Original Research Article

Impact of Climate Change on The Livelihood and Eco-System of Teesta River Basin Char Land of Bangladesh

Abstract

This study anticipates identifying how does climate change affect the livelihood and ecosystem of char land and to recommend some climate smart ways to reduce the vulnerable situation of Teesta River basin char land. In this research, both qualitative and quantitative methodologies will be used. Structured questionnaire and related documents will be used. Both primary and secondary data will be used. Primary data will be collected from char inhabitants who will be the focus of this research. Survey will be conducted in two districts (Rangpur and Nilphamari) and four unions (Lakhitari, Topa Madhupur, Shatibari, Gulmund) of four upazilas (Gangachara, Kaunia, Dimla, Jaldhaka). A total of 50 respondents from each selected char union will be selected following a multistage random sampling procedure. Thus, there will be altogether 200 respondents selected for this study. Data will be collected with the help of a pre-tested questionnaire. Data related to age, education level, occupation, knowledge about climate change of char inhabitants will be collected. Perception of char dwellers regarding climate change will be found. Data related to the main reason and threat of climate change will be identified. Impact of climate change on livelihood and different component of ecosystem will be detected by asking some climate related questions. Finally, some strategies will be applied to mitigate the climate change problem. Some weather data will be also collected as secondary data. Data collected from the respondent (samples) would be verified, compiled, tabulated and analyzed statistically according to the objective of the study. Pearson's product moment Co-efficient of correlation will be used to explore the relationship between the concern variable. The collected data will be analyzed by SPSS software.

Comment [DC1]: Present tense or past tense will be more appropriate instead of future tense. It is to be done in the entire paper.

Comment [DC2]: At lest one line needs to be written relating to findings.

Key words: Livelihood, ecosystem, Climate change, agroforestry, char land, environment

Introduction

1.1 Background of the Study

Bangladesh has achieved significant progress over the last decade, and the country is currently on its path to transitioning from a developing to a developing economy (OECD, 2015, UN, 2018). However, due to unequal distribution of resources and development efforts, not everyone benefits (Attaur et al. 2016). Due to limited access

and rights to resources and even basic requirements, some people in the country tend to remain marginalized (Hossain et al. 2012; Rahman et al. 2017). Furthermore, this situation is deteriorating as the frequency and severity of various climatic problems such as cyclones, floods, river erosion, heavy rain, and drought increase (MoEF, 2009; Parvin et al. 2016). People in Bangladesh are increasingly vulnerable due to a combination of social, economic, and political reasons, as well as the climate calamity.

Bangladesh is one of South Asia's most vulnerable countries to climate change due to its physical, social, and economic characteristics (Huq & Ayers, 2008). Natural hazards such as floods, erosion, cyclones, heavy rain, drought, and other natural disasters are typical occurrences in Bangladesh, and climatic variability is one of the main causes of these catastrophes (Hossain et al. 2012; IPCC, 2014). Bangladesh is a country with extreme geographical vulnerability, with 70% of the population living in flood-prone areas and 26% in cyclone-prone areas (Mahmood, 2014). In Bangladesh, significant natural calamities such as floods, erosion, and cyclones have displaced around 39 million people since 1970. (Alam, et al. 2007; Asaduzzaman, 2016). Experts predict that by 2050, roughly 6 to 8 million more Bangladeshis may be relocated as a result of rising global temperatures and sea levels (Harmeling and Eckstein, 2013).

Chars are home to over 10% of the world's population (chars) (G. Baldacchino, 2006). Furthermore, it is estimated that the char's area, which encompasses roughly 7200km2, is home to 4–5% of Bangladesh's population. (S. Paul, M.R. Islam, 2015). There are 56 large and 226 little chars in this country (Char Banglapedia 2014). Bangladesh's char land is often vulnerable to multiple disasters due to its complex environment. (S. Paul, M.R. Islam, 2015), and the people who live there are the ones who are most at risk. Approximately 12 million char dwellers in Bangladesh are affected by annual floods, erosion, and poverty. (Shafi Noor Islam and E.R., Dewan Ashraf, 2011). Char land, on the other hand, is remote and vulnerable, with nearly 80% of its residents living in extreme poverty. (M.R. Islam, 2018) and don't own any land of their own. More than 70% of the char land population is made up of farmers and fishermen. (Zaman, M.Q., 1991).

Nearly 14 percent of the total cultivated areas of Bangladesh is covered by the Teesta flood plain It provides livelihood opportunities directly to approximately 7.3 percent of the population (Asian Foundation report 2013). 9.15 million people's livelihoods are covered by this flood plain areas in five districts of Rangpur Division (Gaibandha, Kurigram, Lalmonirhat, Nilphamari, and Rangpur) (Mondal, Sanaul H. et el 2017). This river water is being used in various sectors of human life including livelihood, irrigation, fisheries and household uses. For their livelihood around 70% of these people of northern part of Bangladesh are directly dependent on the river. The Teesta flood plain basin is mainly agrarian. Rice, wheat, maize, pumpkin, jute, potato is grown in this area as sole crop. Rubber and tea are cultivated as supplementary crops. Char areas are often

called as the place of multiple vulnerabilities due to access of education, medicine and even daily basic needs are inadequate and insufficient.

1.2 Problem Statement

The inhabitants of Teesta River basin char were heavily dependent on fishing on the Teesta River. The river was very rich in fish and the char land people never returned empty-handed. Every day in the dry season, they caught many kinds of fish and cultivated rice in Char land (a small island on the river). The soil was fertile and suitable for agriculture, and six different seasons seemed to be a blessing to the people. There was seasonal rainfall at the time, it was easy to adjust in winter, and summer temperatures were not as high as they are today. Agriculture and fishing were the main sources of income for the villagers of the Teesta River basin. The Teesta River is small but very deep and has water all year round. The availability of natural resources, weather, seasonality, and livelihoods changed depending on the resources of the river. In recent years, there has been a shortage of river fish. When the river was flowing regularly, it was home to many species of fish such as bagal, petit, carbaus, boilal, boal, butter, and big shrimp. However, most of these fish species are extinct or endangered.The ecosystem of Teesta River Basin has changed. Water scarcity is a major problem in irrigation and fishing. And today, it is difficult to even use fresh water for drinking and home use. The Teesta River is woven, flat and wide, with little flow. Every year, people here have to withstand flash floods and bank erosion. And the number of people losing land due to bank erosion is increasing every day. Today, many families live in shelters on the banks of the Teesta River, making it very difficult for them to meet their basic needs. They have problems with food insecurity, and many cannot eat three meals a day.

Climate change is already affecting biodiversity, and it is expected to become a more serious hazard over the next few decades. The melting of Arctic Sea ice poses a threat to biodiversity throughout the ecosystem and beyond. Water scarcity is found in the char regions due to dryness of Teesta during the pre- and post- monsoon seasons each year. It limits the livelihood options available to the char dwellers. River-dependent livelihood options such as fishing, and boating become unavailable due to the dryness. As a result, char dwellers depend on agriculture as a major means of earning a living. Due to climate change floods, droughts, storms, hailstorms, char erosion, erratic rainfall, cold waves and climate variability have tremendous impact on the livelihood and ecosystem of Teesta River basin char land. Climate change impacts their daily life and livelihood. The char peoples practice agriculture and sometimes they involve another source of income such as livestock rearing, day labor, handicraft etc. Char peoples are below the poverty line. Due to cope up with the changed climate they are required to live through this hard situation. It is needed to find out some climate smart ways and strategies to confirm their better survival.

1.3 Rationale of the Study

Bangladesh is extremely vulnerable to climate change as a result of a lot of hydroelectric dams. geological and socioeconomic factors, such as: (a) its location in the world; (b) the kind of geology; (c) the type of geology; (d) the South Asia is divided into two parts: (a) the Himalayas and the Bay of Bengal; and (b) the remaining 12 percent hilly and 8% flat. (c) extreme climate fluctuation governed by monsoon, (d) high population density and poverty incidence; and (e) terrace region and deltaic terrain with low elevation; and (e) The majority of the population is reliant on crop cultivation, which is heavily influenced by climate change. Climate variability and hazard are two terms that are often used interchangeably. Climate change is already having a negative influence on agriculture, biodiversity, extreme environmental dangers, and socioeconomic situations in Bangladesh. Teesta is Bangladesh's fourth largest trans-border river. The river's upstream influx supports agricultural output in the lower Teesta River Floodplain (TRF) in the country's north-west area. However, after the construction of the Dalia and Gozaldoba barrages, the floodplain has been prone to both drought and flooding. Due to climate fluctuation, there is a massive reduction in water flow and less precipitation throughout the dry season, resulting in cyclic drought. During the 13th rainy season, when strong rains combine with faster Himalayan glacier melting caused by climate change, a series of flash floods occur. As a result, residents of the lower Teesta basin must deal with drought and flood in the same year. The Teesta literature does not provide a detailed and uniform depiction of the key time or adaptation ways.

Rangpur, Nilphamari, Kurigram, Ghaibanhha, Jamalpur, Mymensingh, Sirajgonj, Bogura, Rajshahi, ChapaiNawabgonj, Pabna, Taingail, Shariatpur, Faridpur, Barishal, Patuakhali, Blola, Manikgonj, Munshigonj, and Noakhali are the major Char populated districts of Bangladesh. A vast number of people live in these. Char areas and rely on Char-based farming systems for their livelihood. As a result, an integrated approach with crop and trees is required to increase productivity, maintain ecological balance, and improve the socioeconomic status of the Char land people. Teesta river basin char areas have been highlighted as tremendously vulnerable areas. Several natural disasters such as floods, drought, river erosion etc. are greatly found in those areas. In the char areas, more than 60 percent of people do not have any cultivated land other than homestead only. Therefore, for improving the livelihood of the char land people, increasing productivity of the homestead farming system is necessary. Moreover, there are huge scope to introduce improved cropland agroforestry production systems in char land area of Teesta River basin which may be ensure sustainable environment friendly climate resilience land use systems. Indeed, in char land area climate smart well adapted agricultural option is much needed. But still no systematic and comprehensive study about the impact of climate change on agriculture, eco-system and livelihood has been done. So, considering the fact a study on the impact of climate change on the livelihood and eco-system of the Teesta River char land of Bangladesh will be conducted.

1.4 Research Questions

The research was conducted based on the following questions:

1. What are changes of climate pattern observed by the char dwellers for the last 10 years?
2. What are the impacts of climate change found by the char dwellers on livelihood and ecosystem?
3. What are the most practiced mitigation strategies by the char dwellers?
4. How are climate change parameters related with livelihood and ecosystem of char areas?
5. How demographic characteristics of char peoples are related with mitigation strategies?

1.5 ResearchObjectives

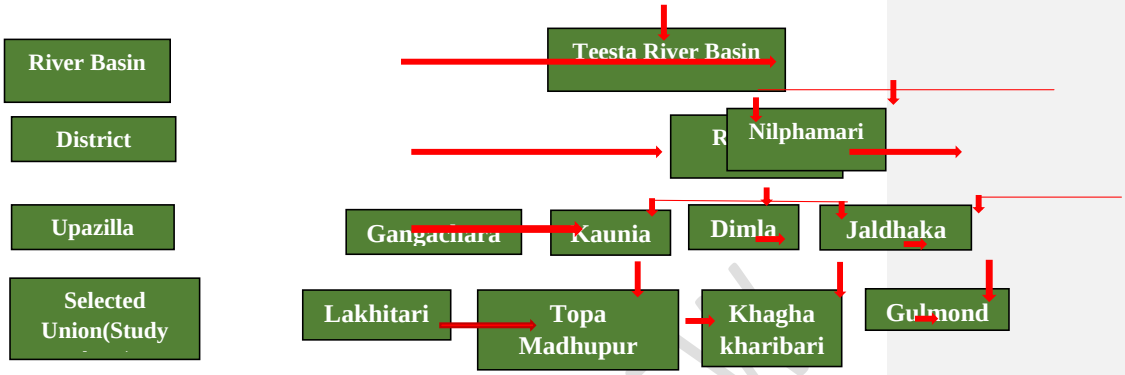
The specific objectives of the study are as follows:

- To conduct an in-depth survey of char communities at risk from or affected by climate change.
- To identify how does climate change affects the livelihood of char dwellers.
- To determine how climate does change affects the ecosystem of char land.
- To determine char dwellers' perceptions and adaptation practices to climate change.
- To recommend some climate smart ways to reduce the vulnerable situation of char land.

Methodology

2.1 Study Area Selection

The study area was specially selected for its location advantages, flood and drought risks, topographical properties and population diversity. The survey is being conducted in the Union of Lakhitariin Gangachara upazila and in the Union of Topa Madhupur in Kaunia Upazila in the Rangpur district and in the Union of Kha Khagibari of the Dimla Upazila and in the Union of Gulmonda in Jaldhaka Upazila in the Nilphamari district (Fig. 1). Both districts are located in the lower part of the Teesta basin. Physically, these two districts are made up of two natural divisions. They are having flat land and low land.



Source: Developed by Researcher

Fig-1: Selection of Study Area

Fig-2Mapofstudy area

2.2 Research Design

Both qualitative and quantitative methods were used to identify the impacts of climate change on livelihood as well as ecosystem of Teesta River basin char land of Bangladesh.

2.3 Data collection methods

Data collection method is the process by which required data are collected. It is one of the most important stages in conducting research. The following data collection methods were used in this study:

2.3.1 Questionnaire Survey

Data was collected with the help of a pre-tested questionnaire. Structured questionnaire was applied for survey to detect how does climate change influence the livelihood and ecosystem of Teesta River basin char land.

2.3.2 Interview

In this research interview was taken about the biodiversity as well as ecosystem of the selected char land and some climate related data were collected from weather office and from some NGOs.

2.4 Sample

Four unions of four Upazilas of two districts were survey to conduct the study. By using multistage random sampling procedure, a total of 96 respondents from each selected char union will be selected.

2.4.1 Sample Size Determination

Sample size is the number of observations taken from a population. It is the part of the population chosen for a survey or experiment. Sample size must be adequate to represent the population. Larger sample size gives more accurate finding of a study. Before collecting data, it is important to determine how many samples are needed to perform a reliable analysis. Sample size determination is the mathematical estimation of the number of population units to be included in the study. Sample size must be adequate to represent the population. The determined size should be optimum and has to be obtained by the scientific method. Determination of sample size is an important element of every research based on sampling. Sample size is influenced by the factors used for sample size calculation such as size of population, margin error, confidence level, variability etc. As the population of the study was heterogenous and simple random sampling method was used, large number of samples were selected to ensure representation of the population. The following well-known statistical formula was used to determine the sample size from an known population (Cochran, 1963).

$$n_O = \frac{Z^2 pq}{e^2}$$

n_0 = ((1.96)2 x .5(.5)) / (.05)2

= (3.8416 x .25) / .0025

=.9604 / .0025

=384.16

=384

Where n_0 is the sample size,

Z^2 is the abscissa of the normal curve that cuts off an area α at the tails.

(1 – α) equals the desired confidence level, e.g., 95%).

e is the desired level of precision,

p is the estimated proportion of an attribute that is present in the population, and q is 1-p.

The value for Z is found in statistical tables which contain the area under the normal curve. e.g., Z = 1.96 for 95 % level of confidence

Table 1 Sample size

Sl No	Name of Districts	Name of Upazilas	Name of Unions	No. of Household	No. of Population	Household Proportion (%)	Household no./Respondents
1	Rangpur	Gangachara	Lakhitari	5262	28165	20.95%	384x20.95% =81
2		Kaunia	Tepamadhupur	9179	35633	36.54%	384x36.54%=140
3	Nilphamari	Dimla	Khaga Kharibari	6100	31200	24.30%	384x24.30%=93
4		Jaldhaka	Gulmund	4573	36305	18.21%	384x18.21% =70
			Total	**25114**	**94998**	**100%**	**384**

2.5 Data Collection procedure

Data collecting is the most crucial element in any research project. The initial step in any research project is to collect data. For the entire study project, data collecting on a specific area is required. The data collected must be accurate and complete, or the research will be invalid. The data and information for this study were gathered from both primary and secondary sources.Primary data was collected on the spot in the research location. To acquire both quantitative and qualitative data, a questionnaire survey was undertaken in the research region. Both primary and secondary data will be used in the research study. Both qualitative and quantitative data play an important role in obtaining reliable information as well as the result of any study. There are two sources of data of any study to get relevant data and information.

2.5.1 Sources of Data

The sources of data for this study were primary and secondary sources.

2.5.2 Primary Sources

Data that has been collected from first-hand- experience is known as primary data. Primary data is collected from the household of Lakhitari, Topa Madhupur, Khaga Khagibari and Gulmunda Union during study period. Furthermore, observation and group discussions were done to acquire additional and extra information concerning the influence of climate change on the livelihood and ecosystem of the study region's char land. Primary data for the study was collected through a survey, one-on-one interviews, and focus group discussions.

2.5.3 Secondary sources

To detect the climate change impact some of the climate related data was collected from different GOs and NGOs office which was treated as secondary sources of data.Some secondary data was used to finish the research task accurately. Secondary data on the study area's physical setting, total household population, institutional framework, policy guidelines, and maps were obtained from a variety of government and non-governmental organizations, including the published Government statistical yearbook, physical map from LGED, Upazilla Agriculture Office, and Vumi Office, among others. Secondary data, on the other hand, was gathered from a variety of government agencies, non-governmental organizations, and published works such as reports, books, records, journals, maps, and papers from various libraries. Secondary data sources for the research of land use and land use change were gathered from the Bangladesh Bureau of Statistics (BBS), the Local Government Engineering Department (LGED), and other websites. The sources of all secondary data sources are mentioned in Table-3.

Result and Discussion

3.1 Demographic characteristics of the study area

Demographic characteristics like age, education level, occupation, annual income, and farm size of the respondents of the Teesta River basin char land is not same. These factors significantly influence the impact of climate change on livelihood and ecosystem of that char unions as well as effect on the mitigation strategies.

3.1.1 Age of the Respondents

The study was conducted on a total of 384 respondents and these respondents were distributed in four villages. The result of the household survey showed that the maximum number of respondents (n=166) belong to the age category of 30-40 years. The second largest age category was > 60 years and there were 110 respondents in this category. There were 80 respondents found in the 50-60 years age category. There were also 78 respondents who were found those age was 41-49 years (Table **3**).

Table-**2** Distribution of Respondents by Age Groups.

Age Group	Study Unions									
	Lakhitari		Tepamadhupur		Khaga Kharibari		Gulmund		Total	
	HH	%	HH	%	HH	%	HH	%	HH	%
30-40	22	27.2	42	30.0	21	22.6	31	44.3	116	124.1
41-49	20	24.	22	15.7	16	17.2	20	28.6	78	86.2

		7								
50-60	20	24.7	26	18.6	17	18.3	17	24.3	80	85.9
>60	19	23.5	50	35.7	39	41.9	2	2.9	110	104
Total	81	100	140	100	93	100	70	100	384	400

3.1.2 Education Level of the Respondents

The respondents' education levels were calculated in terms of their achievement of certificate. The result showed that 78.39% of respondents have recognized education and the rest 21.61% respondents have no formal education. Among the literate respondents 103 respondents took part in primary level, 93 respondents took part in secondary level, 62 respondents achieved higher Secondary School education, 43 respondents achieved Graduation (Table 2).

Table 3. Education Level of the Respondents

Education Level	Study Unions									
	Lakhitari		Tepamadhupur		Khaga Kharibari		Gulmund		Total	
	HH	%	HH	%	HH	%	HH	%	HH	%
Illiterate and No Formal education	29	35.8	11	7.9	28	30.1	15	21.4	83	95.2
Primary	23	28.4	16	11.4	42	45.2	22	31.4	103	116.4
Secondary	21	25.9	42	30.0	15	16.1	15	21.4	93	93.4
Higher Secondary	5	6.2	43	30.7	5	5.4	9	12.9	62	55.2
Graduate	3	3.7	28	20.0	3	3.2	9	12.9	43	39.8
Total	81	100	140	100	93	100	70	100	384	400

3.1.3 Occupation of the Respondents

Respondents are involved in different occupations in the study villages. Agriculture is the key activity in both the villages. Besides this, fishing, stone collecting, boating and daily labor are major activities for northwestern char land of Bangladesh. Analysis of the respondents' (n=384) occupation showed that 158 respondents were primarily engaged in agriculture as a primary occupation followed by small business (107), day labour (33), private service (23). On the other hand, 21 respondents are housewife and other 21 respondents are involved in other activities like Van/ rickshaw puller, auto/nosimon driver. 5 respondents reported that they do govt service and 9 respondents retired from govt service. Another 5 respondents were engaged in livestock rearing activities and

among 384 respondents, 1 respondent is involved in fishing activities and another 1 respondent is engaged in handicraft.

Table-4 Occupation of the Respondents

Occupation	Study Unions									
	Lakhitari		Tepamadhupur		Khaga Kharibari		Gulmund		Total	
	HH	%	HH	%	HH	%	HH	%	HH	%
Housewife	6	7.4	7	5.0	2	2.2	6	8.6	21	23.2
Agriculture	36	44.4	56	40.0	41	44.1	25	35.7	158	164.2
Small business	24	29.6	40	28.6	24	25.8	19	27.1	107	111.1
labor	8	9.9	17	12.1	5	5.4	3	4.3	33	31.7
Private service	6	7.4	3	2.1	8	8.6	6	8.6	23	26.7
Others	0	0	8	5.7	12	12.9	1	1.4	21	20
Fishing	1	1.3	0	0	0	0	0	0.0	1	1.3
Retired	0	0	6	4.3	1	1.1	2	2.9	9	8.3
Government service	0	0	0	0	0	0	5	7.1	5	7.1
Livestock rearing	0	0	3	2.2	0	0	2	2.9	5	5.1
Handicraft	0	0	0	0	0	0	1	1.4	1	1.4
Total	81	100	140	100	93	100	70	100.	384	400

3.1.4 Annual Income

The income of the population is classified into four categories. (Table-4) shows that, among 384 respondents, 188 char inhabitants have income that is upto 1 lac where 101 char peoples have highest annual income that is more than 3 lac. 79 respondents' annual income was 1-2 lac and 16 of the Teesta River basin people's annual income was 2-3 lac.

Table-5: Annual Income

Annual Income	Study Unions									
	Lakhitari		Tepamadhupur		Khaga Kharibari		Gulmund		Total	
	HH	%	HH	%	HH	%	HH	%	HH	%
Upto1 lac	55	67.9	41	29.3	58	62.4	34	48.6	188	208.2
1 lac -2 lac	24	29.6	2	1.4	27	29.0	26	37.1	79	97.1
2-3 lac	0	0	11	7.9	2	2.2	3	4.3	16	14.4
More	2	2.5	86	61.4	6	6.5	7	10.0	101	80.4

than 3 lac										
Total	81	100	140	100	93	100	70	100	384	400

3.1.5 Farm Size

In Teesta River basin char land, highest landowner was found in Khaga Kharibari union (212 decimals) followed by Tepamadhupur union (170 decimals). The lowest landowner was found in the Gulmond union that was 72 decimals. Moderate landowner was observed in Lakhitari union (160 decimals).

Table-6. Farm Size

Farm Size (Average/HH)	Study Unions			
	Lakhitari	Tepamadhupur	Khaga Kharibari	Gulmund
Homestead (Decimal)	120	115	132	62
Others (Decimal)	40	55	80	10
Total	160	170	212	72

3.2 Perception on climate change

3.2.1 Knowledge about climate change

Climate change, as defined by the Eco life dictionary, is a long-term change in local or worldwide weather patterns. Contrary to global warming, which only refers to one component of climate change—a rise in the earth's surface temperature—climate change refers to modifications to a region's general weather patterns, such as changes in precipitation, temperatures, cloud cover, and other factors. However, according to the respondents, there is no concrete definition or understanding of what constitutes climate change. 93% of them clearly grasp that climate change refers to changes in long-term typical weather. They are unsure of the time frame. 3% of respondents have no idea about climate change that will affect the average weather during the next 20 to 30 years (Fig. **1**).

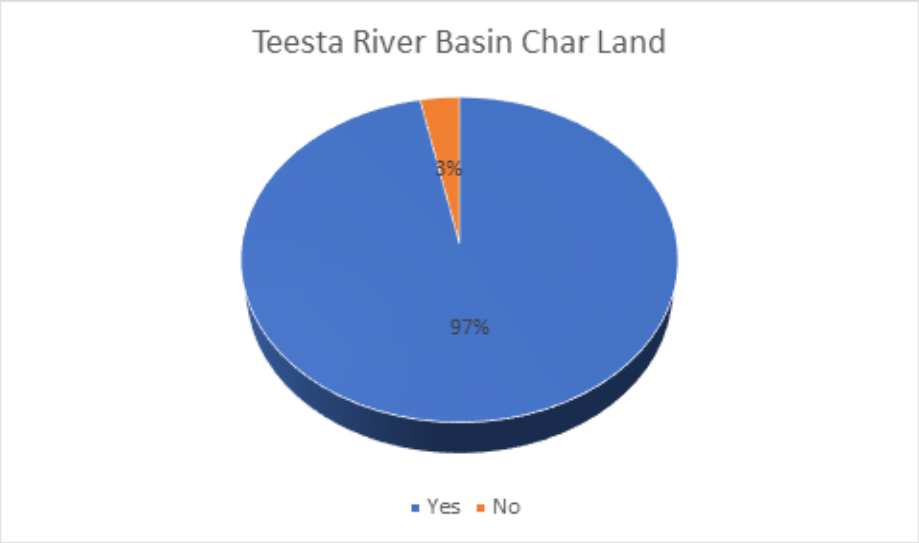


Fig. 3. Knowledge about climate change

3.2.2 Reasons of climate change

The Teesta River basin char dwellers were asked to find out the different reasons of climate change. According to perception of that peoples, it was observed that 42% of the people said that global warming is the main reason of climate change followed by cutting down of trees (23%). 22% of inhabitants observed that overpopulation was the third reason of climate change followed by different pollution (11%). Industrialization was another reason of climate change, and it was perceived by 1% of the peoples of Teesta River basin area. In that area 1% respondents also perceived that climate change occurred naturally (God gifted).

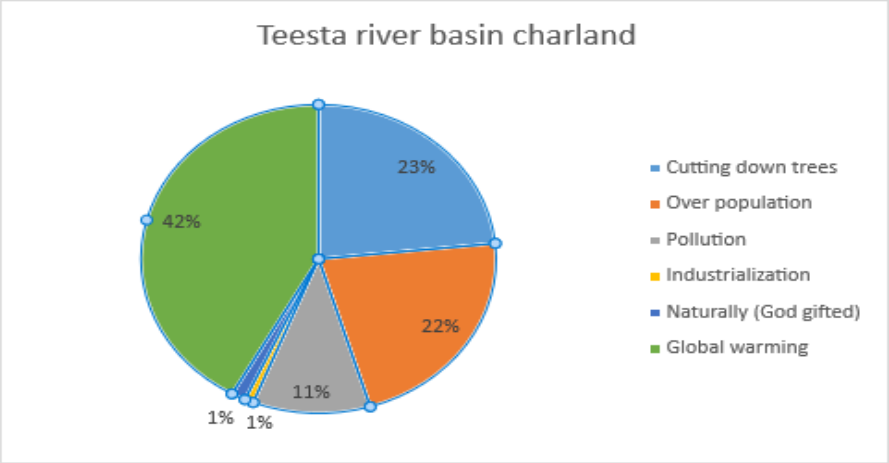


Fig. 4. Reasons of climate change

3.2.3 Threat of climate Change

From the below figure it was observed that ongoing climate change has 78% impact on agriculture followed by health of peoples and other animals that is 20%. Impact of climate was 2% on biodiversity quality and sustainability in Teesta River basin char land. According to the perception of peoples, there was no impact of climate change on transportation communication, business, and instigating disaster.

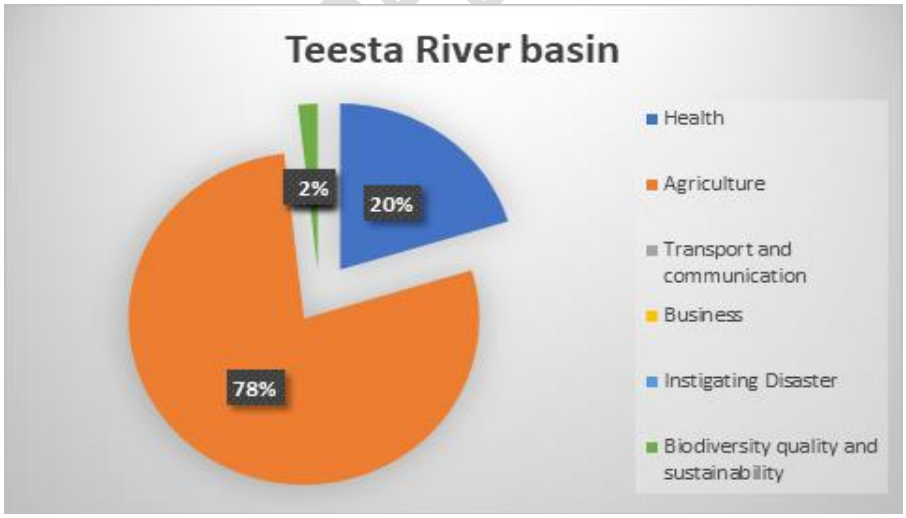


Fig. 5. Threat of climate Change

3.3 Climate Change pattern according to the perception of char inhabitants in Teesta River basin Char land

According to perception of Teesta River basin char people's data were collected on three seasons climate change pattern. In the rainy season they observed increase lightning from sun as the highest effect of climate change that has a WAI of 1.77. Teesta river basin people perceived dry spell frequency as the second highest extent of climate change that has a WAI of 1.74 followed by timing of rain offset, uneven distribution of rainfall and timing of rain onset (Table-3)

The highest extent of climate change was found in the minimum temperature in winter season of the Teesta River basin char land people, and it has highest WAI of 1.72. The second highest extent of climate change was perceived as the late start of winter followed by number of cool days, chilling injury in crop, cold intensity, ending of winter, winter duration and maximum temperature. The lowest extent of climate change was perceived winter rainy days that WAI of 1.02.

In summer season, the highest extent of climate change was identified as maximum temperature with WAI of 1.82. The second highest extent of change was observed as duration of summer season was increased and is has WAI of 1.43 followed by hailstorm, ending of summer, starting of summer, intensity of hot days, summer rainy days. The lowest extent of climate change was found as minimum temperature in summer season with WAI 0.98.

Table-7Climate Change pattern according to the perception of char inhabitants

Components of climate change	**Extent of change**						**WAI**	**Rank order**
	No change		**Increased**	**Decreased**				
	HH	%	HH	%	HH	%		
Rainy Season								
Lightening	13	3.4	307	79.9	64	16.7	1.77	1
Dry spell frequency	13	3.4	296	77.1	75	19.5	1.74	2
Timing of rain offset	16	4.2	294	76.6	74	19.3	1.72	3
Uneven distribution of rainfall	27	7.0	248	64.6	109	28.4	1.58	4
Timing of rain onset	21	5.5	130	33.9	233	60.7	1.28	5
Total amount of precipitation	20	5.2	121	31.5	243	63.3	1.26	6

Wind speed	30	7.8	119	31.0	235	61.2	1.23	7
Rainy days frequency	18	4.7	85	22.1	281	73.2	1.17	8
Season duration	76	19.8	124	32.3	184	47.9	1.13	9
Cloudy weather	33	8.6	55	14.3	296	77.1	1.06	10
Sunshine hours	205	53.4	85	22.1	94	24.5	0.69	11
Winter Season								
Minimum temperature	11	2.9	287	74.7	86	22.4	1.72	1
Starting of winter	48	12.5	176	45.8	160	41.7	1.33	2
Number of cool days	43	11.2	115	29.9	226	58.9	1.19	3
Chilling injury in crop	13	3.4	84	21.9	287	74.7	1.18	4
Cold intensity	5	1.3	56	14.6	323	84.1	1.13	5
Ending of winter	17	4.4	41	10.7	326	84.9	1.06	6
Winter duration	26	6.8	48	12.5	310	80.7	1.06	7
Maximum temperature	63	16.4	84	21.9	237	61.7	1.05	8
Winter rainy days	8	2.1	15	3.9	361	94.0	1.02	9
Summer Season								
Maximum temperature	8	2.1	321	83.6	55	14.3	1.82	1
Duration of season	98	25.5	265	69.0	21	5.5	1.43	2
Hailstorm	9	2.3	138	36	237	61.7	1.34	3
Ending of summer	131	34.1	215	56.0	38	9.9	1.22	4
Starting of summer	151	39.3	209	54.4	24	6.3	1.15	5
Intensity of hot days	6	1.6	52	13.5	326	84.9	1.12	6

Summer rainy days	22	5.7	40	10.4	322	83.9	1.05	7
Minimum temperature	39	10.2	33	8.6	312	81.3	0.98	8

3.4Impact of climate change on livelihood according to Teesta River basin char land inhabitants' perception of previous 10 years

There are five capitals of livelihood. These are: human capital, natural capital, financial capital, physical capital, and social capital. Teesta River basin char respondents have long experience about climate change and weather. As they are permanent residents, they were asked to know about the impact of climate change on their livelihood assets. Perceptions of the char respondents regarding impact of climate change are found as per following.

3.4.1 Human capital

The knowledge, skills, and health that people invest in and accumulate during their lives make up human capital. Teesta River basin char peoples were asked about impact of climate change on their human capital. According to their perception it was found that great extent of loss was found in skills of char peoples (48.35%) followed by knowledge of char peoples (44.27%). It was also observed that a third great extent of loss was found in char peoples good health (41.67%) followed by ability to labor (39.06%).

3.4.2 Natural Capital

Respondents of char land perceived that among all the natural capital assets, climate change has a great impact on soil. Among total respondents (384), 166 (43.2%) observed that soil becomes dry day by day due to climate change followed by rivers becoming dry (37.8%) (Table-4). They found that trees growing become difficult (45.1%), due to drought underground water decreasing (61.7%) and air become dry due to climate change, and these are small extent of loss. They were also asked about sunshine hour reducing and they perceived it was nil that means sunshine hour is increasing day by day.

3.4.3 Financial capital

All the respondents were asked about the impact of climate change on financial capital. They mentioned that among all the financial capital due to climate change great extent of loss were as like flash flood damage crop (49.7%), floods reduce crop yield (39.6%), the peoples were migrated to another source of income (30.5%). A moderate extent of loss was observed, like decreasing of fish production due to lack of pond and river water

(62.8%), pressure on people's deposit (36.5%) and cyclone, tornado causes loss of crops fruits, livestock (43.2%). On the other hand, small extent of loss occurs like depending on taking loan from GO and NGO sources (37.8%) and livestock loss due to drought (71%) (Table-4).

3.4.4 Physical capital

Teesta River basin char inhabitants observed that climate change impact found in all physical capital and great extent impact perceived on people's migration to another place (41.4%) (Table-4). The moderate extent of loss was perceived by 39.6% of the char people and it causes loss in health facilities and loss of property (shops, land, brick field, small cottage industries). 45.1%, 71.9% and 77.6% people perceived that small extent of loss was found due to climate change in cyclone and flood damage home, loss of uses of technologies and health hazard of family members respectively.

3.4.5 Social capital

Climate change impact was observed in social capital. Teesta River basin char land inhabitants were asked about to extend of climate change impact on social capital. 37.8%, 58.6% and 49.5% char inhabitants perceived that small extent of loss occur in social conflict, social community activities and education of family members respectively. There was no loss occur in drop out of children from school (56.5%) due to climate change (Table-4).

Table-8 Impact of climate change on livelihood Teesta River basin char land

Statements	**Extent of loss**									
	Great extent		**Moderate extent**		**Small Extent**		**Nil**		**WAI**	**Rank**
	HH	**%**	**HH**	**%**	**HH**	**%**	**HH**	**%**		
Human Capital										
Skill of char inhabitants	178	46.35	124	32.29	57	14.84	25	6.51	2.18	1
Knowledge of char peoples	170	44.27	107	27.86	80	20.83	27	26.11	2.09	2
Good health	160	41.67	130	33.85	85	22.14	19	4.95	2.07	3
Ability to labor	150	39.06	117	30.47	75	19.53	32	8.33	2.05	4
Natural Capital										
Soil become dry	166	43.2	147	38.3	44	11.5	27	7.0	2.18	1
River become dry	145	37.8	106	27.6	122	31.8	11	2.9	2.00	2

Trees growing become difficult	81	21.1	99	25.8	173	45.1	31	8.1	1.60	3
Due to drought Underground water decreasing	54	14.1	55	14.3	237	61.7	38	9.9	1.33	4
Air become dry	71	18.5	10	2.6	276	71.9	27	7.0	1.33	5
Sunshine hrs reducing	8	2.1	19	4.9	190	49.5	167	43.5	0.66	6
Financial Capital										
Flash flood damage crop	191	49.7	109	28.4	75	19.5	9	2.3	2.26	1
Decreased fish production due to lack of pond and river water	103	26.8	241	62.8	38	9.9	2	.5	2.16	2
Floods reduce yield	152	39.6	125	32.6	103	26.8	4	1.0	2.11	3
Pressure on deposit	110	28.6	140	36.5	132	34.4	2	.5	1.93	4
Depends on taking loan from GO and NGO sources	122	31.8	106	27.6	145	37.8	11	2.9	1.88	5
Cyclone, tornado causes loss of crops fruits, livestock	44	11.5	166	43.2	147	38.3	27	7.0	1.59	6
Migration to another income source	117	30.5	77	20.1	78	20.3	112	29.2	1.52	7
Livestock loss due to drought	10	2.6	71	18.5	276	71.9	27	7.0	1.17	8
Physical Capital										
Health facilities	95	24.7	152	39.6	104	27.1	33	8.6	1.80	1
Migration to another place	159	41.4	68	17.7	34	8.9	123	32.0	1.68	2
Cyclone and flood damage home	81	21.1	99	25.8	173	45.1	31	8.1	1.60	3

Loss of property (shops, land, brick field, small cottage industries)	33	8.6	152	39.6	104	27.1	95	24.7	1.32	4
Uses of technologies	10	2.6	71	18.5	276	71.9	27	7.0	1.17	5
Health hazard of family members	10	2.6	51	13.3	298	77.6	25	6.5	1.12	6
Social Capital										
Social conflicts	122	31.8	106	27.6	145	37.8	11	2.9	1.88	1
Social community activities	13	3.4	15	3.9	225	58.6	131	34.1	0.77	2
Education of family members disturbed	8	2.1	19	4.9	190	49.5	167	43.5	0.66	3
Increased drop out of children from school	16	4.2	42	10.9	109	28.4	217	56.5	0.63	4

3.5Strategies for mitigation of Climate change in Teesta River basin char land according to opinion/perception of char inhabitants

Teesta River basin char dwellers perceived about 24 adaptation strategies to reduce the impact of climate change on livelihood and ecosystem in that area. Among all the adaptation strategies, control of black smoke from vehicles is the most prioritized adaptation strategy of Teesta River basin char areas with a ASI of 1.90. Drought is increasing day by day in Teesta River basin char land areas. So, digging more canals got the second position among all the strategies according to the perceptions of the peoples with ASI 1.84 followed by uses of new technologies and ideas in agriculture that means smart agriculture with ASI 1.63. Rainwater harvesting was the 4th adaptation strategy with ASI 1.50 followed by building embankments around the river and canals to avoid flash flood and it was ASI 1.32. The study observed other adaptation strategies index was as like gas emission mitigation from big industries was 1.30, building river dams was 1.21, control over population growth was 1.21, installing deep tube wells was 1.14, greenhouse effect was 1.10, food processing for livestock was 1.08, stopping tree cutting was 1.04, self-resilience was 0.95, assistance from GOs and NGOs was 0.46, more tree

plantation was 0.42, assistance from international donners was 0.40, increasing awareness was 0.32, assistance from the society/community level was 0.30, social forestry was 0.28, training on climate adaptation was 0.19, adopting agroforestry was o.16, increased educational coverage was 0.16, no adaptation method use was 0.09 and more use of surface water was 0.03.

Table-9 Strategies for mitigation to Climate change in Teesta River basin char land

Strategies	**Not applicable**		**Name of intensification**						**ASI**	**Rank**
			Highly intensified		**Moderately intensified**		**No intensification**			
	HH	**%**	**HH**	**%**	**HH**	**%**	**HH**	**%**		
Control of black smoke from vehicles	98	25.5	193	50.3	59	15.4	34	8.9	1.90	1
Digging canals	115	29.9	179	46.6	81	21.1	9	2.3	1.84	2
Uses of new technologies and idea in agriculture (smart agriculture)	152	39.6	175	45.6	43	11.2	14	3.6	1.63	3
Rainwater harvesting	144	37.5	131	34.1	74	19.3	35	9.1	1.50	4
Building embankments	202	52.6	147	38.3	29	7.6	6	1.6	1.32	5
Gas emission mitigation from big industries	129	33.6	87	22.7	70	18.2	98	25.5	1.30	6
Building river dams	217	56.5	137	35.7	22	5.7	8	2.1	1.21	7
Control over population growth	175	45.6	108	28.1	17	4.4	84	21.9	1.15	8
Installing deep tube wells	220	57.3	115	29.9	42	10.9	7	1.8	1.14	9
Greenhouse effect	94	24.5	34	8.9	63	16.4	193	50.3	1.10	10
Food processing for livestock	236	61.5	133	34.6	2	.5	13	3.4	1.08	11

Stopping tree cutting	241	62.8	125	32.6	6	1.6	12	3.1	1.04	12
Self-resilience	57	14.9	17	4.4	2	0.6	308	80.2	0.95	13
Assistance from GOs and NGOs	312	81.3	45	11.7	13	3.4	14	3.6	0.46	14
More tree plantations	323	84.1	50	13.0	2	.5	9	2.3	0.42	15
Assistance from international donors	331	86.2	49	12.8	1	.3	3	.8	0.40	16
Increasing awareness	340	88.5	39	10.2	1	.3	4	1.0	0.32	17
Assistance from the society/community level	344	89.6	37	9.6	1	.3	2	.5	0.30	18
Social forestry	343	89.3	32	8.3	2	.5	7	1.8	0.28	19
Training on climate adaptation	356	92.7	17	4.4	10	2.6	1	.3	0.19	20
Adopting agroforestry	357	93.0	16	4.2	1	.3	10	2.6	0.16	21
Increased educational coverage	356	92.7	17	4.4	1	.3	10	2.6	0.16	22
No adaptation method used	367	95.6	9	2.3	1	.3	7	1.8	0.09	23
More use of surface water	379	98.7	3	.8	1	.3	1	.3	0.03	24

Conclusion and Recommendations

The findings of the study were revealed that the char of Teesta River basin region is in very vulnerable situation. The researcher will try to find out the present situation of the study area regarding climate change. In this vulnerable situation, the researcher will try to adopt some climate smart ways to reduce this vulnerable situation. Some of the agroforestry system such as homestead agroforestry system, multistoried agroforestry system and social agroforestry system will be applied. Innovation in agriculture will be induced in that areas. The study will pave the way for further research.

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