"Adaptation Strategies of Agricultural Dependent Communities in The Teesta Floodplain Area of Bangladesh: Linking Climate Change and the Water Dispute Issues"

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Executive Summary

This research started on December, 2023 at Independent University Bangladesh. In the later year the research got a fund from International Center for Climate Change and Development. The main focus of this research was to analyze the vulnerability in the Teesta Floodplain area due to climate change and the transboundary river dispute, also the copping mechanism of the community. For that reason, satellite image analysis, qualitative and quantitative data collection from filed are collected. Although after data analysis based on the research findings and the literature reviews a recommended conclusion comes out.

Objectives

- To assess the vulnerability of the agricultural-dependent communities in the Teesta River basin area in Rangpur in the common context of climate change and transboundary water-sharing disputes.
- To identify the adaptation strategies taken by farmers in the Teesta basin area in Rangpur.
- To identify the nature of the adaptation in terms of transformation and sustainability with the changing climatic conditions along with the uncertainty arising from the transboundary water disputes.

Abstract

This study identifies the vulnerability and adaptation strategies of agricultural-dependent communities in the Teesta Floodplain area of Rangpur, Bangladesh, under the simultaneous impacts of climate change and transboundary water-sharing disputes. The Teesta River Basin is highly susceptible to climate-induced changes and anthropogenic water management practices, which exacerbate agricultural challenges. Mixed-methods approach was used in the research for doing the household surveys, key informant interviews, focus group discussions, and GIS-based analysis of land-use changes from 2004 to 2024. Findings aim to reveal the socio-economic impacts on farming communities, evaluate their coping mechanisms, and assess the sustainability of these strategies. This research aims to identify the adaption strategies in the Teesta floodplain area due to the dual threats of climate change and water-sharing disputes. Also, the research identified the transform of different adaptation strategies with sustainability over 20 years.

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1. Introduction

The Teesta River Basin (from now on referred to as TRB) is a transboundary area between India and Bangladesh, later having an area of 2004 square kilometers (I. Khan & Ali, 2019). The river that forms the basin area is perennial, rain and snow-fed rivers originate in the Himalayan region making it susceptible to climate change effects (Krishna, 2011). People living in the basin area downstream of Bangladesh have been facing severe vulnerability due to withdrawal and sudden release of water upstream on the Indian side (Mondal & Islam, 2017). On top of that, climate change has exacerbated the vulnerability condition of people living in the river basin area ("Bangladesh Climate Change Impacts and Vulnerability," 2006). Many studies indicate that precipitation is likely to increase in monsoon along with the increased number of warm days, warm nights, and summer days in the eastern Himalayan region from where the Teesta River originates (Sharma & Goyal, 2020). Hence, the current water dispute between India and Bangladesh regarding the water sharing of the Teesta River will increase the vulnerability of agriculture-dependent communities downstream in Bangladesh in a changing climatic environment (Zannah et al., 2020b). Though several studies have been conducted on the vulnerability of Teesta River communities, they often do not bring water dispute issues into the discussion. Hence this study aims to investigate the vulnerability of agricultural dependent communities in Rangpur district while considering the threats of climate change and the uncertainties arising from the water dispute. The study will also look at the adaptation strategies that the farmers in the region use to survive in a harsh climate.

2. Problem Statement:

The Teesta River Basin (hereinafter referred to as TRB) is a transboundary area between India and Bangladesh, later having an area of 2004 square kilometers (I. Khan & Ali, 2019). People living in the basin area downstream of Bangladesh have been facing severe vulnerability due to withdrawal and sudden release of water upstream on the Indian side (Mondal & Islam, 2017). On top of that, climate change has exacerbated the vulnerability of people living in the river basin area ("Bangladesh Climate Change Impacts and Vulnerability," 2006). Though several studies have been conducted on the vulnerability of Teesta River communities, they often do not bring water dispute issues into the discussion. Hence this study aims to investigate the vulnerability of agricultural dependent communities in Rangpur district while considering the threats of climate change as well as the uncertainties arising from the water dispute.

3. Significance of the study:

The study is significant in understanding the vulnerability due to different climatic issues and the adaptation strategies of the agriculturally dependent community of the Teesta River bank, making the linkage between climate change and the transboundary water-sharing dispute.

4. Literature reviews

The Teesta River, spanning across India and Bangladesh, is profoundly influenced by climate change, which significantly impacts its hydrology and the livelihoods of communities depending on it. Variations in seasonal rainfall, as highlighted by Goyal and Goswami (2018), indicate an increasing trend in monsoon and post-monsoon seasons, particularly in regions such as Kurigram, Kaunia, and Rajarhat, where rainfall increases by up to +11.57 mm/year. Conversely, the pre-monsoon and winter seasons exhibit a decreasing trend in rainfall, except for specific areas like Rajarhat in winter. These fluctuations exacerbate water flow variability, directly influencing agricultural productivity and water resource management (Banerjee, 2010).

The Teesta's elevated and diverse topography intensifies its vulnerability to landslides and flash floods during the monsoon season. The synchronization of flood peaks across the Ganges, Brahmaputra, and Meghna (GBM) rivers under future global warming scenarios, as described by Muhammad et al. (2018), poses a compounded threat to the Teesta Basin. Projected flood flow increases of up to 81% for the Meghna at a 4°C warming scenario highlight the critical risk of severe flooding. Such events threaten the already underdeveloped rural communities reliant on the Teesta River for their livelihoods (Das et al., 2014).

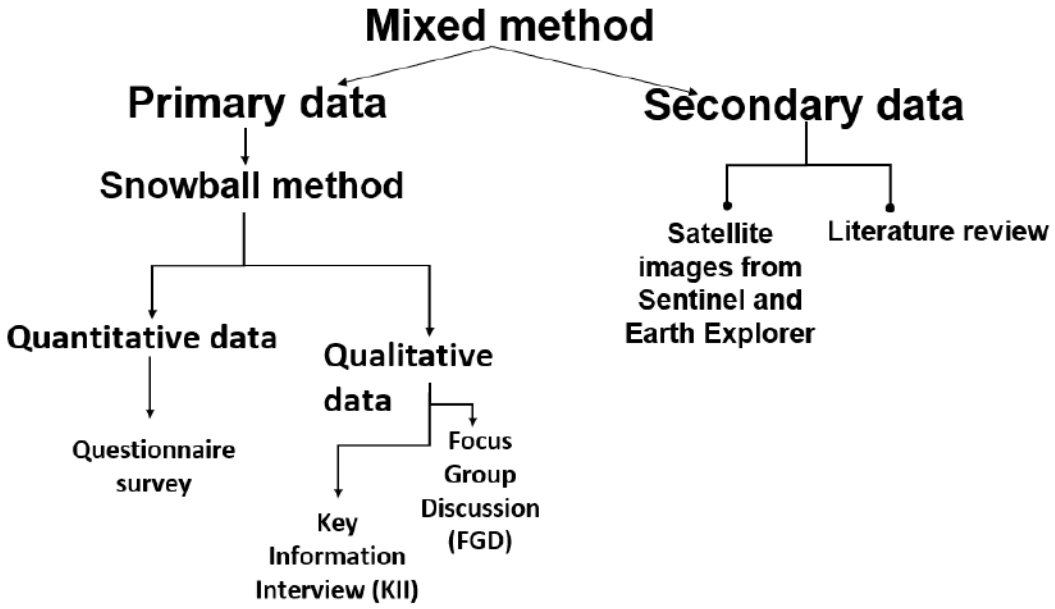
In Bangladesh, where 71% of the Teesta Basin population resides, the increasing frequency and intensity of floods, as well as sporadic cyclonic events, are expected to destabilize agriculture and biodiversity emphasize the necessity of adaptive strategies, including the construction of hydraulic structures and efficient water management practices, to mitigate the adverse impacts. In sum, climate change poses severe challenges to the Teesta River's ecosystem, altering water availability, increasing flood risks, and threatening sustainable development in the region. Coordinated cross-border efforts are critical to ensure resilience against these changes and to safeguard the livelihoods and ecosystems dependent on the river (Mutasim et al. (2015).

5. Study Area: Kaunia is an upazila in the Rangpur district of Bangladesh. From Kaunia the Teesta River is connected to Kurigram and Lalmonirhat district. The Teesta Road Bridge 760m long established in 2012 is a major pathway connecting the Rangpur district with Kurigram and Lalmonirhat is also strategically located in Kaunia (*Teesta Road Bridge*, 2012). The research areas are located in different parts of the Kaunia Upazila and Razarhat Upazila of Kurigram based on the morphological Characteristics of the Teesta River connecting approximately 8.5 km² area. Its coordinates are 25°46'31.479" N, 25°45'21.719" N, and 25°47'9.999" N longitude and 89°26'55.44" E, 89°27'27.195" E, and 89°28'16.399" E latitude (GPS Coordinates --> Latitude and Longitude Finder, n.d.).32.49% people of Kaunia are directly involved in agriculture and 21.56% of people are agricultural laborers (*Kaunia - Wikimapia*, n.d.). The study area is characterized by a monsoon climate dominated as by a semi-arid climate as per superintendent classification and it comes under Agroecological Zone Number-3 (Tista Meander

Floodplain) (*Agroecological Zone - Banglapedia*, n.d.). The unions of Gazirhat, Tepa-Madhupur, and Sarishabari as well as from the upazilas of Kaunia and Razarhat, form its northern, southern, eastern, and western borders respectively selected for the quantitative and qualitative data collection.

6. Methodology

Research Design: The study will employ a mixed-method approach and will use both quantitative and qualitative approaches. Through quantitative approaches, data on the percentage of farmers taking various adaptation strategies will be recorded. In addition, the day-to-day challenges associated with farming related to climate change and transboundary water-sharing issues will also be assessed. To triangulate the findings from quantitative surveys, I will adopt qualitative approaches like key informant interviews. Triangulation will focus on the efficiency of the adaptation strategies, the background information being the process of the adaptation and the overall learning outcomes.



GIS Data Collection & Analysis

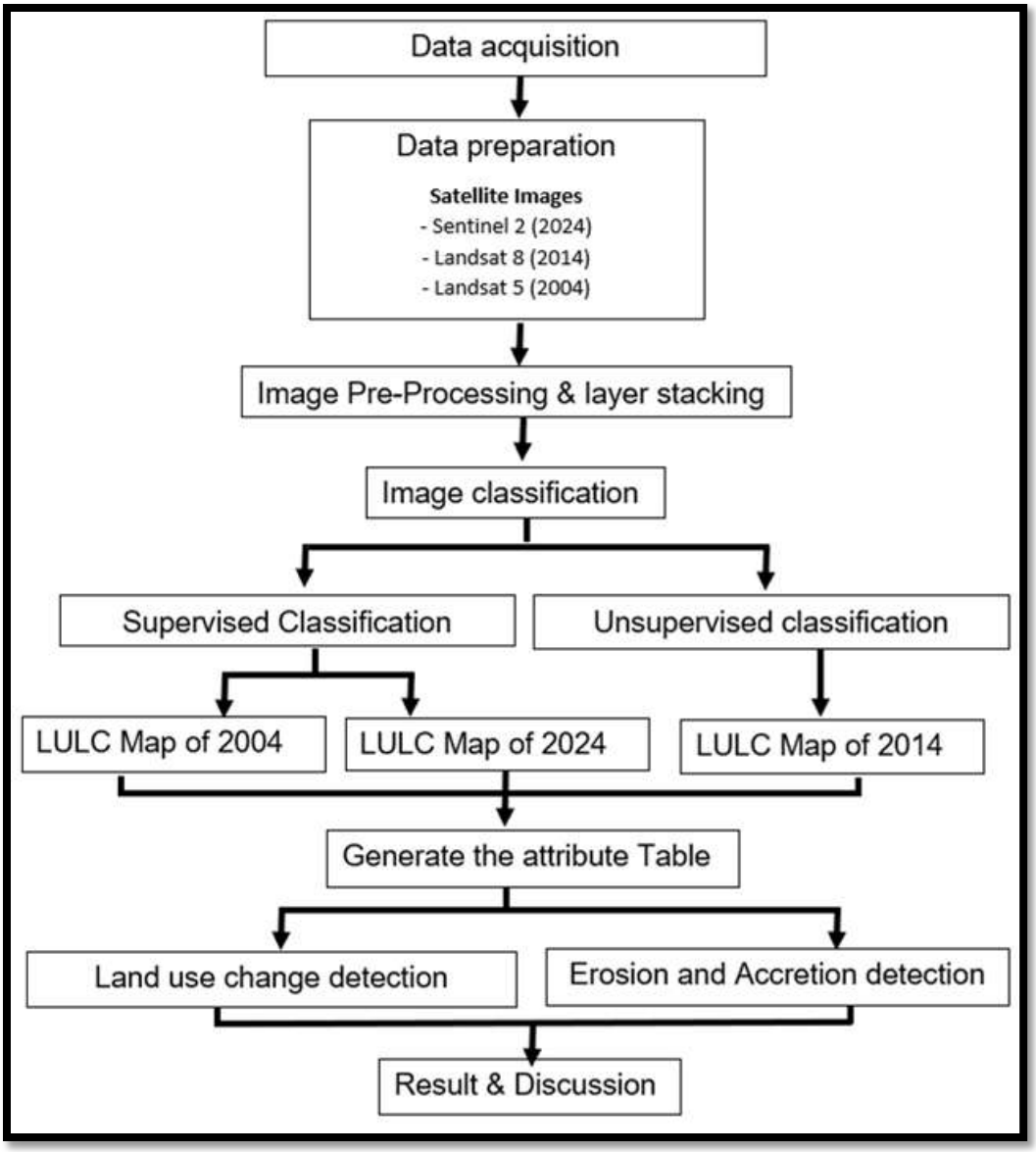
Data Preparation: The methods followed to understand the relation between climate change and land use change in the study area are supervised classification and unsupervised classification. To understand the river shifting three satellite images from 3 different with 10 years gap (from the last 20 years with 10 years intervals) have been used for classification. For supervised classification, satellite image of 2024 is collected from Sentinel 2, Level-2, and for unsupervised classification satellite image of 2014 is collected from Landsat 8, and the satellite image of 2004 is collected from Landsat 5. The research started in January 2024, so the satellite

images are collected during the dry season (October). A shape file of the study area is created to analyze the land-use land cover between 2004-and 2024.

Satellite	Sensor Identifier	Date of Acquisition	Spatial Resolution	Cloud Coverage
Sentinel 2	MSI	2024/02/28	10m	5
Landsat 8	OLI/TIRS	2014/10/31	30m	5
Landsat 5	TM	2004/03/09	30m	5

Image pre-processing and layer stacking

It is important to do pre-processing of the satellite images for analysis and better interpretation. A shape file of the study area is created to analyze the land-use land cover of 2004, 2014, and 2024—first, the clip file is made of all three years, and then the bands were selected based on the satellite sensor. Through band composite, the outcome was different combinations of the true-color composite and false-color composite of the selected study area. For visual interpretation and understanding of the classes of the images pre-processing algorithms and layer, stacking provides better outcomes (Hasan Seyam, 2023).



Sample selection & classification

To ensure the accuracy of the image processing and analysis, the composite picture is then subset into the research area. For the research, it is needed to identify five features from this two-color composite, which are represented by the following classes: "Waterbody," "Char," "Agriculture," "Barren land," and "Natural vegetation". For supervised classification, the classes are selected especially through the fraying sample manager with 5 categories, and then the maximum likelihood classification shows the land use changes data. To ensure the accuracy of the selected features the classification was compared with the band true and false images and based on the found difference reclassification was done. For unsupervised classification, the first ten features were selected and classified more than 3 times, and then after comparing all the unsupervised

data the best one was selected for reclassification, and with that, the five main features were classified through reclassification.

Ground-truthing for accuracy assessment

For ground- truthing we went for a survey in the exact places where we found the most land use changes through classification. After the study area visit, based on the local community's opinions and visual observation we didn't find any big difference in the classified data, and from other secondary sources, the data was assessed multiple times to ensure accuracy.

River erosion and accretion assessment with geographic calculation

To identify the three years (2024, 2014, 2004) of river erosion and accretion first the unchanged area was identified, and then through a geographic calculator the formula below was applied:

Erosion= Previous year river area- Unchanged area

Accretion= Next year river area- Unchanged area (Nayem, 2022)

Sample selection

The total sample size is 150 and through the snowball method, the field data collection has been done. First, we found some community leaders who are leading the agricultural community and from them, through the snowball method, we got to introduce those persons as per our research requirements to conduct KII and FGD (Naderifar et al., 2017).

Primary data collection

Household Surveys: Questioner surveys were conducted among randomly selected 83 people who are primarily dependent on agriculture for their livelihood in Kaunia and among them 51% were male and 49% were female. Data were collected on basic socioeconomic conditions, agricultural practices, monthly or yearly agricultural outputs, market linkage, challenges, and adaptation practices.

Key Informant Interviews: Five Key informant interviews were conducted with local-level experts, an officer of the Department of Agriculture (DAE), one river morphological expert, and local knowledgeable persons. Key information helped to triangulate the data collected from the household surveys.

Focus Group Discussion

Two focus group discussions have been in the research area. The first FGD we did with the young people of the community around 10-12 young male farmers aged 18-35 attended that FGD. In the second FGD, we did with the experienced farmers' age group of 45-60 to understand the historical change in the flood plain area and the socio-economic development in the community over the last 20 years.

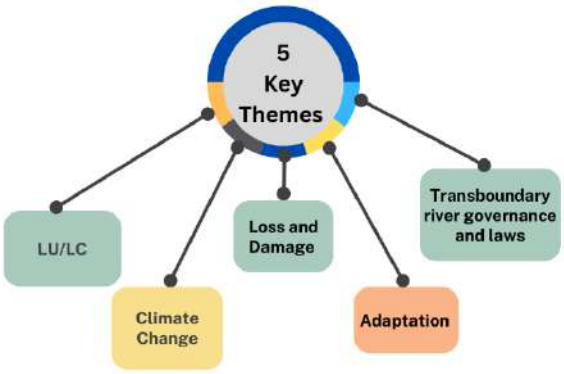
Secondary data collection

The study began with a comprehensive literature review that focused on the intersecting concepts of climate change impacts, agriculture, and transboundary water-sharing issues. The UN Watercourse Convention and other international policy documents related to transboundary river management were thoroughly reviewed. A scoping review helped to compile and identify the climate change scenario at both the local and regional scales and its relation to managing water resources in the Teesta River. An analysis of documents from various projects undertaken to support agriculture in Bangladesh's Teesta River basin area was also reviewed.

Data analysis

Field Data Analysis

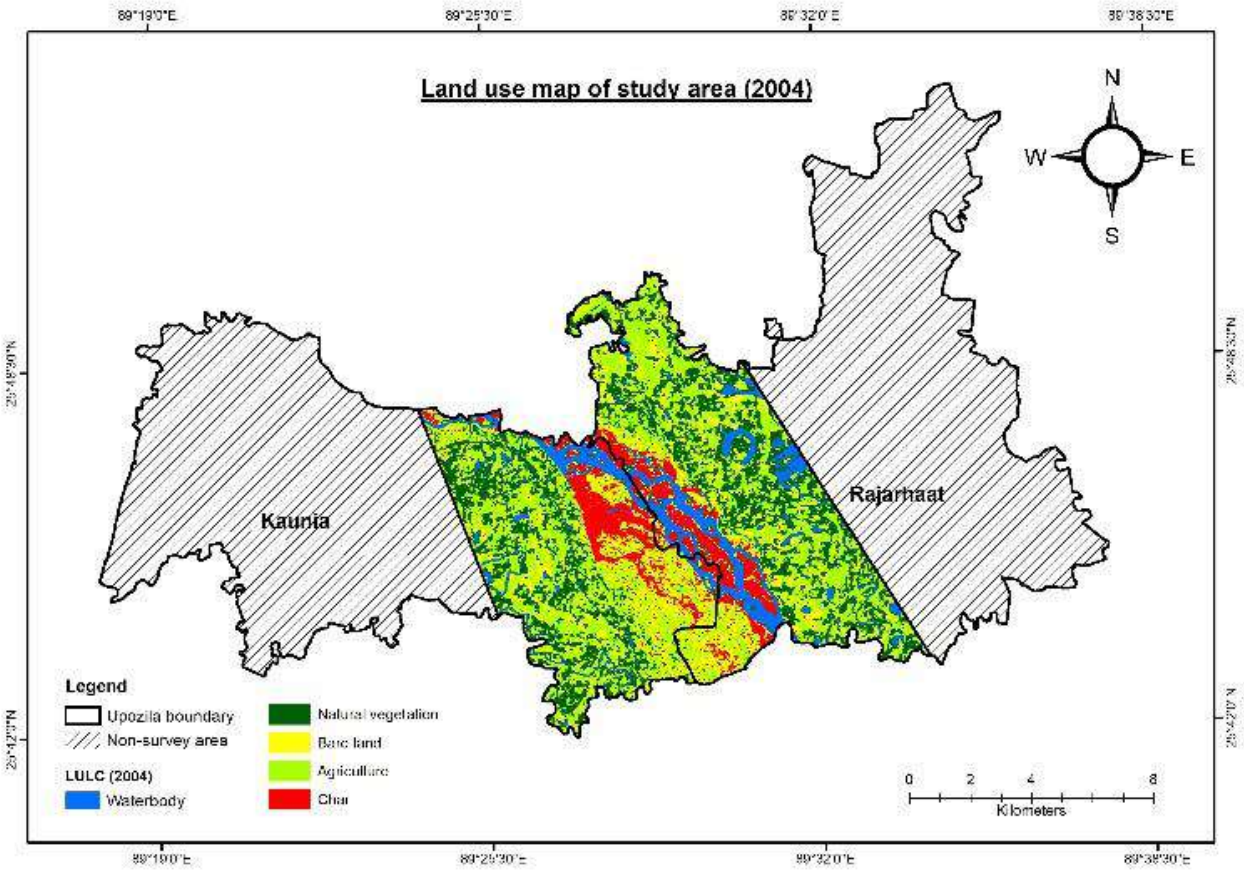
The quantitative data is analyzed by the SPSS software and the qualitative data is analyzed by the Nvivo software. We divided the data into dependent and independent variables and then based on the five major themes the statistical analysis has done The qualitative research design will incorporate multiple methods of data collection, including **Focus Group Discussions (FGDs)**, **Key Informant Interviews (KIIs)**, and **document analysis**. This triangulation of data sources will enhance the validity and reliability of the findings, ensuring a comprehensive understanding of the research problem (Patton, 2002). FGDs will capture collective community insights, while KIIs will provide specialized knowledge from key stakeholders. Literature analysis will contextualize the findings within broader theoretical and practical frameworks. Moreover, the qualitative approach enables the research to address not only the observable practices of the community but also the underlying cultural, social, and institutional factors influencing these



behaviors. By emphasizing the lived experiences and voices of participants, the study seeks to generate actionable insights that are grounded in the local context. This is particularly critical for developing a **sustainable framework** for the agricultural-dependent community that aligns with the community's needs and priorities while addressing broader ecological challenges (Pretty et al., 2011).

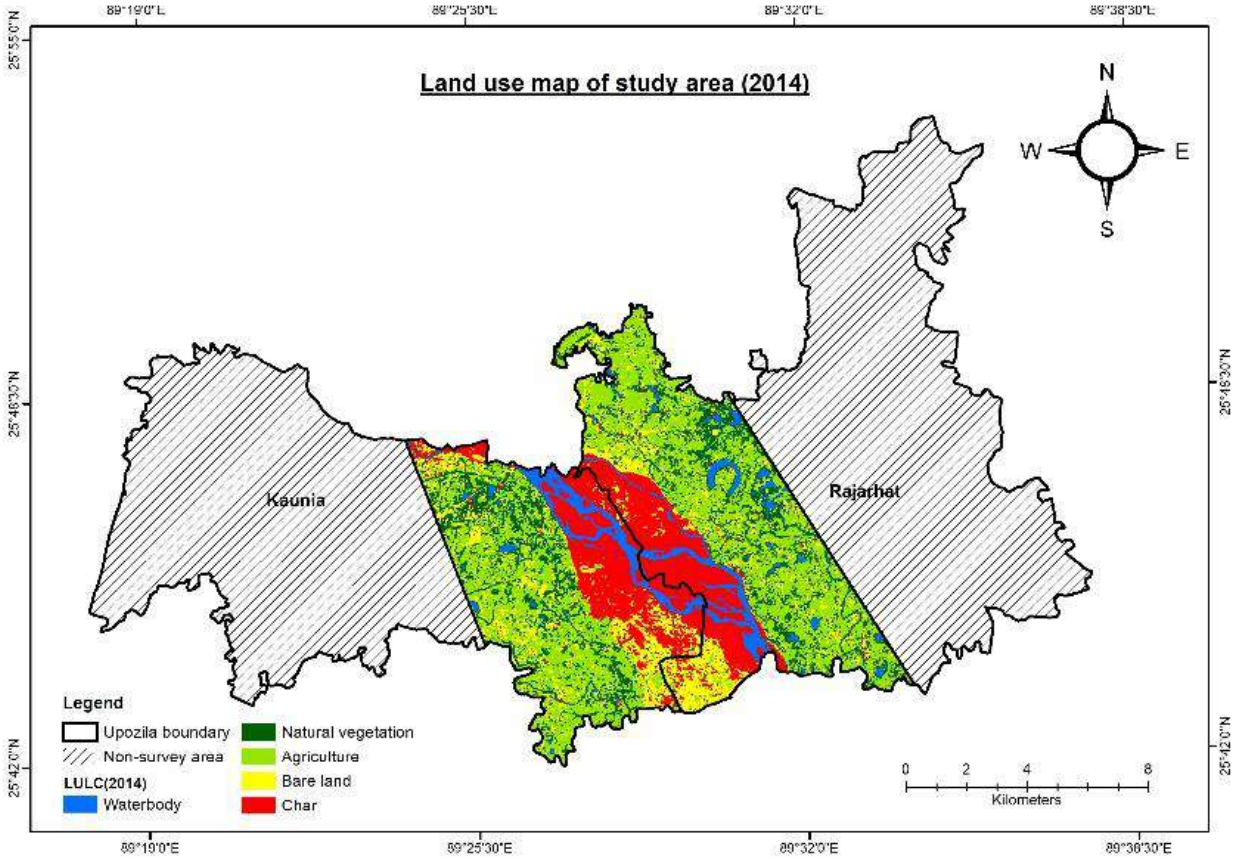
7. Findings and Analysis:

Land use change:



2004 Land Use Change

In 2004 the river supported diverse land uses, with agriculture and natural vegetation being crucial components. Bare land is minimal, indicating lesser degradation. Some natural irrigation channels connected with the river were found, which narrated that in 2004 the use of shallow machines was very less in agricultural activities. Most of the agricultural land was in the highlands because due to the lack of technology people didn't practice in the char areas. However, the char land was not expanded at that time because the erosion and accretion rates were minimal.

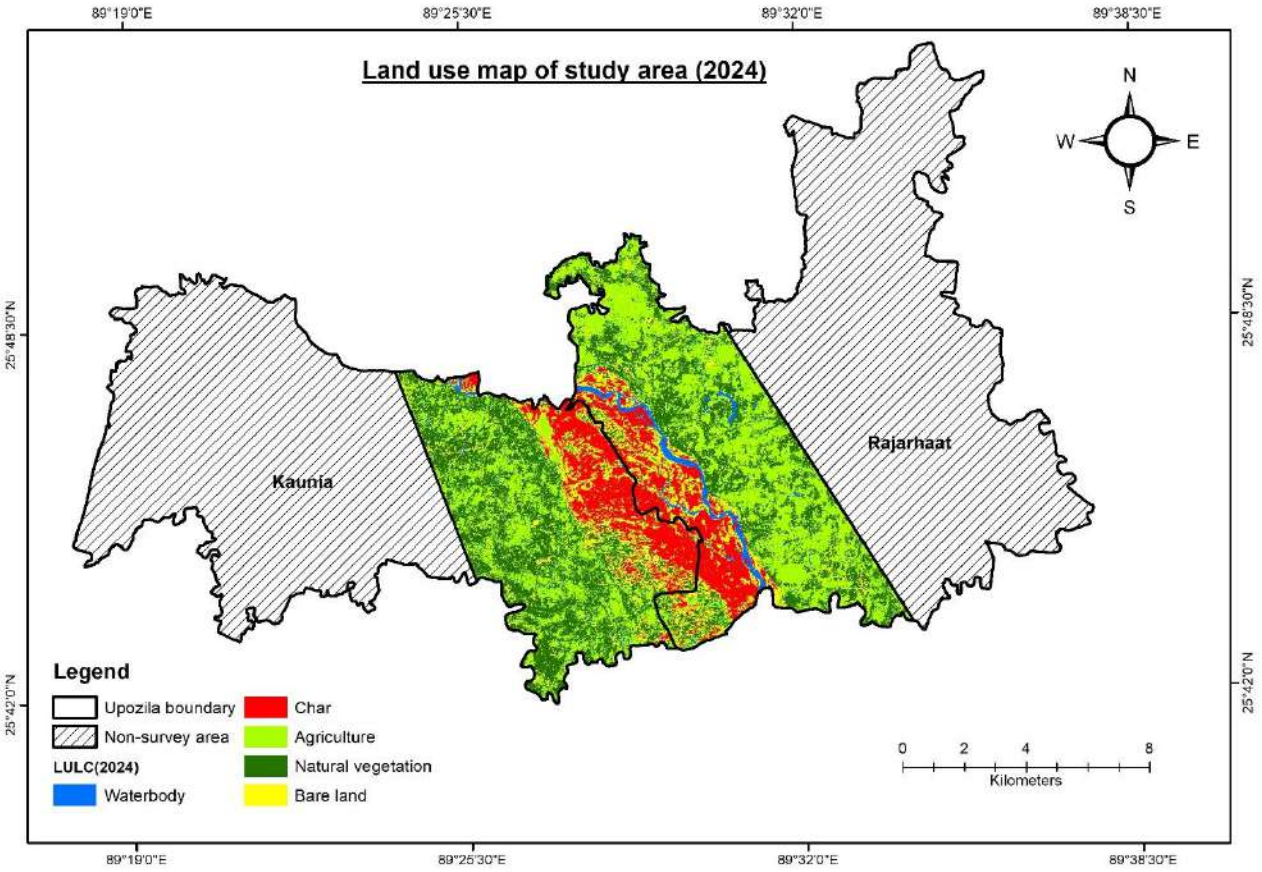


2014 Land Use Change

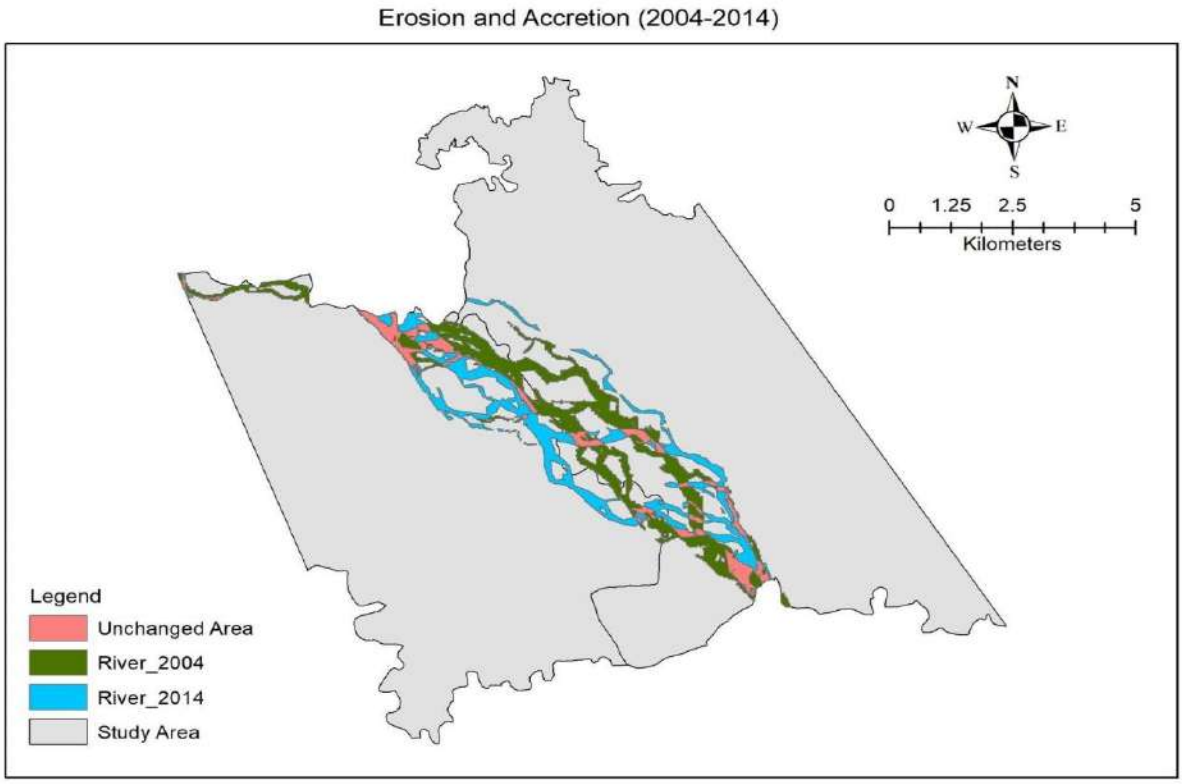
A noticeable increase in agricultural land (yellow), suggests a shift from natural vegetation, and the char areas along the river have expanded, indicating sediment deposition or river dynamics. A slight reduction in natural vegetation compared to 2004. Expansion of agriculture may reflect population growth and increasing dependency on farming. Dynamic char areas expanded at intensified river erosion and due to accretion, the sedimentation rates were also high which is visible in the expansion of char land during this period. Like 2004 in 2014 the river bank and char land agricultural activities were not visible but like 2004 the natural irrigation channels were visible which means that time also people didn't adopt technology for irrigation.

2024 Land Use Change

A significant increase in char areas along the river indicates higher river dynamics and instability. Decrease in natural vegetation, suggesting ongoing deforestation or land conversion for agriculture. Agricultural areas remain much visible but appear stable compared to 2014 because people adopting different disaster tolerance strategies to increase agricultural activities. Bare land increases slightly, hinting at degradation or loss of vegetation. The projected expansion of char areas indicates possible impacts of climate change and riverine erosion, which also clearly visualizes the massive morphological change. Natural vegetation decreases because along with high land the agricultural activities also visible in the char area, which means the agricultural adaptation ability has increased rather than 2004 and 2014.

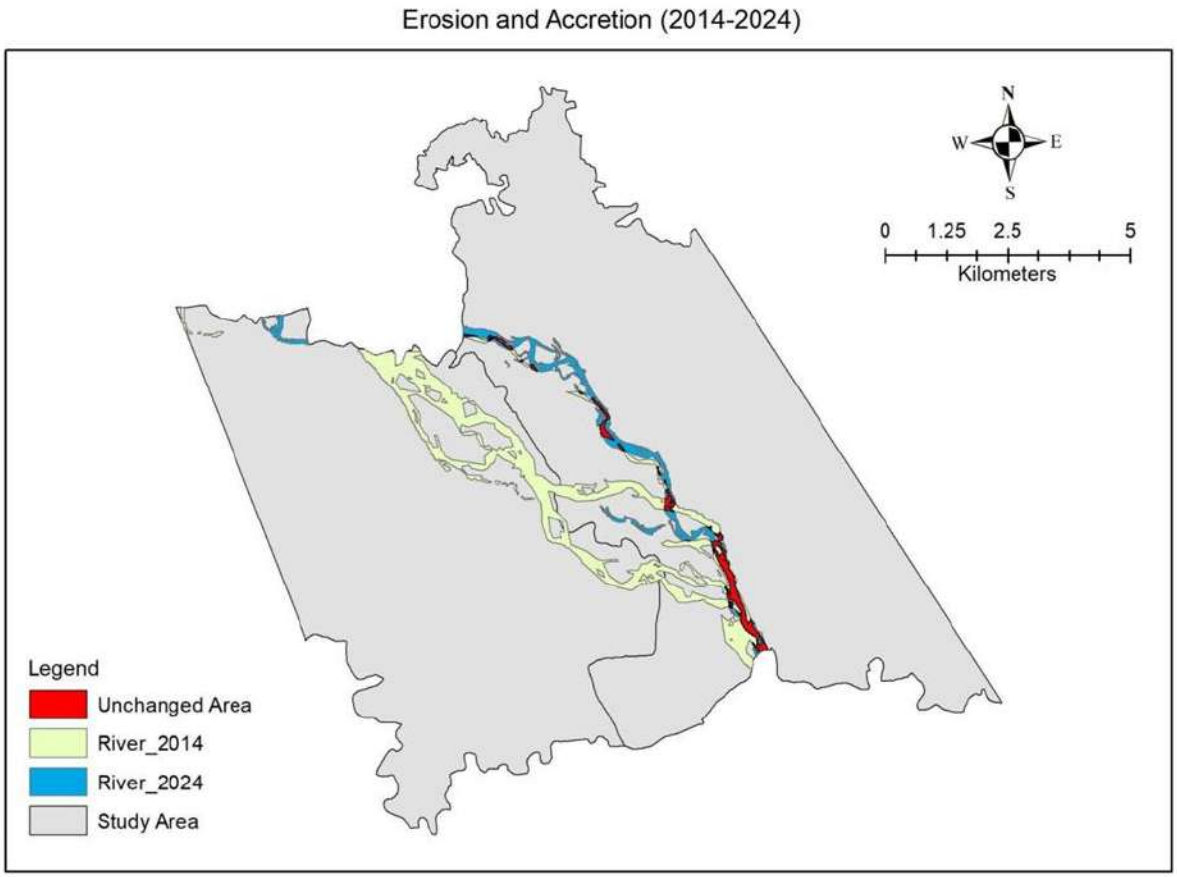


River Erosion & Accretion analysis



Total Area (He)	Unchanged Area (He)	Erosion	Accretion
412.83914	174.175592	500.739334	377.070259

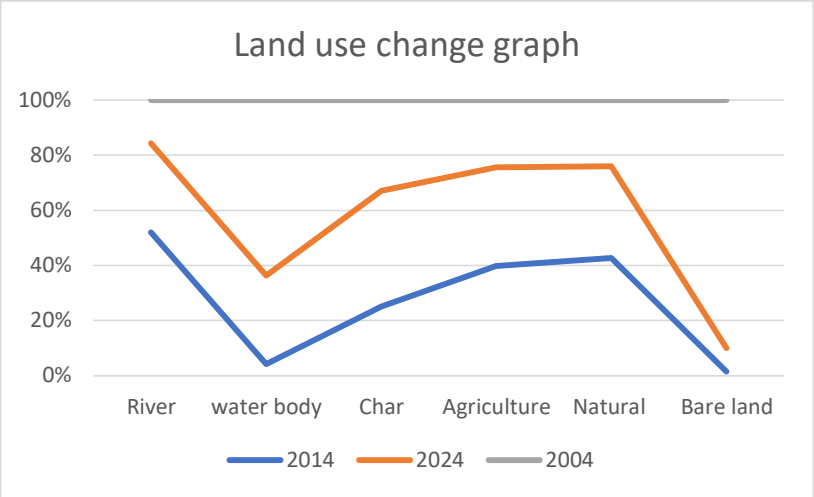
In the above figure, erosion and accretion from 2004 to 2014 are shown. The total area of the study area in the Teesta region from 2004 to 2014 was 412.83914 hector respectively, and the unchanged area in that period was 174.175592 hector. These two values show that from 2004 to 2014 the erosion was 500.739334 hector and the accretion was 377.070259 hector.



Total Area (He)	Unchanged Area (He)	Erosion	Accretion
674.91426	**32.748757**	**642.166169**	**151.021243**

In the above figure, erosion and accretion from 2014 to 2024 are shown. The total area of the study area in the Teesta region from 2014 to 2024 was 674.9426 hectares respectively, and the unchanged area in that period was 32.748757 hector. These two values show that from 2014 to 2024 the erosion was 642.166169 hector and the accretion was 151.021243 hector. The amount of unchanged area decreases due to the river shifting.

Key Insights from GIS Analysis:



- The Teesta River basin exhibits significant land use changes over the studied period, with a trend of increasing agricultural activities and dynamic riverine processes.
- Expansion of char areas and reduction of natural vegetation could be linked to anthropogenic pressures, climate variability, and river dynamics.
- Effective management of land resources, including afforestation and flood control, is critical to address future challenges posed by these changes.

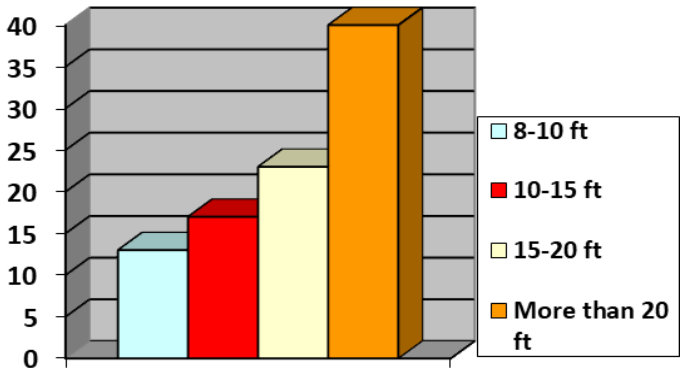
Findings from Primary Data:

The dataset comprises a comprehensive survey of 83 respondents, capturing various dimensions of climate change impacts and adaptation strategies in a vulnerable region. The data structure encompasses 158 variables, covering demographic characteristics, socioeconomic indicators, agricultural practices, environmental challenges, and adaptation responses. The respondents' profiles include diverse age groups, with predominantly farming backgrounds, varying educational qualifications, and different household compositions. The dataset captures multiple aspects of agricultural vulnerability, including exposure to natural hazards such as cyclones, floods, and river erosion. It documents agricultural challenges for issues like crop damage, pest attacks, irrigation difficulties, and market access problems. The survey also records adaptation strategies, including the adoption of climate-resilient farming practices, access to agricultural support services, and participation in community-based initiatives. A notable feature is the detailed documentation of communication and early warning systems, with variables tracking multiple notification channels for different types of disasters.

The economic dimension is represented through variables measuring monthly income, savings patterns, and access to credit facilities. Infrastructure and institutional support are captured through indicators of access to agricultural department facilities, NGO services, and government project interventions. The dataset provides valuable insights into local adaptation practices and the effectiveness of various coping strategies in response to climate-induced challenges. This rich dataset enables analysis of the relationships between socioeconomic factors, environmental challenges, and adaptation responses, making it particularly valuable for understanding climate change vulnerability and resilience at the community level.

Characteristic	Percentage (%)
Age Groups	
18-30 years	32.5
31-45 years	41.0
46-60 years	19.3
Above 60 years	7.2
Education Level	
No formal education	15.7
Primary	24.1
Secondary	38.6
Higher education	21.6
Monthly Income Level	
Low income	35.8
Medium income	42.2
High income	22.0
Primary Occupation	
Farming	89.2
Business	6.0
Day labor	3.6
Others	1.2

Impact/Strategy	Percentage (%)
Environmental Challenges	
Flooding	82.5
River erosion	76.3
Cyclones	68.9
Drought	59.4
Adaptation Strategies	
Changed cropping pattern	73.6
Adopted resilient crops	65.2
Used solar irrigation	42.8
Implemented water harvesting	38.5
Community-based initiatives	56.7



Agricultural Adaptation: Rangpur division (24%) has the largest number of diesel pumps, followed by Khulna (22%) and Rajshahi (22%). The central part of the country hosts 22% of diesel pumps—12% operating in Dhaka and 10% in Mymensingh. The eastern and southern parts of the country use fewer diesel pumps ("Feasibility Study of Solar Irrigation System in Rural Areas of Pirgacha Upazila of Rangpur District, Bangladesh," 2022). The solar irrigation project in Kaunia started in 2019. Due to the drought drought, the project was established to solve the irrigation problem. According to the farmers, this project helped them to extract water from the ground and mitigated the use of diesel in irrigation water pumps. During flood periods the chance of crop damage and animal mortality is very high when the water level has increased to danger level. From our quantitative survey, we learned that in the last 20 years a lot of domestic animals died and crops were damaged due to floods. But now some of the farmers make elevated shade and crop storage which help to mitigate the damage.

Community people, especially youth, use social media such as YouTube and Facebook to get ideas about agricultural adaptation. Shahin from Char Gonai Union said he got to know about different disaster-adaptive rice, Bina 75 and Bina 17, from a Facebook group. He also learned about a new variety of coconut trees that has a high production chance in the Rangpur region. He is inspired to cultivate these crops as a trial to be profitable. The use of organic fertilizer through Verme composting is increasing due to the different community-based projects of the Agriculture Department, which helps to maintain soil fertility. Pheromone trap is used in agricultural land to mitigate pest attacks on the crops which is also a better adaptation method rather than using chemicals. So overall the agricultural-dependent community of Kaunia is adopting new technologies and methods for socio-economic development but also due to extreme flood and erosion, they face massive loss and damage every year.

In the agricultural-dependent community of Kaunia, several interrelated challenges significantly impact the livelihoods of its residents. Transportation issues hinder farmers from efficiently accessing markets, resulting in delayed sales and potential loss of income. The market price fluctuations for agricultural products often leave farmers vulnerable, as they struggle to predict the profitability of their crops. Additionally, the role of seed and fertilizer dealers is crucial; however, limited access to quality inputs can compromise crop yields and overall

productivity. The lack of storage facilities further exacerbates these challenges, as farmers are forced to sell their produce immediately after harvest, often at lower prices, due to the risk of spoilage. Displacement also poses a significant threat, as environmental changes or economic pressures can force farmers to abandon their land, disrupting their livelihoods and community stability. Together, these challenges create a complex web of issues that hinder the development and resilience of the agricultural sector in Kaunia, requiring comprehensive strategies for improvement.

Locally-led water reservoir

Near the solar irrigation pump, the farmers made a water reservoir sized approximately 10 feet by 8 feet to collect water for emergencies and share the water with the nearby agricultural fields for irrigation. When the solar doesn't give proper support, especially in winter then this reservoir gives them support to collect the water.

Pumpkin project

In the char area, rice cultivation is so difficult because of the sandy land and for that reason, farmers are motivated to cultivate pumpkin because it's relevantly easy and profitable. Pumpkin cultivation is a revolutionary project in the chars of Teesta. Pumpkin cultivation started in 2017 with the traditional cultivation method in 50 hectares area but due to the variation of river flow and extreme drought, the farmers were struggling to increase the production. In 2019 when the farmers got the facility of solar irrigation system then pumpkin production increased massively and now in the char farmers cultivate pumpkins in around 100 hectares area. In 2024 around 17 chars in Kaunia with 200 hectares area cultivated pumpkin, while the farmers got profit with low production cost. More than 300 farmers are involved in pumpkin production. The average size of pumpkin there is 10-15 kg and the farmers sell it in the local wholesale market for 15 tk per kg but when it comes to Dhaka or other city areas then the wholesalers sell it for 30-35 tk per kg and the retail price goes to 40-60 tk per kg. Sometimes due to floods, heavy rainfall, and due to transportation problems, the farmers have to face loss, that's why in the Gotiasham union of Kaunia the farmers formed a locally-led organization called "Mohajot" to enhance

networking to directly sell in the city wholesale market for better market price with minimum loss.

Organic Fertilizer

In the char areas due to the sandy soil, the use of fertilizers is necessary to maintain fertility. In that case, there is less availability of organic fertilizer and the production cost of organic fertilizer is also so high. That's why most farmers use chemical fertilizers like TSP, Potash, and urea. But chemical fertilizer is also a prime cause of land degradation and it also decreases the nutritional value of crops (Islam & Hossain, 2016). In the Dhushmara char of Razarhat upazila the Department of Agriculture (DOE) started a vermicompost technology with 5 selected farmers in 2020. Vermicomposting is a method where organic fertilizer is produced from a worm mixture, that's why a lot of farmers don't feel comfortable working with worms. But those farmers who use this technology got a positive result in cultivating several crops and for that reason, in January 2024 DOE started a new trial project of organic Trico compost with those five farmers, where they can utilize the daily household waste for composting. So far this Trico composting method is giving positive results and every month the Sub-Assitant Agriculture Officer of that area also monitors the organic composting project. The community believes if the Trico composting project sustains then other farmers also want to use this method as a sustainable and cost-efficient alternative to chemical fertilizer.

8. Result & Discussion: Vulnerability because of climate change is now a common phenomenon for the indigenous people, especially in the coastal areas of Bangladesh. But in the near Teesta Floodplain vulnerability mainly increases because of the transboundary water-sharing dispute. The research highlights the compounded effects of climate change and the transboundary water-sharing dispute on the agricultural-dependent communities of the Teesta River Basin in Kaunia, Bangladesh. Due to global warming and climate change, glacier melting has increased in Sikkim, which has also increased the rate of floods ("Ian Davis," 2014). Climate change has intensified rainfall variability and extreme weather events, leading to frequent floods and river erosion that disrupt agricultural productivity. Concurrently, the ongoing water-sharing dispute between India and Bangladesh exacerbates water availability issues, particularly during critical dry seasons, further threatening the livelihoods of farmers. The maximum temperature of the Teesta River basin in Bangladesh varies from 25.1 to 35.8°C (Arifa Iffat Zerin, 2011). Over the period the rise of temperature complemented the melting rate of glaciers in Sikkim. In a webinar local activist from Sikkim Mayalmit Lipcha said, the temperature has increased more than before in the last 10-12 years because in Sikkim people don't usually use fans in their households but since the last 10-12 years people have lived in Teesta River bank of Sikkim feel

also the direct impact of climate change. The Pauhunri mountains in the Eastern Himalayas, which is the origin of the Teesta River. It flows through India (83%) and Bangladesh (17%) by draining out the water of 12,159 km2 area. Several topographical variations are present in the basin. India's Sikkim is a hilly region, while West Bengal is made up of both low hills and plains (Nayeem,2022). The study reveals significant land-use changes over the years, including a decline in natural vegetation and an increase in char areas and agricultural land, driven by population pressure, river dynamics, and climate-induced factors. Farmers have adopted various adaptation strategies, such as elevated crop storage, the use of organic fertilizers, and disaster-resilient crop varieties, yet these measures remain insufficient to fully mitigate the dual threats. The findings emphasize the urgent need for sustainable adaptation practices and coordinated cross-border water resource management to ensure resilience and stability for the vulnerable communities in the region.

Community people especially youth use social media such as YouTube and Facebook to get ideas about agricultural adaptation. Shahin from Char Gonai union said he got to know about different disaster adaptive rice Bina 75 and Bina 17 from a Facebook group and also, he knew about a new variety of coconut trees that has a high production chance in Rangpur region. He is inspired to cultivate these crops as a trial to be profitable. Some young farmers shared that they take suggestions from Facebook and YouTube to mitigate paste attacks, about new varieties of crops and fertilizers. In the area of Char Gonai, the young farmers have a Facebook group for communication, which makes it easier for them to share their daily agricultural activities. However, it's not enough for the community to overcome climate vulnerability because the amount of loss and damage they face every year makes their life difficult and also increases the migration rate, which is not fixable with different agricultural adaptations because they are not able to save their land. A sustainable solution is needed from the policy level, which will help the community to protect their lands and improve their socio-economic status.

9. Conclusion

The farmers have adopted many strategies over 20 years but due to loss and damage, they are not able to protect their agricultural land. So, the only sustainable solution for the socio-economic development of the agricultural community in the Teesta River is an inclusive transboundary water-sharing agreement between India and Bangladesh. According the articles 5, and 6 of the international transboundary water sharing law, the upstream country has to notify the downstream country before opening the gate of the water reservoir, and in terms of socioeconomic development of both countries, the water must be shared equally (Norman & Bakker, 2008). But in reality, the Teesta region in Bangladesh suffers 8-9 months of drought every year, and during monsoon, the increased flow of flash floods expands the river and changes the morphological pattern also.

But this geo-political problem is now also complementing the impact of climate change. It means if the government of both countries doesn't negotiate a water-sharing inclusive agreement then the adaptation strategies will not be sustainable solutions for the agricultural-dependent

community in the Teesta River Bank, because the way frequently Teesta is changing morphologically, in the future it will complement the vulnerability more strongly than before.

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11. Appendix:

Research Timeline

	Jan. 2024	Feb. 2024	Mar. 2024	Apr. 2024	May. 2024	June 2024	July 2024	Aug. 2024	Sep. 2024	Oct. 2024	Nov 2024
Literature Review											
GIS Image Analysis											
Primary Data Collection											
Data Analysis											
Report writing											
Submission											
Dissemination											

Budget

Budget	Unit	Unit Cost (BDT)	Total Cost (BDT)
Long travel	2	1500.00৳	3000.00৳
Accommodation and food	10	35,00.00৳	350,00.00৳
Local Travel	10	500.00৳	500.00৳
Stationaries			5,000.00৳
Total			**43500.00৳**

FGD Checklist

- What recent changes have you observed regarding the shifting of the Teesta River? Why is this happening (guide the discussion through the issues of climate change as well as water dispute)?
- What are the main sources of income in this area? What crops did you use to cultivate 10/20 years ago? What do you cultivate now?
- What are the changes regarding agriculture happening in your areas? (changes may include cultivation practices like cropping pattern and intensification, it may also include crop

diversification, cultivating new crops, use of technology, etc) Are those changes beneficial for your family and community? Why or why not?

- What support (self and external) do you get for agriculture? (support from GO/NGO, support in the form of cash, loan, advice, seed, calling to call center or anything related to agriculture, self-support may include watching vlogs, YouTube videos of prominent agriculturalists and others)
- How do you adjust your agricultural activities to the changing river conditions?
- What other support do you need to manage agriculture properly?

KII Transcripts

Latif Sir- Madrasa teacher, Bajemojkur Balika Dakhil Madrasa

Q1: We heard your name from the farmers several times about your contribution to the agricultural development in Chargonai. Can you tell us how you are bonding with farmers and how you motivate them?

Answer: Laif sir introduced himself as a Madrasa teacher and also, he is involved in agricultural activities. He has a perfect relationship with local farmers through technology and his networking with the agricultural department. As an educated member of the neighborhood, he always tries to motivate the farmers with new information. He always tries to introduce new projects regarding new crop variety test projects and climate smart **agricultural projects with the help of Bangladesh Agricultural Research Institute (BARI) and the DAE.**

Q2: How did you make the relationship with BARI?

Answer: In 2014 the Bangladesh Agriculture Research Institute (BARI) came to his area (Char Gonai- Tepamadhopur, Kaunia, Rangpur) to make a trial project of newly invented hybrid crops for char resilience like cucumber, onion, garlic, nut, and rice. From that time BARI made Latif sir as a delegate of the farmers. That year, BARI experimented with two new varieties of nuts there, BARI nuts 8 & 9.

Q3: Can you tell us about any climate smart agricultural project in your area?

Answer: In 2022, the Transforming Agrifood System in South Asia (TAFSSA) started a trail project in Chargonai with 20 farmers in high land and char. Through the Agriculture Department, TAFSSA contacted Latif sir, and then in his courtyard, a workshop was arranged by foreign delegates, and officers from the Agriculture Department. They selected 20 farmers for this trail project and the main goal of this project is to cultivate different types of crops in the whole year. In 20 Shotok lands first the farmer cultivates Aman then after harvesting Aman they will cultivate Napa shak in 5 shotok, cucumber in 5 shotok, and potato in 10 shotok. After harvesting those vegetables, they will cultivate corn in 5 shotok and nuts in 15 shoto. Latif sir gave us some names and numbers of some farmers who are working on this trail project, Amirul, Jahangir, Omar, Kholilur, and Motiur among them. Also, Latif sir shared that last year the farmers used

excessive pesticides during BINA rice cultivation and that's why during harvesting the result was not up to the mark. According to the monitoring data the project team selected two farmers to identify why the BINA rice was damaged in the harvest period. For this yearly trail project in 2023 the farmers got the seed of BRRI rice 75.

Md. Taher, General Security of Krishok Somaj Unnoyon Somobay Somity

Md. Taher is the General Secretary of "Krishak Shomaj Unnayan Somobay Somity" established in 2022. According to him, this youth-led organization has been made to mobilize the young farmers and help the agricultural community by giving loans, seeds and fertilizer. The main goal of this organization is to remove the financial crisis from the farmer community and help them to save their money. A total of 50-60 farmers are involved with this organization. Mainly the organization provides loans with 5% interest to the farmers during the season of cultivation. In addition, they provide loans for buying domestic animals and renovating farmers' houses after the disaster. Most of the elder persons from the community do not like their organization due to religious and Indigenous norms. There are some criteria to get the membership of the organization. The criteria are:

1. The person must be a farmer.

2. The person needs to ensure the stability of the number of shares he/she buys from the organization.

3. The person needs to pay 500 take every month in the organization's fund.

4. The person needs to sign a five-year agreement.

The upcoming plan of the organization is to build a community-based agricultural farm. If they get financial support from Govt. or NGOs, they want to buy domestic animals, autos or rickshaws for the jobless and least poor people in the community.

Anwar Hossain, Sub-Assistant Agriculture Officer, DAE, kaunia, Rangpur

Anwar Hossain is the Sub Assistant Agriculture Officer of the Kaunia sub-district. According to him, 5-10 years before there were no drought-friendly crops cultivated in Kaunia's char. Now with the collaboration of the Agriculture Department, NGOs, and other administrative organizations, the farmers can cultivate different types of crops in the char. The organizations took the opinion of the farmers to understand their convenience for cultivating different variables of crops. Then a trial project first started in around 2015 or 2016. The project was organized by RDRS, EMFOSIS, and BRAC. Based on the farmer's opinion the trial project was started with corn, nuts, potatoes.

Section-1: Socioeconomic and agriculture related information			
1	Your Name:		
2	Your age:	1. 18-25	

		2. 25-30 3. 30-35 4. 35-40 5. 40-45 6. 45-50 7. 50-55 8. 55-60 9. More than 60	
3	Gender:	1. Male 2. Female 3. Don't want to share	
4	Your Occupation: (Possibility of more than one answer)	1. Student 2. Farmer 3. Day labor 4. Businessman 5. Van/ Rickshaw / Auto driver 99. If others then mention	
5	Your educational qualification	1. Below than primary 2. Primary 3. Below than 8th grade 4. SSC/ Dakhil 5. Below than HSC / Fazil 6. HSC/ Fazil pass 7. Undergraduate 8. Illiterate 9. Only can sign	
6	How many times you have been staying here?	r ears years 5 years 0 years than 20 years birth	
7	Your family size?	1. 2 people	

		2. 3 people 3. 4 people 4. 5 people 5. 6 people 6. More than 6 people	
8	Your monthly income?	1. 5-10 thousand 2. 10-15 thousand 3. 15-20 thousand 4. 20-25 thousand 5. 25-30 thousand 6. More than 30 thousand	
9	Do you have any monthly savings?	1. Yes 2. No	If yes then how much?
10	Do you have any loans?	1. Yes 2. No	If yes then how much?
11	From where you have taken the loan?	1. Government bank 2. Private bank 3. Agriculture Development Bank 4. NGO 5. Neighbors 6. Relatives 7. Small loan organizations 8. Financially efficient rich people 99. If others then mention	
12	Do you have a smartphone?	1. Yes 2. No	
13	Your household structure?	1. Plastered building 2. Tin shade house 3. Tin surrounded house 99. If others then mention	

<table>
<tr><td>14</td><td>Your household type?</td><td colspan="3">1. Ranted
2. Own</td><td></td></tr>
<tr><td>15</td><td>What type of agricultural activity?</td><td colspan="3">1. Cultivate in own land
2. Cultivate in borrowed land
3. Both</td><td></td></tr>
<tr><td>16</td><td>In which season do you cultivate which type of crops?</td><td>Robi: 16th October to 15th March (কার্তিক থেকে ফাল্গুন)</td><td>1. Yes
2. No</td><td></td><td>If yes then mention the crops.</td></tr>
<tr><td></td><td></td><td>Kharip-Season1 14th March-15th July (চৈত্র-আষাঢ়)</td><td>1. Yes
2. No</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Kharip-2 16th July-15th October (শ্রাবণ-আশ্বিন)</td><td>1. Yes
2. No</td><td></td><td></td></tr>
<tr><td>17</td><td>Which type of agricultural facilities do you have in your area?</td><td colspan="3">1. Officer from the Agriculture Department
2. Officer from the Livestock Department
3. Agriculture call center
4. NGO project
5. Government project
6. Community based organizations

99. If others then mention</td><td></td></tr>
<tr><td>18</td><td>For irrigation which type of water do you use?</td><td colspan="3">1. River water
2. Diesel pump
3. Own solar pump
4. Community-based solar pump</td><td></td></tr>
<tr><td></td><td>Do you have any domestic animals?</td><td colspan="3">1. Yes
2. No</td><td></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>19</td><td>If yes then which type and how many domestic animals do you have?</td><td><table>
<tr><td>1. Cow</td><td></td></tr>
<tr><td>2. Goat</td><td></td></tr>
<tr><td>3. Duck</td><td></td></tr>
<tr><td>4. Chicken</td><td></td></tr>
<tr><td>5. Lamp</td><td></td></tr>
<tr><td>99. If others then mention</td><td></td></tr>
</table></td><td></td></tr>
<tr><td></td><td colspan="2">Section 2: Climate change-related information</td><td></td></tr>
<tr><td>20</td><td>What are the seasonal disasters in your area?

Disaster level:

A. Very high
B. Normal
C. Very low</td><td><table>
<tr><td>1. Boishakh to before monsoon</td><td>1. Boishakhi storm
2. Cyclone
3. Sheela rain</td></tr>
<tr><td>2. During monsoon</td><td>1. River erosion
2. Flood
3. Lighting
4. Heavy rainfall</td></tr>
<tr><td>3. During winter</td><td>1. Drought
2. Temperature fall</td></tr>
<tr><td>99. If others then mention</td><td></td></tr>
</table></td><td></td></tr>
</table>

21	How do natural disasters affect your agricultural activity? Level of loss: A. Very high B. Normal C. Very low	1. Lack of water for irrigation 2. Damage to crops 3. Excess past attack 4. Excess crop production cost 5. Low crop prize 6. Facing problems with transporting crops in the market 7. Facing the problem of storing the crop 99. If others then mention	More than one answer will be applicable
22	In the last 20 years, because of natural disasters, how much has your neighboring area changed? Level of change: A. Very high B. Normal C. Very low	1. Change in the river size 2. Damages of crops increase 3. Natural vegetation decreases 4. House shifting increases 5. Char area increases 6. Death rate increases 7. Domestic animal death rate increases 8. Fish production decreases 9. All of above 99. If others then mention	More than one answer will be applicable
23	Due to natural disasters have you ever seen any type of ecological changes (rivers, water bodies, char, trees)?	1. Yes 2. No	
24	In the last 20 years, how much has the river changed because of natural disasters? Disaster level: A. Very high B. Normal C. Very low	erosion increases erosion decreases iver is shifted from its place rmal water flow of the river chars are produced broken increases nd water level decreases cultural land decreases due to river erosion iver is dry for a long period ural vegetation decreases 99. If others then mention	More than one answer will be applicable

25	How many days does the flood sustain?	1. 2-4 days 2. 5-10 days 3. 10-15 days 4. More than 20 days	
26	Do you think the river area expanded more than before?	1. Yes 2. No	
27	How much area is lost every year due to river erosion?	1. 8-10 ft 2. 10-15 ft 3. 15-20 ft 4. More than 20 ft 77. Not applicable	
28	Due to the change in the river are there any changes you feel any changes in agriculture?	1. Irrigation becomes easier 2. Irrigation becomes more harder 3. Due to the water level being down the engine motor increases 99. If others then please mention	
29	What are the prime causes do you think changing pattern of the river?	1. Climate change 2. Unplanned uses of river 3. River grabbing 4. Illegally sand extraction from river 5. Bangladesh- India Teesta dispute 6. Sudden river water flow increases in monsoon 7. Heavy rainfall 8. Heavy drought 99. If others then mention	More than one answer will be applicable
30	Do you know about the Teesta water-sharing dispute and if yes then what do you know	1. Yes 2. No	

	about it?		
	If yes then which type of information do you know?	1. India doesn't give water to us 2. India gives excess water in monsoon 3. India doesn't give any information on water flow 4. India tries to stop water flow in the river 5. Bangladesh can't use the river properly 6. Lack of political attention 99. If others then mention	More than one answer will be applicable
31	Do you know about climate change?	1. Yes 2. No	উত্তর হ্যা হলে মতামত শেয়ার করুন।
32	Last year which type of changes have you seen in different agriculture seasons due to environmental challenges?	1. In last few years due to the optimum temperature changes, how it affects the agriculture? 2. How changes of rainfall affect agriculture? 3. Which type of changes you have noticed in crop cultivation? 4. How much crop damage due to the lack of water? 5. Which type of challenges you have faced due to water shortage?	

		99. If others then mention			
	Section-3: Agriculture and natural disaster-related information				
33	Does your agricultural activity face any barriers due to natural disasters?	1. Yes 2. No			
34	In which season does your agricultural activity have to face very challenging situations?	1. Summer	1. Heatwave 2. Water crisis 3. Past attacks on crops 4. Crop colour change 5. Crop disease 99. If others then mention		
		2. Monsoon	1. Crop damage due to sheet rain 2. Crop damage due to heavy rain 3. Past attack on crop 4. Crop fall underwater 5. Crop colour change 6. Crop disease 99. If others then please mention		
		3. Winter	1. Excess water extraction due to water crisis 2. Past attacks on crops 3. Crop becomes fade 4. Crop colour change 5. Crop disease 99. If others then please mention		
35	Do you lose any agricultural land due to natural disasters	1. Yes 2. No			
36	If yes then how much land did you lose and did you get back				

	those lands?		
37	Did you migrate alone or with your family due to a natural disaster?	1. Yes 2. No	
38	Have you ever left your agricultural activity?	1) Yes 2) No	
39	Have you ever needed to shift your home due to a natural disaster or you are at risk of shifting, if it is yes then how many times did you shift?	1. Yes 2. No 3. There is a risk of shifting the home	
40	In last 10-20 years how many times your family needs to shift home due to river erosion?	1. 1 -3 times 2. 3-5 times 3. 5-7 times 4. 7-10 times 5. 10-15 times 6. More than 15 times 77. Not applicable	
41	Have you lost any domestic animals due to natural disasters, if yes then how many?	1. Yes 2. No	
42	If the answer is yes then which type of domestic animals are died and how many?	1. Cow 2. Goat 3. Duck 4. Chicken 5. Lamp 99. If others then mention	
	Section-4: Adaptation-related information		

<table>
<tr><td>43</td><td>Do you get any notifications before disasters, if yes then from which sources do you get the notifications?</td><td><table>
<tr><td>Flood</td><td>1. Yes
2. No</td></tr>
<tr><td>Drought</td><td>1. Yes

2. No</td></tr>
<tr><td>River erosion</td><td>1. Yes

2. No</td></tr>
<tr><td>Heavy rainfall</td><td>1. Yes

2. No</td></tr>
</table></td><td></td><td></td></tr>
<tr><td>44</td><td>If the answer is yes then from where did you get those notifications?</td><td colspan="2">1. Mobile massage/voice call
2. NGO
3. Govt. Office
4. TV / Newspaper
5. Websites
6. Social talk from the market
7. From relatives
8. Agriculture call center
9. Mobile app

99. If others then mention

77. Not applicable</td><td></td></tr>
<tr><td>45</td><td>By understanding the weather conditions can you guess which disaster can come?</td><td colspan="2">1. Yes
2. No</td><td></td></tr>
<tr><td>46</td><td>If the answer is yes then how?</td><td colspan="2">1. From the river flow
2. Through cloud movement
3. Type of rainfall

99. If others then mention

77. Not applicable</td><td></td></tr>
</table>

47	Do you take any preparation before starting any disaster?	1. Yes 2. No	
48	Which type of preparation you have taken?		
49	In your area are there any meetings you do regarding climate change and natural disasters, if yes then who arranges those meetings?	1) Yes 2) No	
50	If yes then who and when arrange those meetings?		
51	Are there any organizations or government agencies that helped you during the disaster?	1. Yes 2. No	
52	If yes then who gives those aid?		
53	Are there any adaptation strategies you want to implement but can't because of lot of barriers?	1. Yes 2. No	

<table>
<tr><td></td><td>If yes then why?</td><td>1. Financial crisis
2. Lack of proper planning
3. Lack of proper direction
4. Lack of man power
5. Community based mess
6. Lack of government support
7. Lack of NGO support

99.If others then mention

77.Not applicable</td><td></td></tr>
<tr><td>54</td><td>Have you ever done any agricultural adaptation</td><td>1. Yes
2. No</td><td></td></tr>
<tr><td>55</td><td>If yes then mention them?</td><td>
<table>
<tr><td>1. Different crops in same land</td><td>1. Yes
2. No</td><td></td></tr>
<tr><td>2. Disaster friendly crops</td><td>1. Yes
2. No</td><td></td></tr>
<tr><td>3. Give disaster friendly food to the domestic animal</td><td>1. Yes
2. No</td><td></td></tr>
<tr><td>4. Solar irrigation</td><td>1. Yes
2. No</td><td></td></tr>
<tr><td>5. Digital irrigation</td><td>1. Yes
2. No</td><td></td></tr>
<tr><td>6. Sprinkle irrigation</td><td>1. Yes
2. No</td><td></td></tr>
<tr><td>7. Rain water harvesting</td><td>1. Yes
2. No</td><td></td></tr>
</table>
</td><td></td></tr>
</table>

			8. Organic compost	1. Yes 2. No			
			9. Tree plantation to reduce soil erosion	1. Yes 2. No			
			10. GMO special crop cultivation	1. Yes 2. No			
			11. Past reduce from crop	1. Yes 2. No			
			12. Agricultural loan	1. Yes 2. No			
			13. Community based communication	1. Yes 2. No			
			14. YouTube, Facebook, social media, information from internet websites	1. Yes 2. No			
			15. For information exchange is there any community-based organization do you have in your area?	1. Yes 2. No			
			16. To sell the crops do you have any connection with the dealers or any company?	1. Yes 2. No			

		17. To improve your agricultural activity did you ever attend any agricultural training?	1. Yes 2. No			
		18. To reduce crop damage do you get any notification?	1. Yes 2. No	1)		
		19. Which are digital technologies do you use for agriculture?	1. Yes 2. No			
		20. Is there any community-based shelter you have in your area?	1. Yes 2. No			
		99. If others then mention				
56	Is there any successful locally-led agricultural adaptation did you adapt which was so successful? If yes then mention them.	1) Yes 2) No				
57	Why do you do these adaptations? Do you think government and other stakeholders how can help you more?					
	Section-5: End remarks					

58	If you want, you can share other important information.		
	আপনি এই গবেষণার ফলাফল সম্পর্কে যদি জানতে চান, তাহলে আপনার ইমেইল কিংবা ফোন নাম্বার আমাদের সাথে শেয়ার করুন। আমাদের টীম ভবিষ্যতে আপনার সাথে যোগাযোগ করবে। আপনি প্রয়োজনে এই প্রকল্পের গবেষকের সাথে 01799828802 এই নাম্বারে যোগাযোগ করতে পারেন। আপনাকে ধন্যবাদ। **ইমেইলঃ** **ফোন নংঃ**		

Analysis plan

For Descriptive Statistics

Possible Heading	**Variables**
Socioeconomic condition of the respondents	Q.2 Age, Q.3 Gender, Q.4 Occupation, q.5 education, q.7 family size, q.8 income, q.9 savings, q.10 loans, q.12 smartphone, q.13 hh structure, q.14 hh type
Agricultural activities	q.15 agricultural activity, q.16 seasonal crops, q.17 agricultural facilities, q.18 irrigation water source, domestic animals, q.19,
Climate change- perceptions	q.20 seasonal patterns of disasters, q.21 disaster affecting agricultural activity, q.22 changes due to disaster in the last 20 years, q.23 disaster and ecological changes, q.24 disaster and changes in river, q.25 days flood sustain,
Impacts	q.26 river expansion, q.27 area lost, q.28 changes in agriculture, q.29 changing pattern of the river, q.31 do you know about climate change, q.32 changes have you seen in different agriculture seasons, q.33 agricultural activity face any barriers due to natural disasters, q.34 challenges in agri activity, q.35 loss of agricultural land, q.37 migration, q.38 leaving agricultural activity, q.39-40 shifting home, q.41-42 loss of animals,
Transboundary water dispute	q.29 What are the prime causes do you think changing pattern of the river (option 5 and 6)? q.30 know about the Teesta water-sharing dispute,
Climate change adaptation	q.43-44 any notifications before disasters, q.45-46 self-

	assessment on information, q.47-48 preparation, q.49-50 meetings, q.51-52 external support, q.54-55 agricultural adaptation, q.56-57 locally led agricultural adaptation, q.38 Have you ever left your agricultural activity?
Barriers for adaptation	q.53 barriers for adaptation

For Regression or other advanced analysis

Independent Variables	**Dependent Variables**
q.8 your monthly income	q.54 Have you ever done any agricultural adaptation (Yes, No) q.55 if yes then mention them? (different crops on the same land, solar irrigation, digital (smart) irrigation, tree plantation to reduce erosion, GMO crop cultivation, accessing agricultural loans, information seeking from social media, attending trainings, community based organization formation, use of digital technologies,
q.9 Do you have any monthly savings?	
q.12 Do you have a smartphone?	
q.15 What type of agricultural activity?	
q.21 How do natural disasters affect your agricultural activity?	
q.24 In the last 20 years, how much has the river changed because of natural disasters?	
q.25 How many days does the flood sustain?	
q.27 How much area is lost every year due to river erosion?	
q.29 What are the prime causes do you think changing pattern of the river?	
q.30 Do you know about the Teesta water-sharing dispute and if yes then what do you know about it? (second part of this question also)	
q.31 Do you know about climate change?	
Q.53 second part	