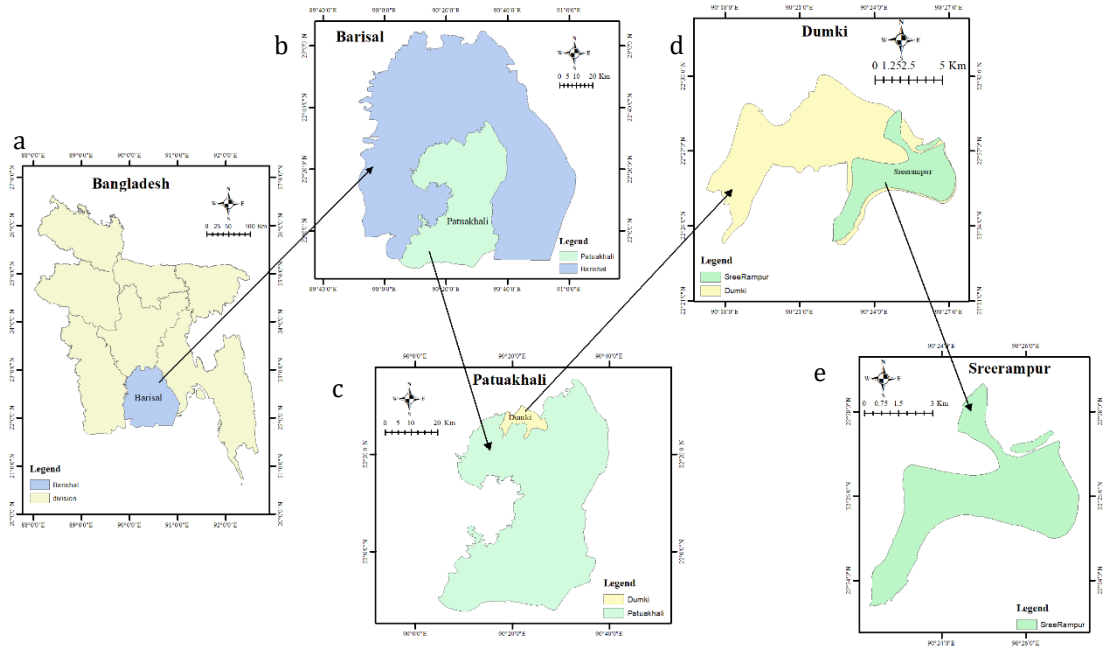

Fig.1. Study area map (a) Shows position of Barisal division in Bangladesh map; (b) Shows Barisal division and position of Patuakhali District in Barisal division map; (c) Shows Patuakhali district and position of Dumki Upazilla in Patuakhali District map; (d) Shows Dumki Upazila and the the position of Srirampur union in Dumki; (e) Shows Srirampur union map

2.2 Research approach

This study was designed as a localized case study to examine the utilization and perceived effectiveness of climatic information services among marginal farmers in Srirampur Union. Purposive sampling was adopted to select respondents who met predefined inclusion criteria, including being a marginal farmer, residing permanently in the study area, and having farming experience. The objective was to obtain in-depth information from a climate-vulnerable farming community rather than to produce statistically representative estimates for all coastal regions of Bangladesh.

This study adopted a mixed-methods approach, integrating both qualitative and quantitative techniques to provide a comprehensive understanding of the research problem. The qualitative component involved a review of relevant literature to establish the conceptual and empirical context of climatic information services and their role in enhancing farmers' adaptive capacity. The quantitative component consisted of structured interviews with marginal farmers to generate empirical data on access to, utilization of, and perceptions regarding CIS. The integration of these approaches enabled triangulation, enhancing the reliability and depth of the findings (Harvey, 2019).

2.3 Research strategy

A cross-sectional research design was employed to capture a snapshot of the current status of climatic information service utilization among marginal farmers. A survey-based strategy was used for primary data collection, allowing for the systematic gathering of standardized information from respondents. This approach facilitated the analysis of patterns related to access, usage, perceived effectiveness, and influencing factors within a defined timeframe. The cross-sectional design was considered appropriate for addressing the study objectives efficiently (Jones, 2015).

2.4 Sample size calculation

The sample size is calculated through the following equation (Suissa & Shuster, 1985): Total population, N = 18530; Confidence level = 95%; Margin of error, e = 10%; 95% level of significance, Z= 1.96; Estimated Proportion of success, Standard Deviation, P =0.5; Estimated proportion of failures, q = (1-p) = 0.5. From the formula, study found the sample size would be 96, but for more justification of the research, the study done 100 household surveys.

$$\text{Sample Size, } n0 = \frac{(z^2 * p * q)}{e^2} = \frac{1.96^2 * 0.5 * 0.5}{0.1^2} = 96.04 = 96 \quad \text{(Eq. 1)}$$

$$\text{Adjusted, } n = \frac{n_0}{1+\left[\frac{n_0-1}{N}\right]} = \frac{96}{1+\left[\frac{96-1}{18530}\right]} = 95.51 = 96 \quad \text{(Eq. 2)}$$

2.5 Data collection and analysis

A purposive sampling technique was employed to select 100 marginal farmers from Srirampur Union, Dumki Upazila. The structured questionnaire was developed following an extensive review of relevant literature on climatic information services, climate change adaptation, and agricultural resilience. Respondents were selected based on predefined inclusion criteria to ensure that participants possessed sufficient farming experience and exposure to climate-related hazards. The inclusion criteria were: ownership or cultivation of marginal agricultural land, active involvement in farming for at least five years, permanent residency in the study area, and willingness to participate voluntarily in the survey. Commercial farmers, landless agricultural laborers, and individuals unwilling to provide informed consent were excluded from the study.

The effectiveness of climatic information services was assessed based on farmers' self-reported perceptions and experiences regarding awareness, accessibility, reliability,

utilization, confidence, behavioral changes, and perceived reduction in agricultural losses. The study did not include objective measurements such as crop yield records or verified economic loss assessments. Prior to the main survey, a pilot study was conducted with 15 marginal farmers from a neighboring union possessing similar socio-economic characteristics. The pilot survey was undertaken to assess the clarity, comprehensibility, and appropriateness of the questionnaire. Based on participant feedback, several questions were revised to improve wording and eliminate ambiguity. Data collected during the pilot survey were not included in the final analysis. The collected data were coded and entered into Microsoft Excel for analysis. Descriptive statistical techniques were applied to summarize the data, and results were presented using tables, bar charts, and pie charts to identify trends and patterns. This approach enabled a clear assessment of the role and effectiveness of climatic information services in supporting farmers' decision-making processes (Paparrizos, 2021).

2.6 Accessibility and study limitations

Efforts were made to ensure that the research process was accessible and inclusive for all participants. The questionnaire was designed in a simple and understandable format, and interviews were conducted in local language at convenient times and locations. Additionally, the findings of the study are intended to be disseminated in accessible formats for key stakeholders, including policymakers, non-governmental organizations, and local communities, to enhance the practical relevance and impact of the research (Antwi-Agyei et al., 2021b).

This study has several limitations that should be considered when interpreting the findings. First, the study was conducted in a single coastal union of Patuakhali District; therefore, the findings may not be fully generalizable to all coastal regions of Bangladesh. Second, the study employed purposive sampling with a relatively small sample size (n = 100), which may limit the statistical representativeness of the results. Third, the analysis relied primarily on self-reported information collected through structured interviews, which may be subject to recall bias and respondents' perceptions. Finally, the study mainly employed descriptive statistical analyses, limiting the ability to establish causal relationships among variables. Future studies should include larger randomly selected samples, multiple study sites, and more advanced inferential statistical techniques to provide a more comprehensive assessment of climatic information services and farmers' adaptive capacities. Furthermore, the assessment of climatic information services was based primarily on respondents' perceptions rather than objective agricultural outcome data. Although perception-based assessments are widely used to evaluate technology adoption and service utilization, future studies should combine perception data with verified crop yield, production, and economic loss information to provide a more comprehensive evaluation of service effectiveness.

2.7 Ethical considerations

Ethical standards were strictly maintained throughout the study. Informed consent was obtained from all participants prior to data collection, ensuring that they were fully aware of the study's objectives, procedures, and their rights, including the right to withdraw at any time. Confidentiality and anonymity were ensured by securely handling personal data and excluding identifying information from analysis and reporting. Interviews were conducted respectfully, with careful attention to minimizing any potential discomfort or harm to participants. These measures ensured the integrity and ethical compliance of the research process (Jones, 2015).

3. Results and Discussion

3.1 Results

3.1.1 Demographic characteristics of respondents

The demographic profile of the respondents provides important insights into their socio-economic conditions and capacity to utilize climatic information services (CIS). Out of the 100 respondents, 79% were male and 21% were female, indicating a male-dominated agricultural workforce in the study area (Table 1). This gender imbalance may influence access to and utilization of climatic information, as women often face additional barriers in accessing agricultural resources and information. The age distribution reveals that the majority of farmers are relatively older. The largest proportion (38%) falls within the 51-60 years age group, followed by 17% each in the 41-50 and 61-70 age categories. Younger farmers are comparatively underrepresented, with only 12% aged between 21-30 years (Table 1). This indicates an aging farming population, which may affect the adoption of new technologies and the effective use of climate-related information services. Educational attainment among respondents is notably low. A substantial majority (84%) have no formal education, while 11% have completed primary education, 4% secondary education, and only 1% higher secondary education. None of the respondents possess tertiary-level education (Table 1).

This low level of literacy may significantly constrain farmers' ability to interpret and apply climatic information, particularly when such information is disseminated through text-based or digital platforms. In terms of farming experience, most respondents are highly experienced. Approximately 41% of farmers have 25-34 years of farming experience, followed by 20% with 35-44 years and 15% with 15-24 years of experience (Table 1). This suggests that although farmers possess substantial practical knowledge, their long-established practices may limit their willingness or ability to adopt new, climate-informed agricultural strategies. Crop cultivation patterns indicate a degree of diversification among farmers. As farmers were allowed to report more than one cultivated crop, the percentages for this variable exceed 100%. Dal was the most commonly cultivated crop (98%), followed by rice (80%), pepper (43%), corn (9%), nuts (8%), and sunflower (7%).

This finding indicates that marginal farmers commonly practice crop diversification to reduce production risks associated with climate variability and improve household food security. (Table 1). This diversification strategy may help reduce vulnerability to climate risks by spreading production across different crop types. Income levels among respondents are generally low. The majority (78%) earn between BDT 1,000 and 5,000 per month from farming, while the remaining 22% earn between BDT 5,000 and 10,000 (Table 1). Such low income levels limit farmers' capacity to invest in improved technologies, inputs, and adaptive practices, thereby increasing their vulnerability to climate-related shocks. Regarding livelihood diversification, 68% of respondents rely solely only one income source, whereas 32% have alternative income sources. The lack of diversified income streams further increases financial vulnerability, particularly in the event of crop failure or adverse climatic conditions. All respondents (100%) reported experiencing changes in weather patterns, highlighting the widespread perception of climate variability in the study area. The most commonly observed change is an increase in temperature, reported by 84% of farmers. Additionally, 15% of respondents noted changes in rainfall patterns, including irregular rainfall and prolonged dry periods. Only 1% reported an increase in the frequency and intensity of storms or cyclones, and none identified sea-level rise as a direct concern (Table 1).

These findings suggest that rising temperatures and changing rainfall patterns are the most immediate and perceptible climatic challenges affecting farmers. Despite limited formal awareness of climate change as a concept, farmers are directly experiencing its impacts. This underscores the importance of delivering accessible and context-specific

climatic information services to support informed decision-making and enhance adaptive capacity among marginal farmers.

Table 1. Socio-demographic information of the respondents (Frequency, N = 100)

Variable	Values	Percentage (%)
Gender	Male	79
	Female	21
Age profile	21-30 years	12
	31-40 years	15
	41-50 years	17
	51-60 years	38
	61-70 years	17
	71-80 years	1
Educational Status	No formal education	84
	Primary Education	11
	Secondary Education	4
	Higher Secondary Education	1
	Tertiary Education	0
Farming Experience	5-14 years	13
	15-24 years	15
	25-34 years	41
	35-44 years	20
	45-55 years	11
Monthly Income (BDT) from Farming	1000-5000	78
	5000-10000	22
Alternative Income Source	Yes	32
	No	68
Main crops cultivated	Rice	80
	Dal	98
	Pepper	43
	Corn	9
	Nuts	8
	Sunflower	7
Changes in weather patterns observed	Yes	100
	No	0
Specific Changes Observed (Single Option Answer)	Increased Temperature	84
	Changes in Rainfall Patterns	15
	Increase the Frequency and Intensity of Storms/Cyclones	1
	Rising Sea Levels	0

Note: Multiple responses were permitted for this variable; therefore, percentages exceed 100%

3.1.2 Evaluation of the effectiveness of climatic information services

3.1.2.1 Awareness of climatic information services

The findings indicate a low level of awareness regarding climatic information services (CIS) among marginal farmers. Only 14% of respondents reported being aware of CIS, whereas 61% stated that they were not aware of such services. In addition, 25% of farmers were uncertain about their existence or purpose. These results suggest that the majority of farmers have limited exposure to climate-related advisory services. Low awareness significantly limits the potential benefits of CIS, as farmers who are unaware of these services are unlikely to utilize climate information in their agricultural decision-making processes. Since climatic information services can support farmers in preparing for adverse weather conditions, reducing crop losses, and improving resilience, increasing awareness through community outreach, agricultural extension programs, and local communication channels is essential.

3.1.2.2 Reliability rating of climatic information services

Respondents expressed mixed opinions regarding the reliability of climatic information services. Among the surveyed farmers, 35% considered the services unreliable, while 25% remained neutral. In contrast, 30% rated the services as reliable, and 10% perceived them as very reliable. Notably, none of the respondents classified the services as very unreliable (Fig. 2). These findings indicate that although a portion of farmers trust the information provided through CIS, a considerable number remain skeptical about its accuracy and usefulness. Such uncertainty may reduce farmers' willingness to rely on climatic information when making farming decisions. Enhancing the accuracy, timeliness, and consistency of weather forecasts and advisory services could improve farmers' confidence and encourage greater utilization of CIS.

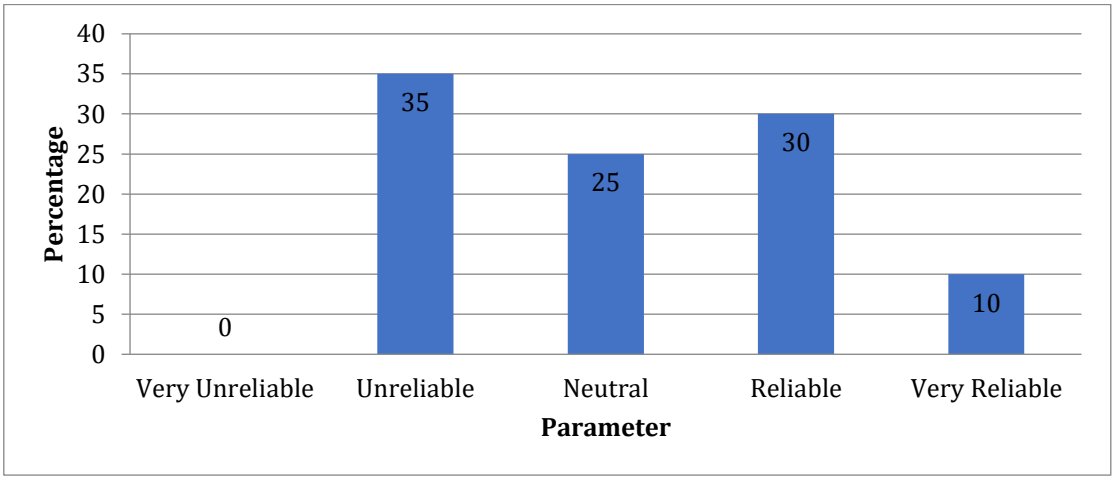

Fig. 2. Reliability rating of climatic information services

3.1.2.3 Accessibility rating of climatic information services

The results reveal significant challenges regarding the accessibility of climatic information services. Only 7% of respondents considered the services very accessible, while 13% rated them as accessible. A substantial proportion (35%) expressed neutral opinions, indicating neither satisfaction nor dissatisfaction with accessibility. However, 40% of respondents reported that the services were inaccessible, and an additional 5% considered them very inaccessible (Fig. 3). These findings suggest that many farmers face barriers in accessing climate-related information. Limited access may result from inadequate communication infrastructure, lack of technological resources, poor dissemination systems, or low literacy levels. Improving the accessibility of CIS through mobile-based platforms, local extension services, and community-based communication systems could help farmers receive timely information and make more informed agricultural decisions.

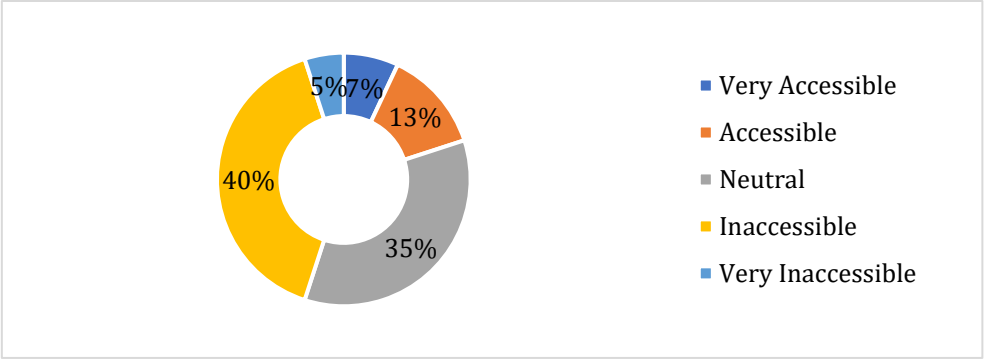

Fig. 3. Accessibility rating of climatic information services

3.1.2.4 Clarity of climatic information services

The responses indicate varying perceptions regarding the clarity of climatic information services. Approximately 12% of farmers reported that the information was very clear, while 28% considered it somewhat clear. In contrast, 30% stated that the information was unclear, and 40% were uncertain about its clarity and usability (Fig. 4). The findings suggest that many farmers experience difficulties understanding or interpreting climatic information. This may be linked to low literacy levels, technical language used in forecasts, or insufficient explanation of climate advisories. Improving the simplicity, language, and presentation of climatic information could enhance farmers' understanding and increase the practical usefulness of these services in agricultural planning and disaster preparedness.

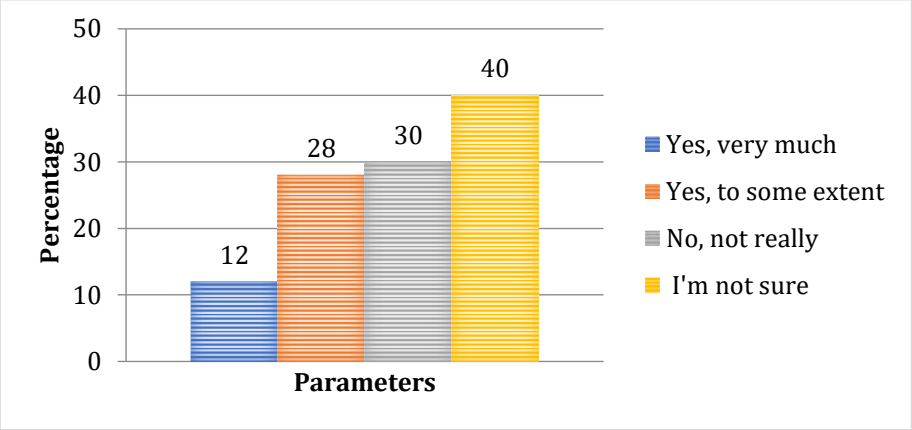

Fig. 4. Clarity and accessibility of climatic information services

3.1.2.5 Knowledge of climate change and its impact on farming

The study findings reveal moderate to low levels of knowledge regarding climate change and its impacts on agriculture among respondents. None of the farmers rated their knowledge as "Very High." Only 12% considered their knowledge to be "High," while the majority (60%) reported a neutral level of understanding. Additionally, 28% rated their knowledge as low, and no respondents identified their knowledge as "Very Low" (Fig. 5). These results indicate that although farmers are experiencing the effects of climate variability, many lack a comprehensive understanding of climate change and its implications for agricultural production. Limited knowledge may reduce farmers' ability to adopt effective adaptation strategies and utilize climatic information efficiently. Therefore, awareness campaigns, farmer training programs, and agricultural extension activities are necessary to improve climate literacy and strengthen adaptive capacity among marginal farmers.

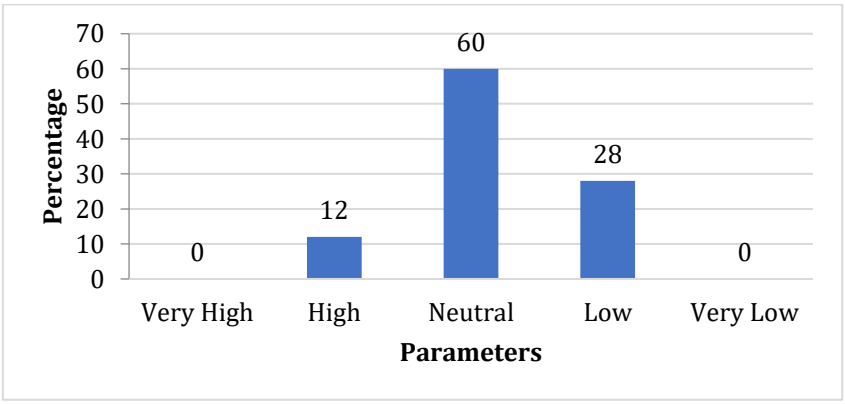

Fig. 5. Knowledge rating about climate change and its impact on farming

3.1,2.6 Activeness in seeking information and updates related to climate change and agricultural practices

The findings indicate that the majority of farmers are not actively engaged in seeking information related to climate change and improved agricultural practices. Only 5% of respondents reported that they frequently seek such information, while 20% do so occasionally. In contrast, 40% rarely seek climate-related information, and 35% never attempt to access such updates (Fig. 6). These results suggest a low level of proactive information-seeking behavior among marginal farmers. Limited engagement with climate and agricultural information may reduce farmers' capacity to adapt to changing environmental conditions and adopt improved farming practices. Increasing farmers' motivation and opportunities to access relevant information through extension services, training programs, and community-based awareness campaigns could strengthen their adaptive capacity and improve agricultural resilience.

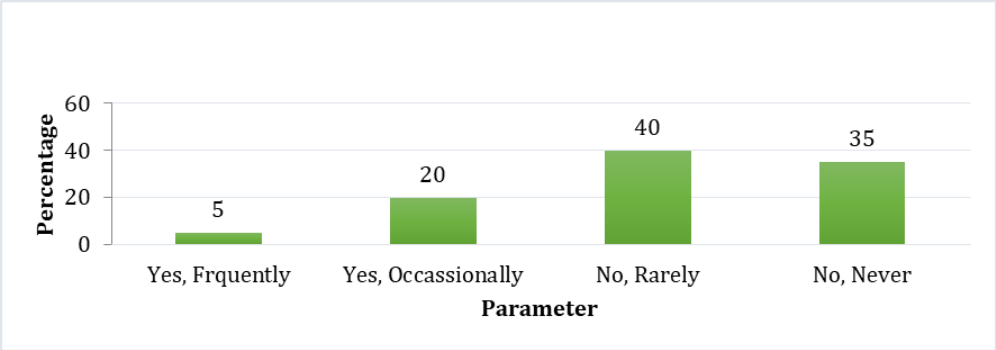

Fig. 6. Activeness in seeking information and updates related to climate change and agricultural practices

3.1.2.7 Understanding of climatic information

The study findings reveal varying levels of understanding of climatic information among respondents. Only 5% of farmers reported a very good understanding of climatic information, while 21% indicated that they understand it well. Additionally, 27% demonstrated a moderate level of understanding. However, the largest proportion of respondents (47%) reported having a poor understanding of climatic information. None of the respondents identified their understanding as very poor (Fig. 7). These findings indicate that although a small proportion of farmers can effectively interpret climate-related information, the majority have limited comprehension. Poor understanding of climatic information may restrict farmers' ability to make informed decisions regarding crop planting, irrigation, harvesting, and disaster preparedness. Strengthening farmers' climate literacy through targeted training, simplified communication methods, and agricultural extension support could improve the practical application of climatic information in farming activities.

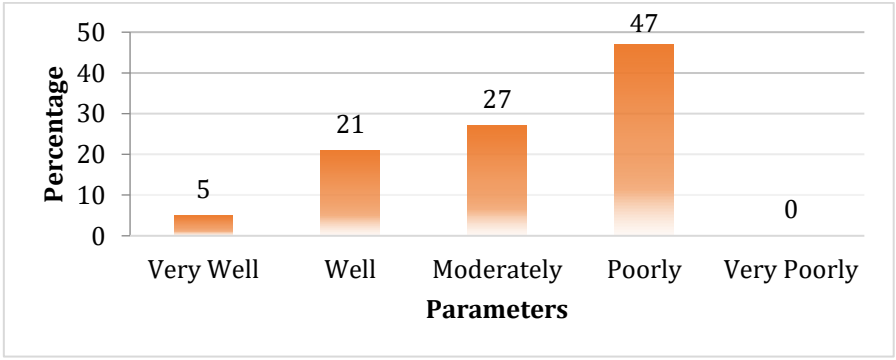

Fig. 7. Understanding of climatic information

3.1.2.8 Clarity and comprehensibility of climatic information

The responses demonstrate that many farmers face difficulties understanding climatic information provided through existing services. Only 8% of respondents stated that the information is very clear and easy to understand, while 12% considered it somewhat clear. In contrast, 20% reported that the information is unclear, and a substantial majority (60%) indicated that the information is not clear at all (Fig. 8). These findings highlight significant communication gaps in the delivery of climatic information services. Technical terminology, complex presentation formats, and low literacy levels among farmers may contribute to difficulties in understanding climate advisories. Improving the simplicity, language, and presentation of climatic information could enhance farmers' comprehension and increase the effectiveness of these services in supporting climate-resilient agricultural practices.

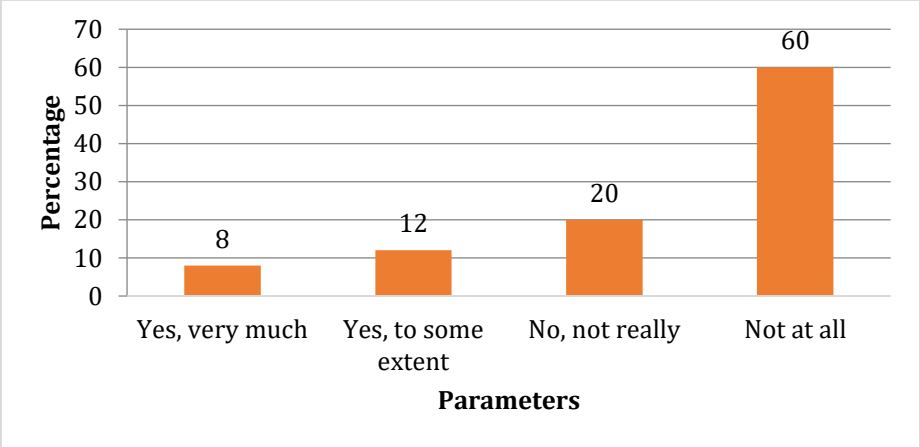

Fig. 8. Clarity and comprehensibility of climatic information

3.1.2.9 Changes made in farming practices based on climatic information

The findings indicate that only a minority of farmers have modified their farming practices based on climatic information. Among the respondents, 32% reported making changes in their agricultural practices, while the majority (68%) stated that they had not adopted any changes. This suggests that although some farmers are utilizing climatic information to adapt their farming activities, large proportions are either unable or unwilling to translate climate information into practical action. Limited understanding, lack of trust in the information, financial constraints, and inadequate extension support may contribute to the low adoption of climate-informed agricultural practices. Encouraging greater utilization of climatic information services and promoting practical adaptation strategies could improve farmers' resilience to climate-related risks.

3.1.2.10 Effectiveness of adaptation measures in reducing loss and damage

The results reveal mixed perceptions regarding the effectiveness of adaptation measures in reducing climate-related loss and damage. Approximately 32% of respondents believed that adaptation measures are effective, whereas 15% considered them ineffective. However, the majority of farmers (53%) were uncertain about their effectiveness. These findings suggest that many farmers lack confidence in existing adaptation strategies or have insufficient experience to evaluate their outcomes. The high level of uncertainty may be associated with limited awareness, inadequate technical support, or inconsistent results from adaptation practices. Strengthening farmer training programs, improving access to practical adaptation knowledge, and providing demonstration-based learning opportunities could increase farmers' confidence in adaptation measures and enhance their capacity to reduce climate-related risks.

3.1.2.11 Reliance on climatic information for decision-making in farming activities

The findings reveal a low level of reliance on climatic information for agricultural decision-making among respondents. Only 8% of farmers reported fully relying on climatic information services, while 20% stated that they partially rely on such information. In contrast, 40% indicated minimal reliance, and 32% reported not using climatic information at all in their farming decisions (Fig. 9). These results suggest that most farmers are not effectively integrating climatic information into agricultural planning and management. Limited reliance on climatic information may reduce farmers' ability to make informed decisions regarding planting, irrigation, harvesting, and disaster preparedness. Factors such as limited accessibility, poor understanding, and lack of confidence in the information may contribute to the low utilization rate. Strengthening awareness, improving the quality of information delivery, and enhancing trust in climatic information services could encourage greater use of climate information in farming activities.

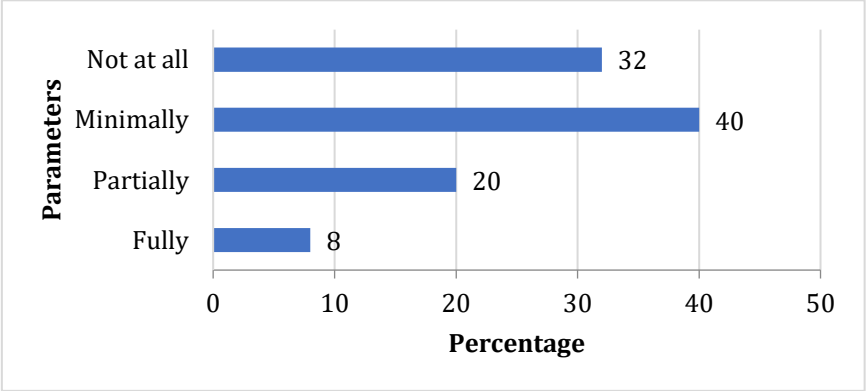

Fig. 9. Reliance on climatic information for decision-making in farming activities

3.1.2.12 Experience with crop failure or yield losses due to climatic factors

The study findings indicate that climate-related factors have significantly affected agricultural production in the study area. A substantial majority of respondents (95%) reported experiencing crop failure or yield losses due to climatic factors, while only 5% stated that they had not faced such problems. These findings demonstrate the high vulnerability of marginal farmers to climate variability and extreme weather events. Crop losses directly affect household income, food security, and overall livelihood sustainability. The widespread occurrence of climate-induced agricultural losses highlights the urgent need for effective adaptation strategies and improved climatic information services to support risk reduction and climate-resilient farming practices.

3.1.2.13 Effectiveness of climatic information services in minimizing loss and damage

The results reveal generally negative perceptions regarding the effectiveness of climatic information services in reducing agricultural loss and damage. Only 6% of respondents considered the services very effective, while 10% rated them as effective. Approximately 27% remained neutral regarding their effectiveness. However, the majority of respondents perceived the services negatively, with 53% considering them ineffective and 4% rating them as very ineffective (Fig. 10). These findings indicate that climatic information services are currently not meeting the expectations or practical needs of many farmers. Poor accessibility, limited clarity, lack of trust, and inadequate understanding may reduce the effectiveness of these services in supporting adaptation and risk reduction. Enhancing the accuracy, relevance, and user-friendliness of climatic information, along with strengthening extension support and farmer training, could improve the practical value of these services.

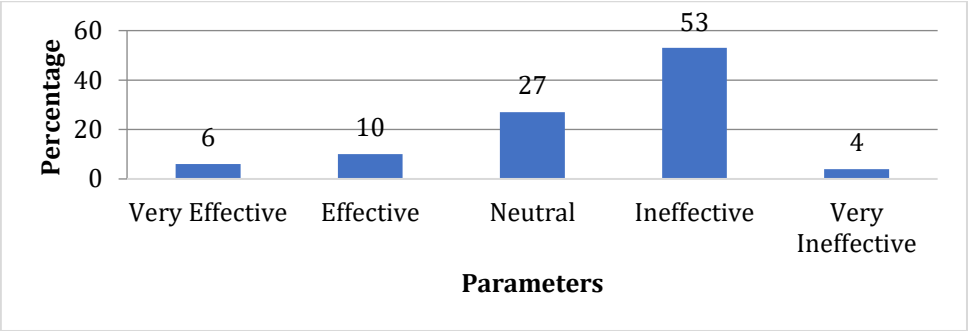

Fig. 10. Effectiveness of climatic information services in minimizing loss and damage

3.1.2.14 Reduction in agricultural losses since utilizing climatic information

The findings suggest limited perceived impact of climatic information services on reducing agricultural losses. Only 6% of respondents reported a reduction in losses after utilizing climatic information, whereas 15% stated that they had not observed any reduction. A large majority of respondents (79%) were uncertain about whether climatic information had contributed to minimizing losses. The high level of uncertainty indicates that many farmers are unable to clearly assess the benefits of climatic information services. This may result from irregular use of climate information, limited understanding of adaptation practices, or the absence of measurable improvements in agricultural outcomes. Improving communication regarding the practical benefits of climatic information and providing demonstration-based training may help farmers better understands its role in reducing agricultural risks and losses.

3.1.2.15 Confidence in the reliability of information provided by climatic information services

The results indicate low levels of confidence among farmers regarding the reliability of climatic information services. Only 2% of respondents reported being very confident in the information provided, while 21% expressed confidence. Additionally, 13% remained neutral regarding their level of trust. In contrast, the majority of respondents (61%) stated that they were not confident in the information, and 3% reported having no confidence at all (Fig. 11). These findings suggest that trust in climatic information services remains limited among marginal farmers. Lack of confidence may discourage farmers from utilizing climate information in their farming decisions and adaptation planning. Improving the accuracy, consistency, and timeliness of climatic information, along with strengthening communication between service providers and farmers, could help build greater trust and enhance the effectiveness of climatic information services in supporting climate-resilient agriculture.

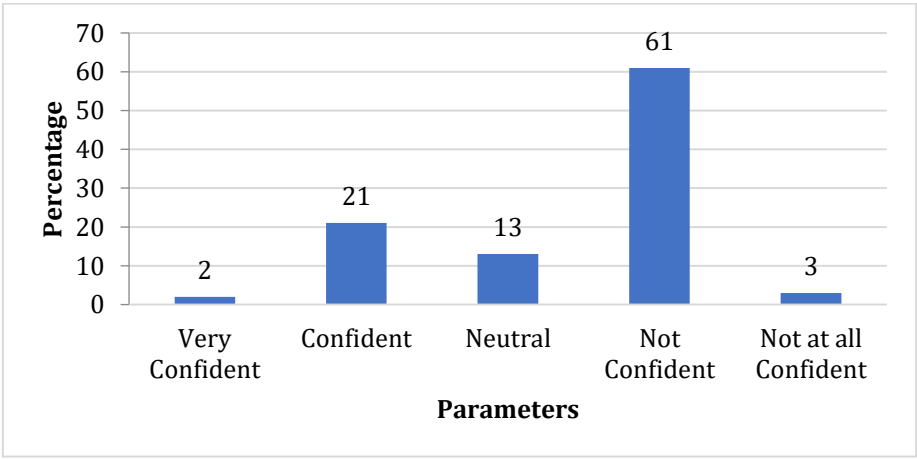

Fig. 11. Confidence in reliability of information provided by climatic information services

3.1.3 Barriers to the successful utilization of climatic information services

3.1.3.1 Awareness of climate change

The findings reveal a very low level of awareness regarding climate change among the respondents. Only 12% of farmers reported that they were aware of climate change, whereas the vast majority (88%) indicated that they had no awareness of the issue. This lack of awareness represents a major barrier to the effective utilization of climatic information services. Without a basic understanding of climate change and its impacts, farmers may be less likely to recognize the importance of climate-related information or adopt adaptation measures. Improving awareness through education programs, community campaigns, and agricultural extension services is essential to enhance farmers' adaptive capacity and preparedness for climate-related challenges.

3.1.3.2 Belief that observed changes are due to climate change

The results indicate that only 19% of respondents believe that the observed environmental and weather changes are caused by climate change. In contrast, 67% do not associate these changes with climate change, while 14% remain uncertain. These findings suggest that although farmers are experiencing changes in temperature, rainfall, and seasonal patterns, many do not clearly understand the underlying causes of these changes. The absence of scientific understanding regarding climate change may limit farmers' willingness to adopt climate-resilient agricultural practices or utilize climatic information services effectively. Therefore, awareness-building and educational initiatives are necessary to improve farmers' understanding of climate change and its impacts on agriculture.

3.1.3.3 Concern about the impacts of climate change on farming activities and livelihoods

The study findings show varying levels of concern among farmers regarding the impacts of climate change on agriculture and livelihoods. Only 2% of respondents reported being very concerned, while 47% expressed concern about the impacts of climate change. Additionally, 35% remained neutral, whereas 14% stated that they were not concerned (Fig. 12). These findings indicate that although a considerable proportion of farmers are concerned about climate-related risks, a substantial number remain indifferent or unconcerned. This may result from limited awareness, lack of information, or the normalization of environmental changes over time. Understanding farmers' perceptions and concerns is important for designing effective adaptation programs and encouraging greater engagement with climatic information services.

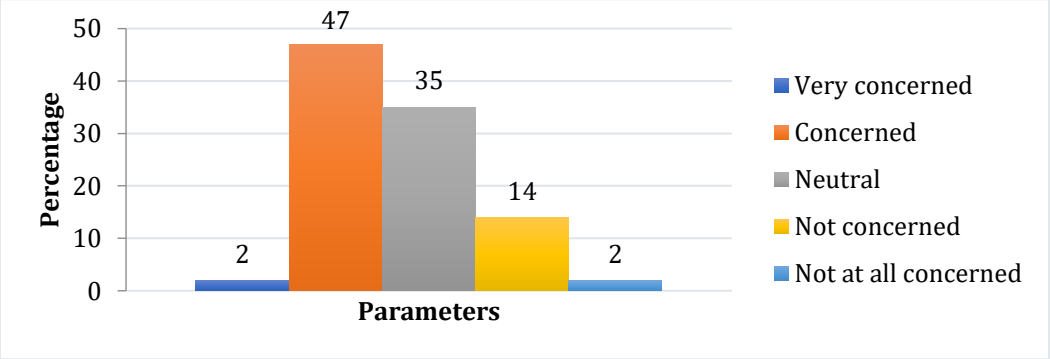

Fig. 12. Concern about impacts of climate change on farming activities and livelihood

3.1.3.4 Membership in local community organizations or cooperatives

The findings reveal very low participation of farmers in local community

organizations or cooperatives. Only 8% of respondents reported being members of such organizations, while the overwhelming majority (92%) were not involved in any local cooperative or community-based group. Low participation in community organizations may reduce farmers' access to shared knowledge, training opportunities, financial support, and collective adaptation strategies. Membership in cooperatives and local organizations can strengthen social networks, improve access to agricultural information, and enhance resilience through collective action. Encouraging greater participation in these organizations could improve farmers' access to climatic information services and support more effective adaptation to climate-related challenges.

3.1.3.5 Participation in formal agricultural training or workshops

The findings indicate limited participation of farmers in formal agricultural training programs and workshops. Only 20% of respondents reported attending such training, whereas 65% had never participated in any formal agricultural training. Additionally, 15% of respondents were uncertain about whether they had attended any related programs. These results suggest that most farmers have limited access to structured agricultural education and capacity-building opportunities. Formal training programs can play a significant role in improving farmers' knowledge of modern farming techniques, pest management, efficient resource utilization, and climate adaptation practices. Limited participation in such programs may reduce farmers' ability to adopt innovative and climate-resilient agricultural practices. Expanding access to training and extension services could therefore enhance agricultural productivity and strengthen farmers' resilience to climate-related challenges.

3.1.3.6 Support or assistance received from governmental or non-governmental organizations

The study findings reveal very low levels of institutional support among respondents. Only 4% of farmers reported receiving assistance from governmental or non-governmental organizations, while the overwhelming majority (96%) stated that they had not received any support. This lack of institutional assistance represents a major barrier to improving agricultural resilience and the effective utilization of climatic information services. Support from government agencies and NGOs can provide farmers with access to agricultural inputs, financial assistance, technical training, climate information, and disaster preparedness resources. The absence of such support may limit farmers' adaptive capacity and increase their vulnerability to climate-related risks. Strengthening institutional outreach and support mechanisms could significantly improve farmers' livelihoods and resilience.

3.1.3.7 Access to internet or smartphones

The findings indicate limited digital connectivity among respondents. Only 10% of farmers reported having access to the internet or smartphones, whereas 90% not access in internet. Limited access to digital technologies restricts farmers' ability to receive timely climatic information, agricultural advisories, market updates, and modern farming knowledge. As many climatic information services increasingly rely on digital platforms, poor internet and smartphone access may significantly reduce farmers' ability to benefit from these services. Expanding digital infrastructure and improving affordable access to mobile technologies could enhance information dissemination and support more effective climate adaptation among marginal farmers.

3.1.3.8 Disruptions faced in receiving climatic information

The study findings show that the majority of farmers experience disruptions in accessing climatic information. Only 13% of respondents reported not facing any problems in receiving climatic information, whereas 87% indicated that they encounter difficulties in

accessing such information. These disruptions may result from poor internet connectivity, inadequate communication systems, limited technological access, or insufficient dissemination channels. Difficulty in receiving timely climatic information can reduce farmers' ability to plan agricultural activities effectively and respond to weather-related risks. Improving communication infrastructure, strengthening local information delivery systems, and enhancing farmers' access to technology are essential to ensure the effective dissemination of climatic information services.

3.1.4 Recommendations for improving the design, delivery, and accessibility of climatic information services

The findings of this study highlight several important areas for improving the effectiveness, accessibility, and utilization of climatic information services (CIS) among marginal farmers in coastal Bangladesh. The recommendations presented below are based on the responses and experiences of the surveyed farmers.

3.1.4.1 Likelihood of recommending climatic information services

The results indicate generally positive attitudes toward climatic information services among respondents. Approximately 16% of farmers reported that they would be very likely to recommend these services to other farmers, while 50% stated that they would likely recommend them. In addition, 34% of respondents remained neutral. Notably, none of the farmers indicated that they were unlikely or very unlikely to recommend climatic information services. These findings suggest that, despite existing limitations in accessibility and effectiveness, many farmers recognize the potential value of climatic information services in supporting agricultural decision-making. Positive user experiences and farmer-to-farmer communication could play an important role in promoting wider adoption of CIS within farming communities.

3.1.4.2 Awareness of available features and functionalities of climatic information services

The findings reveal a low level of awareness regarding the features and functionalities of climatic information services. Only 14% of respondents reported being aware of the available tools and services, whereas 86% indicated that they had little or no knowledge of these features. This lack of awareness limits farmers' ability to fully utilize climatic information for agricultural planning and risk reduction. Climatic information services can provide important information related to weather forecasts, rainfall variability, temperature changes, pest outbreaks, and disaster warnings. Increasing farmers' understanding of these services could significantly improve their adaptive capacity and decision-making processes.

3.1.4.3 Recommendations

Based on the study findings, the following recommendations are proposed to improve the design, delivery, and accessibility of climatic information services for marginal farmers in coastal Bangladesh. Awareness campaigns and educational programs should be implemented to improve farmers' understanding of climate change and the importance of climatic information services. Community workshops, farmer field schools, and educational materials in local languages can help enhance climate awareness and encourage greater utilization of CIS. Access to climatic information should be improved through investments in communication infrastructure, including weather stations, rural mobile networks, and community information centers. Training programs should also be provided to help farmers access, interpret, and apply weather forecasts and climate advisories effectively.

Collaboration among government agencies, non-governmental organizations (NGOs), research institutions, and local community organizations should be strengthened to

improve the dissemination of climatic information. Coordinated efforts can help ensure that information reaches marginalized and climate-vulnerable farming communities more effectively. Farmers should be actively involved in the development and implementation of climatic information services. Community-based initiatives, such as farmer cooperatives, climate adaptation groups, and participatory planning processes, can encourage knowledge sharing and collective adaptation strategies.

Investment in innovative and affordable technologies, such as mobile applications, SMS-based advisory systems, and remote sensing tools, can improve the timeliness and accuracy of climatic information. These technologies should be designed to meet the needs and capacities of smallholder farmers, considering factors such as literacy, affordability, and internet connectivity. Regular training and capacity-building programs should be organized to strengthen farmers' knowledge of climate-resilient agricultural practices. Training topics may include water management, soil conservation, crop diversification, agroforestry, and disaster preparedness to enhance farmers' adaptive capacity and reduce climate-related risks. The effectiveness of climatic information services should be continuously monitored and evaluated through farmer feedback, participatory assessments, and performance reviews. Regular evaluation can help identify gaps and improve service delivery according to farmers' changing needs and local environmental conditions. Overall, implementing these recommendations could significantly improve the effectiveness and utilization of climatic information services, thereby enhancing the resilience and sustainability of marginal farming communities in coastal Bangladesh.

3.2 Discussion

The findings of this study provide important insights into the demographic characteristics of marginal farmers and the effectiveness of climatic information services (CIS) in coastal Bangladesh. The demographic analysis revealed that the majority of respondents were male (79%) and belonged to the 51–60 years age group (38%), indicating an aging and male-dominated farming population. Educational attainment among respondents was extremely low, with 84% of farmers having no formal education, while only 1% had completed higher secondary education. In addition, most respondents had extensive farming experience, with 41% engaged in farming for 25–34 years, and the majority depended solely on agriculture for their livelihoods, as 68% reported having no alternative source of income. These socio-economic conditions may significantly influence farmers' ability to access, interpret, and utilize climatic information effectively. Although all respondents (100%) reported observing changes in weather patterns, only 12% were aware of climate change as a concept, and 67% did not believe that the observed environmental changes were associated with climate change.

This finding highlights a substantial gap between farmers' lived experiences and their scientific understanding of climate variability and climate change impacts. The finding that only 12% of respondents were aware of climate change, despite all respondents reporting noticeable changes in weather patterns, reflects a substantial knowledge gap rather than a lack of environmental experience. This discrepancy may be explained by the very low educational attainment of the study population, as 84% of respondents had no formal education. Limited literacy reduces farmers' opportunities to access scientific information and understand climate-related terminology. Moreover, insufficient climate awareness campaigns, weak agricultural extension services, and limited exposure to climate education programs may have further restricted farmers' understanding of climate change. Similar findings have been reported in Bangladesh and other developing countries, where farmers frequently recognize changes in local weather conditions but do not associate these observations with the broader concept of climate change (Hoque et al., 2019; Antwi-Agyei et al., 2021a). This finding suggests that climate adaptation initiatives should prioritize awareness-building activities alongside the dissemination of climatic information.

The study further revealed that awareness of climatic information services was very limited, as only 14% of farmers were aware of such services, while 61% had no awareness

and 25% remained uncertain. Perceptions regarding the reliability and accessibility of CIS were also mixed. Approximately 35% of respondents considered the services unreliable, 40% reported them as inaccessible, and 60% found the information unclear and difficult to understand. These findings suggest that low literacy levels, technical complexity, and ineffective communication methods significantly restrict the practical effectiveness of climatic information services among marginal farmers. However, previous studies have demonstrated that climatic information services can play a crucial role in reducing agricultural loss and damage. Early warning information regarding floods, droughts, cyclones, and other extreme weather events enables farmers to take preventive measures to protect crops, livestock, and agricultural infrastructure. Such measures may include timely harvesting, adjusting planting schedules, securing farming assets, and implementing soil and water conservation practices (Sultan et al., 2020; Ofoegbu & Ifejika Speranza, 2021; Suckall & Soares, 2022).

In addition, some CIS platforms provide market information and price forecasts, enabling farmers to make informed marketing decisions and improve their economic resilience (Etwire et al., 2017; Ouédraogo et al., 2018). Despite the recognized benefits of climatic information services, the findings of this study indicate a low level of practical utilization among respondents. Only 8% of farmers fully relied on climatic information for agricultural decision-making, while 32% reported modifying their farming practices based on climate information. Furthermore, 53% of respondents perceived climatic information services as ineffective in minimizing agricultural loss and damage, and only 6% reported a reduction in agricultural losses after utilizing such services. Similar studies have shown that access to accurate and timely weather forecasts can help farmers optimize planting, irrigation, and harvesting activities according to prevailing weather conditions, thereby reducing crop losses and improving agricultural productivity (Huq et al., 2015; Naab et al., 2019). Research from various regions also indicates that integrating climate information into agricultural decision-making processes enhances adaptive capacity and strengthens resilience among farming communities (Jones et al., 2015; Bruno Soares et al., 2018; Singh et al., 2018; Jakariya, 2020).

The low level of perceived effectiveness identified in this study may be associated with limited trust in the reliability of climatic information services, as 61% of respondents expressed a lack of confidence in the information provided. In addition, several institutional and infrastructural barriers were identified. Only 8% of farmers were members of local organizations or cooperatives, 4% had received support from governmental or non-governmental organizations, and only 10% had access to the internet or smartphones. Previous studies have similarly reported that inadequate infrastructure, limited internet connectivity, low income levels, lack of access to credit, and poor literacy significantly constrain farmers' ability to access and utilize climate information effectively (Hoque et al., 2019; Antwi-Agyei et al., 2021a). Moreover, 87% of respondents reported disruptions in receiving climatic information, and 65% had never participated in formal agricultural training or workshops. These structural and institutional limitations substantially reduce farmers' capacity to access timely climate information and adopt climate-smart agricultural practices. Despite these challenges, farmers generally demonstrated positive attitudes toward climatic information services. Approximately 66% of respondents indicated that they would likely or very likely recommend CIS to other farmers. This positive perception suggests that farmers recognize the potential benefits of climatic information, even though existing services remain limited in effectiveness and accessibility. Therefore, improving awareness, accessibility, clarity, digital connectivity, institutional support, and farmer training programs could significantly enhance the effectiveness of climatic information services and strengthen the resilience of marginal farmers against climate-related risks in coastal Bangladesh.

Overall, the findings demonstrate that the effectiveness of climatic information services extends beyond the mere availability of weather information. Their successful utilization depends on farmers' awareness, educational background, access to communication technologies, institutional support, and trust in the information provided. Consequently,

improving climatic information services requires an integrated approach that combines technological innovation with farmer education, capacity building, strengthened agricultural extension services, and locally tailored communication strategies. Such interventions are essential for enhancing adaptive capacity and reducing climate-related agricultural losses among marginal farmers in coastal Bangladesh.

4. Conclusion

This study assessed the effectiveness of climatic information services in supporting marginal farmers in coastal Bangladesh to reduce climate-related agricultural loss and damage. The findings indicate that although farmers recognize changes in local weather conditions, the utilization of climatic information services remains limited because of low awareness, inadequate access to climate information, poor digital connectivity, insufficient institutional support, and limited confidence in the reliability of available information. These barriers reduce the potential of climatic information services to strengthen farmers' adaptive capacity and climate resilience. Improving awareness, strengthening agricultural extension services, enhancing digital infrastructure, and delivering locally relevant and easy-to-understand climatic information are essential for increasing the effectiveness of these services. The findings provide valuable evidence for policymakers and development practitioners to strengthen climate information systems and promote climate-resilient agriculture among marginal farmers in coastal Bangladesh.

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Author Contribution
M.F.: conceptualization, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing-review & editing; T.Y.: conceptualization, data curation, formal analysis, methodology, resources, software, validation, visualization, writing-original draft, writing-review & editing; M.K.S.: conceptualization, methodology, writing-review & editing; T.A.: conceptualization, writing-review & editing.

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Informed Consent Statement
Informed consent was obtained from all subjects involved in the study.

Data Availability Statement
Unavailable due to ethical restrictions.

Conflicts of Interest
The authors declare no conflict of interest.

Declaration of Generative AI Use
During the preparation of this work, the author(s) used ChatGPT and Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the author(s) reviewed and edited the content as needed and took full responsibility for the

content of the publication.

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