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Adaptation to Critical Stress Moments in Livelihood: A Case Study at Downstream Teesta River Basin of India

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ABSTRACT

Critical stress moments may be treated as those moments when peoples, local communities, their socio-economic parameters i.e. livelihood options are very much vulnerable to climate related risks and hazardous conditions. This paper examines some climate related risks and hazards that sustain as critical moments experienced by local livelihood in the downstream of Teesta river basin in India. Here Critical stress moments are act as drivers to the livelihood sustainability, community perceptions of the environment and adaptation practices. Therefore, the present paper takes an attempt to determine different potential adaptation practices to critical stress moments in agriculture and non-agricultural livelihoods sustain over the study sites through proper investigation of the climate induced factors responsible for the hazards.

1. Introduction

The sub-Himalayan West Bengal being situated not far from the Himalayan margin and dissected by the snow peak dependent Rivers has always been liable to floods. The reasons for high floods are excessive and intensive rainfall within small duration in small catchments and continuous rainfall of several days in bigger catchments during monsoon. The simultaneous melting of snow accumulated on high mountains and rainfall in lower catchments often caused floods of devastating nature. ((Kusari A.M. et al. 1981; Ramaswamy C. 1987; Sarkar S., 2004; Sanyal C.C., 1969, 1970) The River Teesta has a typical mixed hydrological regime (Starkel L. & Basu S., 2000), fed by snow, ice and groundwater which receives the most energy from extreme continuous rain that repeats every 20 to 50 years (Starkel L., 1972, Sarkar S., 2004b). In the downstream of River Teesta, floods and riverbank erosion are the major hazards. Lives and livelihood systems became vulnerable after each devastating flood due to disruption of agricultural production, education system, communication, and sanitation facilities. Besides, erratic rainfall, heavy gusty wind during monsoon, and drought, fog, cold waves, and heat waves during dry season have large impact on the lives and livelihoods of the people of the Teesta downstream. Communities across downstream of the Teesta River basin are responding to these critical stress moments with their parental and experiential knowledge at a limited scale. Up scaling of present practices and other new adaptation or coping actions with critical scientific and policy review are required for betterment of their lives and livelihoods in all areas of the Teesta River basin (Hassan, et al., 2021). Moreover this paper consists of qualitative and quantitative assessment of adaptation practices to hydrological and climatic critical moments in their livelihood at the hazard prone Teesta River basin in India.

2. Significance of the study:

The United Nations Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report IPCC (2014) projected that there is high confidence of extreme climate events that will have an increasing impact on human health, security, livelihoods, and poverty. Key impacts projected for Asia are:

I. More frequent and intense heat waves that will increase mortality and morbidity in vulnerable groups;
II. Heavy rain and temperature rise that will increase the risk of diarrheal diseases, dengue fever, and malaria; and
III. Increasing frequency and severity in floods and droughts that will exacerbate rural poverty, in part as a result of negative impacts on the rice crop resulting in an increase in food prices and the cost of living.

To address the adverse impacts of hydrological along with climate variability and change, it is essential to communicate an understanding of climate impact assessment to policy makers and communities. There are many possible reasons for the general lack of concern about climate change; it is possible that people are bored or fatigued because the subject is extensively discussed in the media worldwide (Nick P., 2012). Moreover Critical moment on sustainable live and livelihood and their assessment to its impact, vulnerability, climatic risk, coping strategies and adaptation is important to communicate the policy makers and reduce the vulnerability among the local community residing across the downstream of Teesta River basin.

3. Study area:

The Sub-Himalayan parts of West Bengal i.e. the North Bengal experiences frequent floods during the monsoon period from June to September. Among the six districts of North Bengal though Jalpaiguri is most prone to flood, the

district of Jalpaiguri also experience the hazardous effect of flood during the monsoon period. Jalpaiguri district is situated in the foothills of eastern Himalayas and across the district Teesta has flowing towards River Brahmaputra. Jalpaiguri district is located between 26° 16' and 27° 0' North latitudes and 88° 4' and 89° 53' East longitudes. The terrain in the district is both hilly and plain. Teesta is some of the important rivers of this district have a fragile bio-physical conditions, complex climate and socio-economic conditions as well. For the purpose of the study the plains or downstream of River Teesta has taken under consideration.

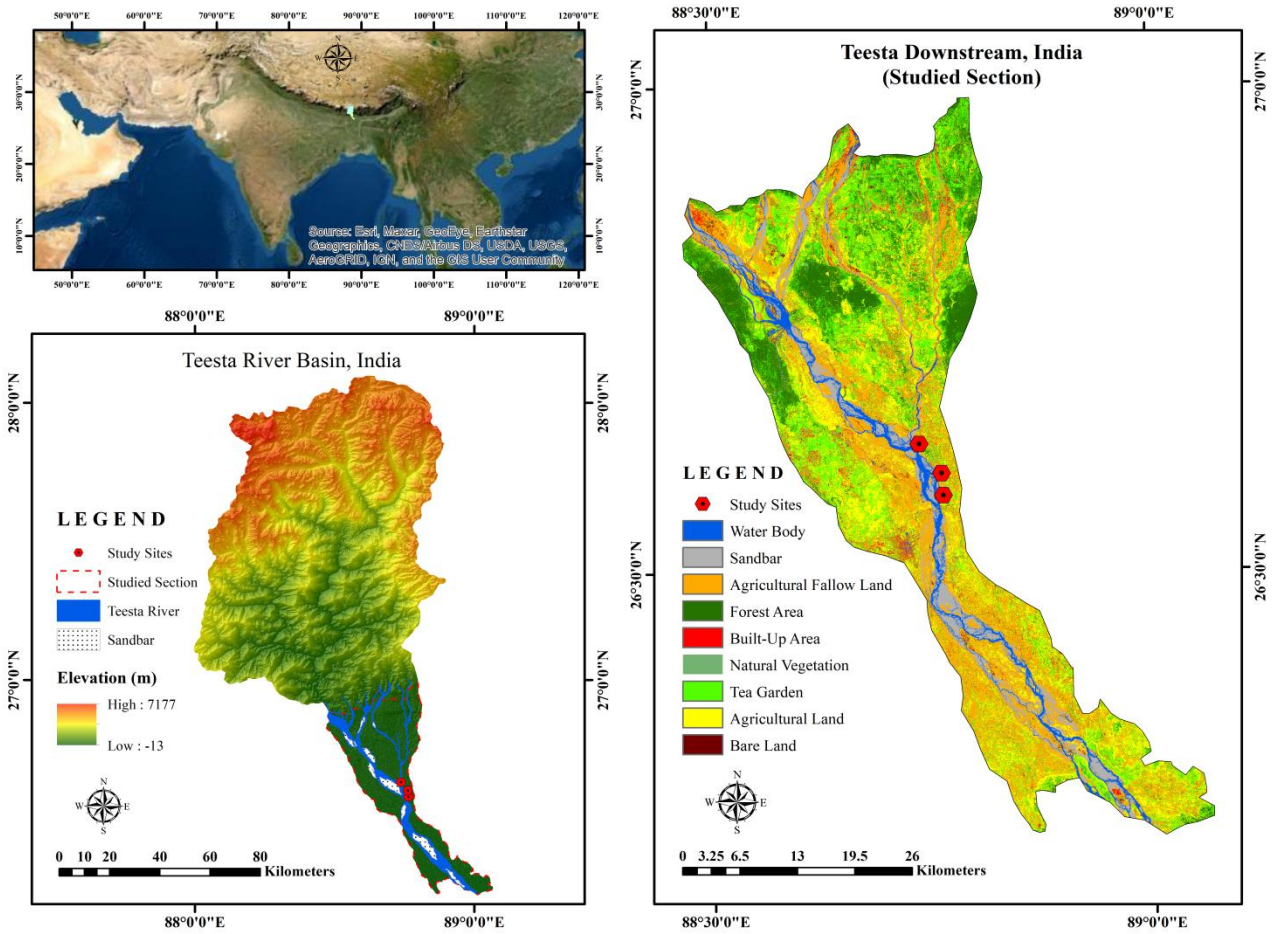


Figure1: Location of the study sites at Teesta River basin.

The downstream study sites consists of Basusuba (621.83 hectares) under Chapadanga GP of Maynaguri block, Chatrar par (301.58 hectares) and Barman para (637.89 hectares) under Domohoni GP of Mal block is located at foothills of Himalaya in Jalpaiguri district. To be precise, it is located about 11.5 kilometers North of Jalpaiguri town on the right bank of river Teesta. Basusuba, Chatrarpar and Barman para have vulnerable to frequent erratic rainfall, flooding and river bank erosion because of its proximity to mighty Teesta. Different climatic risks and hazards are every year phenomenon which causing a lot of damage to agriculture, property, livestock etc in the downstream of River Teesta basin.

4. Objectives:

4.1 To identify the moments when people and their livelihood systems are supposed to be most vulnerable to different hydrological risks and hazards.

4.2 To assess the adaptation strategies or responses to critical stress moments by the local peoples.

5. Database & Methodology:

The critical moments study utilized a mixed methods approach to identify stress periods. This may effective and achieved through the use of both quantitative and qualitative survey methods. The quantitative survey was aided through the structured questionnaire while qualitative critical-moments assessment follows a participatory research approach adopted by Groot et al. (2017) which includes focus group discussions (Figure1), case studies and key informant interviews. The participants included mostly vulnerable people i.e. farmers, fishermen, daily wage worker, local administration, and local NGO representatives, among others. At the side of primary data collection in this study the data has also been collected from various secondary sources i.e. Assessment Report of IPCC (2014), District Census Handbook (2011) are mostly consulted to used and different relevant books, journals and papers are also referred to review and analyzed. The map thus prepared through Arc GIS which made a height to the research paper.

The data and findings of the study may be treated as quantitative case and qualitative as well with various evidences

to generalize the scope of study. For the purpose of the study 133 households are selected and determined 10% from each village under the assumptions of simple random sampling.

Table1: Distribution of sample size across the study villages.

River basin	Elevation	District/ State	C.D. Block	Gram Panchayet	Selected villages	Actual household	Surveyed household (10% taken)
Teesta	Downstream	Jalpaiguri, West Bengal	Mal	Chapadanga	Basusuba	530	53
			Maynaguri	Domohoni I	Chatrarpar	433	43
			Maynaguri	Domohoni I	Barman para	368	37
			Total			**1331**	**133**

6. Findings:

It is evident that in Sub-Himalayan belt River Teesta is a mighty river having fragile bio-physical characteristics along with its specific climatic conditions experienced by the local people residing its basin area. Over the long period of time River Teesta serve various livelihood systems whereas the sustainable lives and livelihoods are facing also different climatic variability. From this point of view nowadays it is necessary to assess critical stress moment, to cope some adaptive strategies to take policy and action. In this research we have found in the downstream of River Teesta (India) how people perceive the impacts of hydrological and climatic stress moments and how they can adapt the potential strategy relating to critical moments.

6.1 Livelihood as a socio-economic parameter:

Teesta River basin is densely populated with around 30 million people. However, intra basin differences in population are vast. Around 27% population of downstream is residing in West Bengal of India, which comprises sub Himalayan plain region. Around 78% of the population in the Teesta river basin is rural while the remaining 22% is urban (Waslekar et al., 2013). The rural areas in the downstream are underdeveloped where people being highly dependent on the river with its ecosystem services for their survival.

In the downstream of River Teesta in particular Jalpaiguri, people around 20 years ago were engaged in regular traditional system of low-land agriculture, fishing, and wage labour in the nearby towns and Siliguri town, and marketing of agriculture produce for subsistence needs. However, after the completion of Teesta barrage at Gajoldoba, the situation changed and the area is affected by recurrent and severe floods degrading the agriculture land suitable for cultivation (Hassan, et al., 2021).

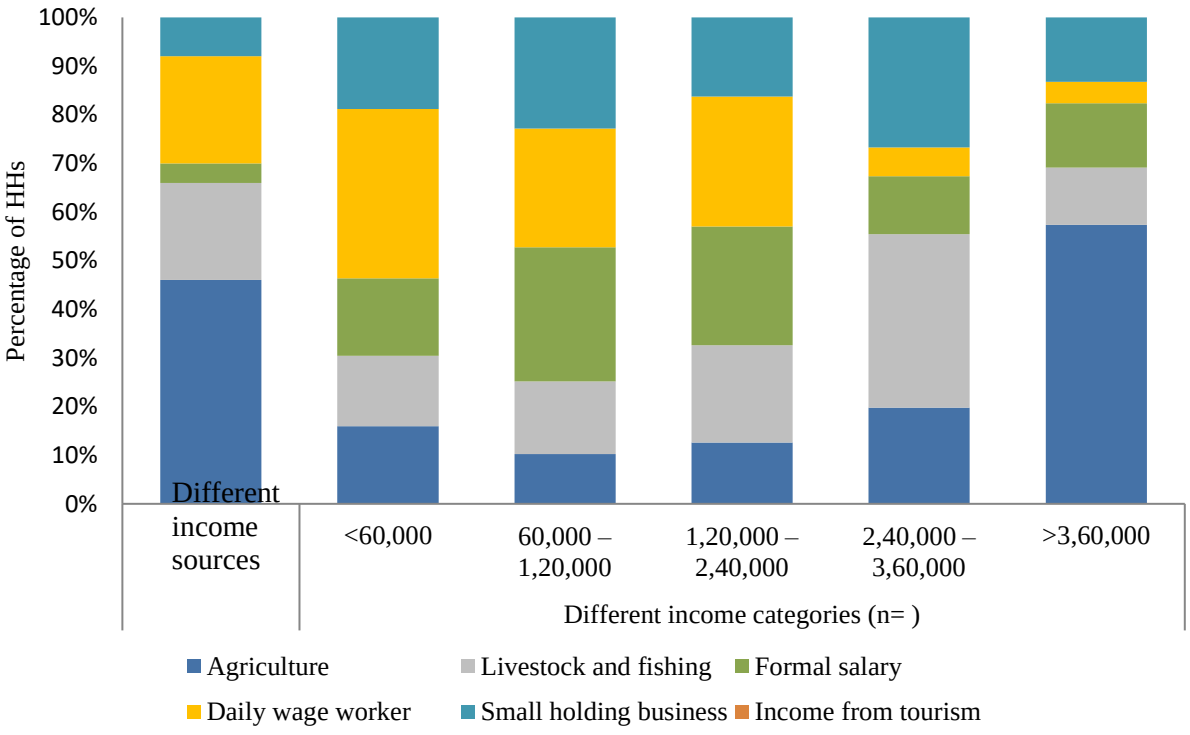


Figure2: Major livelihoods of surveyed household and their income sources

This is surveyed in some villages residing at hazard prone downstream of River Teesta that is densely populated of which 46% people are directly or indirectly involved with agriculture while 22% engaged as daily wage workers. Agriculture is the primary livelihood of the people living in the downstream areas which followed by daily wage worker,

livestock and fishing. Average land holding of the people in this area is less than one acre. Paddy is the major crop grown across the downstream area of the basin whereas ground nut, water melon and winter vegetables highly productive crop in this region. Average cropping intensity on the Indian side is 169% (BBS-GOB, 2012; FAO, 2013). It is noticeable that the present sources of income and livelihoods of surveyed households in the downstream areas of Teesta basin is agriculture, daily wage labour, livestock and fishing, , small holding business and formal salary. Most of the households have more than one income sources but agriculture is the major one where as daily wage labour, livestock and fishing are also generate income of people residing there. As per surveyed account that 45% respondents from surveyed area has reported, in the last decade income from agriculture has decreased due every year floods in the downstream area which damage the crop every year. While its increasing in daily wage labour and in livestock activities.

6.2 Perception to natural hazards and extreme events:

In the downstream, floods occur each year in the Teesta floodplains in India experiencing seasonal longer-duration floods which inundate large areas and impact on the lives and livelihoods residing in these areas. Occurrences of intense rainfall in the downstream come about during the monsoon (June to September). In the downstream areas, riverbank erosion is a regular and recurring phenomenon for areas adjacent to the Teesta River, largely caused by river dynamics particularly flooding. Large-scale riverbank erosion occurs during pre-monsoon (April to June) and post-monsoon (September to October) periods (Hassan, et al., 2021).

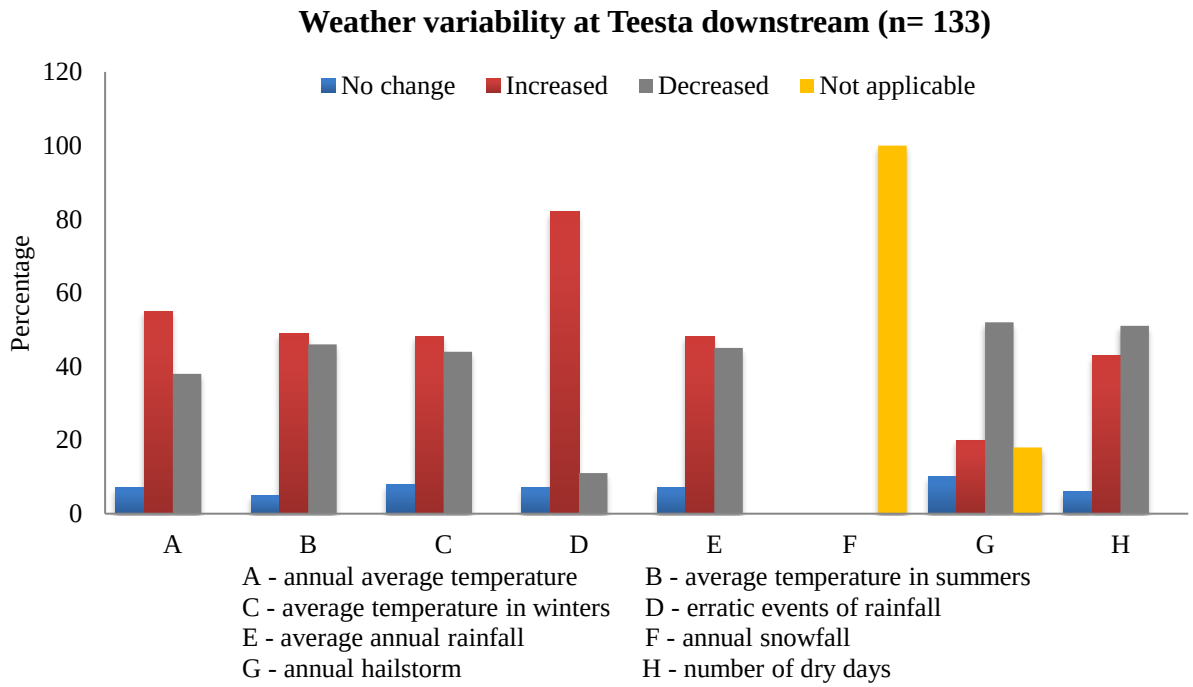


Figure3: Perception of weather variability and hydrological change current situation compared to 10-20 years ago in downstream of Teesta River basin in percentage values of respondents.

In a very recent study of water scarcity and vegetation in Teesta river basin shows that, overall vegetation and soil moisture content in downstream declined over the study period which has been correlated to the water scarcity. In relation to water needs for livelihoods Teesta Barrage Project (TBP) boundary has not correlated with these changes. Disparity between supply and demand has been increased due to climate change, less water flows in Teesta River during dry season and high demand for irrigation, biodiversity and human consumptions. Teesta River water is playing an important role to keep balancing among water supply in this region. Uneven water control in upstream can be a reason of massive damage in downstream because supply of irrigation water for downstream crops is a matter of life and death (Sarker et al., 2011).

Table2: Perception (%) of natural hazards and extreme events in the downstream of Teesta River basin

Natural hazards or extreme events attributed to hydrological changes	Downstream, India (n=133) [Basusuba (n=53). Chatrarpar (n=43). Barman para (n=37)]					
	Q1		Q2		Q3	
	Yes	No	IC	DC	IC	DC
Cold waves	11	89	58	42	53	47
Drought	26	74	30	70	36	64
River bank erosion	20	80	61	39	55	45

Erratic rainfall	43	57	96	4	4	96
Flood	85	15	63	37	64	36
Hail storm	12	88	51	49	57	43
Heat waves	9	91	89	11	81	19
Outbreak of diseases	44	56	90	10	79	21
Pest attack on diseases	27	73	74	26	78	22
Storm	39	61	71	29	51	49
Thunderstorm	17	83	71	29	63	37
Water logging	87	13	67	33	70	30
Q1 - Perceived change in hazards/ events; Q2 - Frequency of hazards/events; Q3 - Intensity of hazards/events; IC – increased; DC - decreased						

Post-monsoon erosions are more severe in nature than pre-monsoon. Local people those are mostly vulnerable has said that construction of dam at Gajoldoba, Jalpaiguri have decreased the flow of the river during dry season and releases unpredictable water during peak monsoon that are pouring out riverbank erosion processes in the downstream of River Teesta with no flood control structures. In the downstream areas, it is perceptible in accordance to local people that average rainfall has increased by 48% where the erratic rainfall has highly increased during monsoon by 82%. In addition mean monthly temperature (during summer and winter as well) has also increased by the long term perception.

6.3 Impacts of Critical moments in different livelihoods:

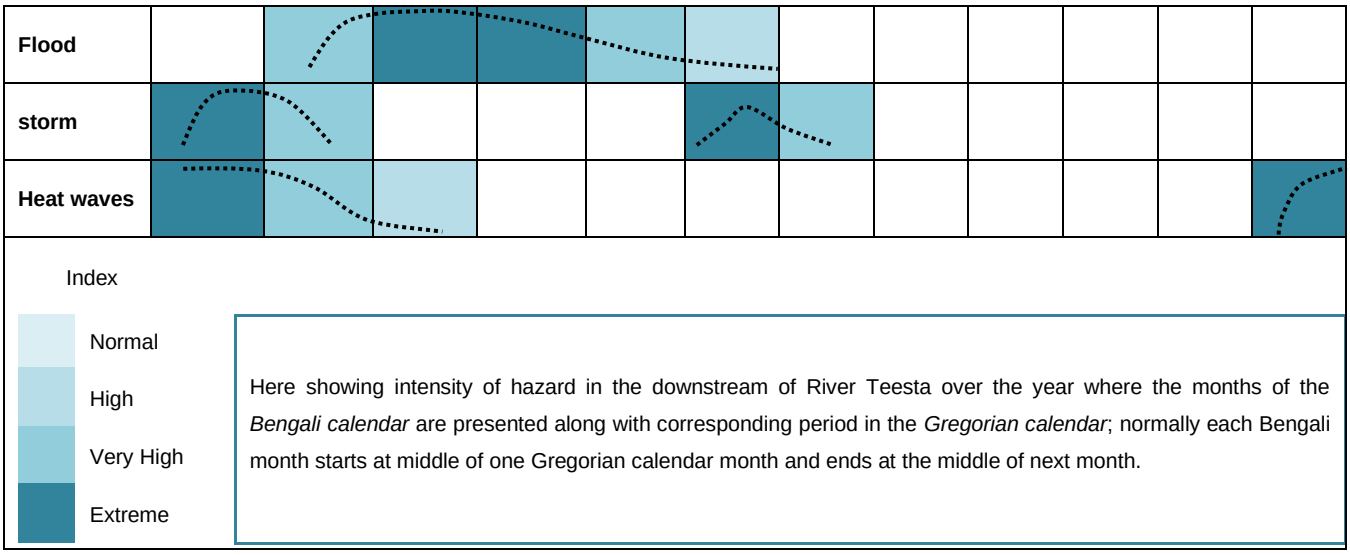
In the Himalayan Adaptation, Water and Resilience (HIAWARE) research 'Critical climate-stress moments' has precisely illustrated where 'critical moments', distinct when households, communities, and the dependent livelihood systems are especially vulnerable to climate and weather-related risks and hazards whereas these risks and hazards include floods, droughts, riverbank erosion, heat waves, cold spells, hail storms, and so on. The concept of critical moments can be introduced as an approach to vulnerability, aimed at overcoming several bottlenecks, particularly when it comes to bridging science and policy-making in transforming adaptation policy and plans into concrete actions at the right time. Critical moments are a combination of specific socio-economic and biophysical conditions, in which critical stressors are particularly likely to be risky and adverse to a particular household or community and the systems they depend on. A 'critical moment' may last days, weeks or even months, depending on the socioeconomic or and bio-physical drivers (Groot et al., 2017).

6.3.1 Agricultural livelihoods:

It is surveyed that in the flood plain of River Teesta around 46% of household residing there primarily engaged in agriculture. In the dry season farming is limited as because river does not provide sufficient irrigation water due to high levels of inundation from upstream and midstream limits access to water during this season. Meanwhile in peak monsoon chars (landmass emerging from river bed) are becoming less ideal for agriculture. Actually the sustainable lives and livelihoods of cultivators on the chars as they are under regular threat of river bank erosion and flooding. In kharif season (April to September) variety of paddy is the major crop which experience every year erratic rainfall and flooding risk whereas winter vegetables are main crop subsequently ground nut, water melon, green chili, potato in the rabi season (October to March) harmed by fog and cold waves and increasing frequency and intensity of storms hampered to green chili during summer season (Table4). Late blight diseases outbreak highly exposed for potato field and reduce the yield of crops due to high intensity of fog and cold waves in the month of December and January. Moreover farmers reported that climatic critical moment's i.e. erratic nature of rainfall, increased water logging (staying 2 to 4 week) due to increased intensity of flooding, increased intensity of fog and cold waves poses significant risk on agricultural community in the floodplain of River Teesta.

Table3: Hazard calendar in downstream of Teesta basin in India.

Crop	Baishakh (Apr - May)	Jaistha (May – Jun)	Ashar (Jun – Jul)	Shrabon (Jul – Aug)	Vadro (Aug – Sep)	Aswin (Sep – Oct)	Kartik (Oct – Nov)	Agrahayan (Nov – Dec)	Poush (Dec - Jan)	Magh (Jan - Feb)	Falgun (Feb - Mar)	Chaita (Mar - Apr)
Cold waves												
Drought												
River bank Erosion												
Erratic rainfall												



6.3.2 Non-agricultural livelihoods:

The field study conduct to reveal that the rural economy of the community residing at floodplain of Teesta downstream is greatly dependent (nearby 20%) on livestock and fishing after agriculture. It not only acts as a primary source of food or nonfood items but is also essential in contributing to rural livelihoods by way of providing employment, generating a source of income as well as allaying poverty for the local inhabitants of the study area.

During the field survey it was observed that the most important livestock are cattle, goats, duck and poultry with a predominance and preference for cattle and poultry cultivation by the local community. Therefore it can be asserted that livestock ranching plays a significant role in the livelihood pattern of the residents within this study area. But it is perceived by the locals due to increased heat stress in summer diseases outbreak affected the dying of animals whereas during flood period due to scarcity of fodder animal dying is also common occurrence in every year.

Table4: Crop calendar of major crops and critical moments in the downstream of Teesta River basin, India.

Crop	Baisha kh (Apr - May)	Jaisth a (May – Jun)	Ashar (Jun – Jul)	Shrab on (Jul – Aug)	Vadro (Aug – Sep)	Aswin (Sep – Oct)	Kartik (Oct – Nov)	Agrahay an (Nov – Dec)	Pous h (Dec - Jan)	Magh (Jan - Feb)	Falgu n (Feb - Mar)	Chait a (Mar - Apr)
Paddy	S	S/P	W/I	W/I	F	H	H					
	ERRATIC RAINFALL, FLOOD & RIVER											
Ground Nut						S	P	W/I	W/I	F/W/I	F/I	H
									FOG & COLD WAVE			
Water melon									S/P	W/I	W/I	H
										COLD WAVE		
Green Chili	H							P	W/I	W/I	F/I	H
	STORM								FOG & COLD WAVE			
Winter Vegetables							P	W/I	W/I	F/H/I	F/H/I	H
									FOG & COLD WAVE			

Potato								P	W/I	W/I	F/I	H
									FOG & COLD WAVE			
S - sowing; P - planting; W - weeding; F - flowering; H - Harvesting; I - irrigation												

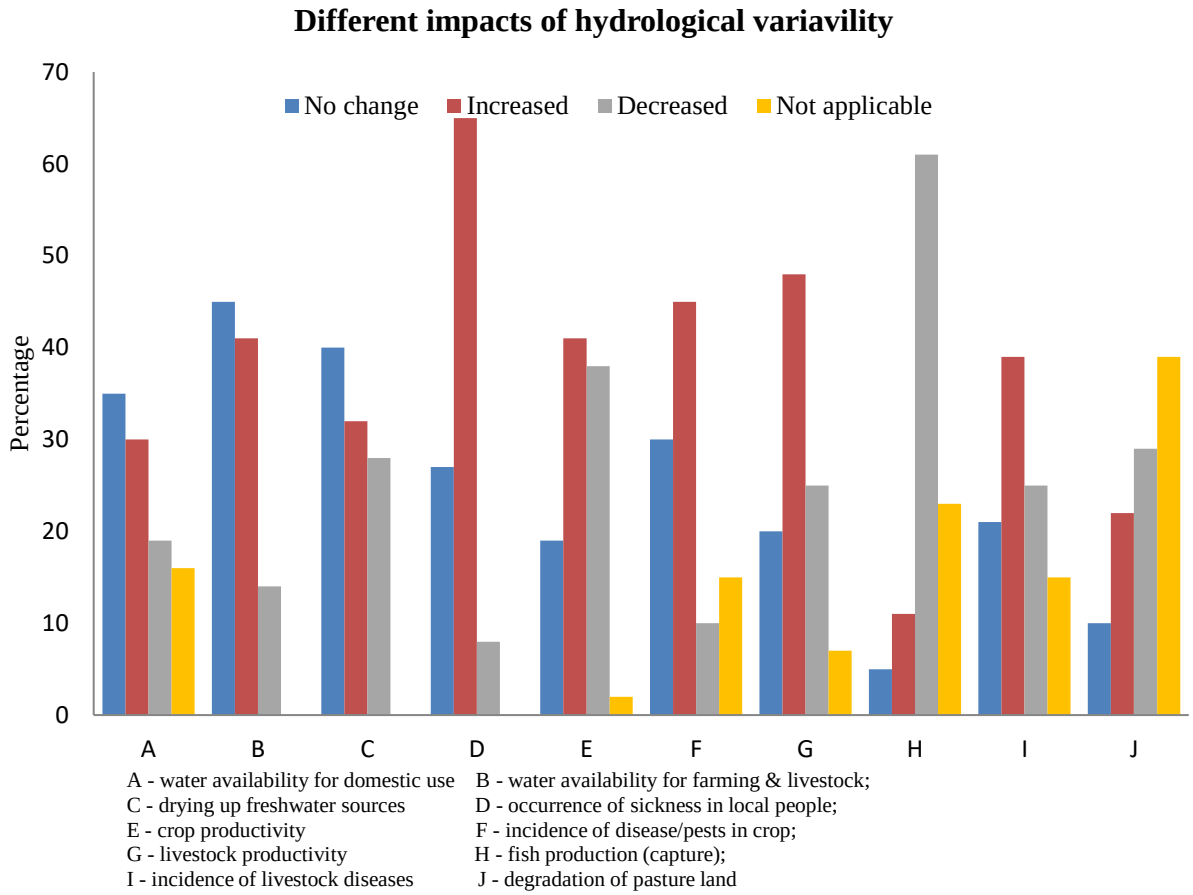


Figure4: Perception of households about impacts of hydrological variability compared to 10-20 years ago in Teesta basin in percentage values of respondents.

Figure5: Flood water logged the village

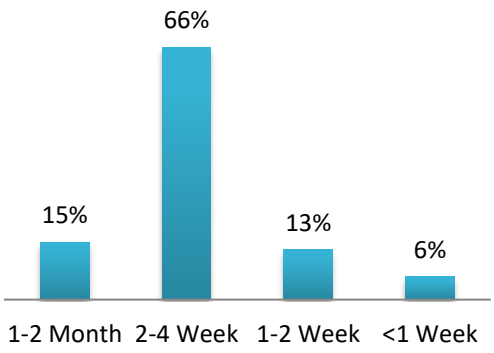


Figure6: Duration of water logging

It is found that nearby 10% local community are directly involved in this occupancy and it have been categorized with their frequency of activity i.e. People who are hunting fish for their daily consumption and the fishing community who are hunting fish for their livelihood. So, it is asserted that fishing at downstream plays an important role for economic development of the villagers live in. Favorable weather conditions for fishing is always important to sustainable the economic condition but nowadays fishermen are constant threat under unavailability of water during dry season and flood in monsoon when river currents too strong having high discharge of water with high velocity. Under these

conditions it is very difficult to fishing. In this study it is perceived that fish production (capture) in last 20 years it is decreasing in nature. Moreover stress moment for the fishing communities constitute very much vulnerable in nature as because they are geographically located near to the river.

6.4 Adaptation to critical stress moments:

The more effective adaptation strategies was taken by agricultural households as use of modern technology for crop calendar with amendment of timing, improved irrigation as per need, in some places organic fertilizer have also been used, changing cropping pattern and cropping cycle, improved harvesting system and introduction of new verities. However Government also takes some specific potential strategies for local livelihood i.e. started effective flood early warning system, effective seasonal forecast, potential weather information are the important.

Table5: Adaptation in Kharif crop to critical moments in the downstream of Teesta basin, India.

Kharif Crop	Stress moments	Climatic extremes & hazards	Stress by hydrological condition	Other factors leading to vulnerability	Adaptive strategies	Potential adaptive measures
Paddy	Early to mature stage (sowing to harvesting)	Flood	Damage to seedlings Delay transplantation	Inundation due to flood Economic crisis	Re sowing, adjustment of timing Borrowing loan	Introduction of new variety Effective flood early warning
		Erratic rainfall	Damage crops			
		Late monsoon onset	Delay transplantation			Effective seasonal forecast
		Drought	Damage crops		Irrigation	
		Storm	Severe damage to crops			

It is very important in respect to vulnerability those people residing proximity to River Teesta that the facilities form the government is provided to the village people to cultivate at chars but due to no registration and no geographical location to residing at the land have no facilities being used in a proper manner.

Table6: Adaptation in Rabi crop to critical moments in the downstream of Teesta basin, India.

Rabi Crop	Stress moments	Climatic extremes & hazards	Stress by hydrological condition	Other factors leading to vulnerability	Adaptive strategies	Potential adaptive measures
Ground Nut	Weeding and flowering	Fog and cold wave	Damage crops & Less production	Economic crisis	Borrowing loan & improved harvesting system	Potential weather information
Water melon	Early to Weeding	Cold wave	Damage crops	Economic crisis	Borrowing loan & improved harvesting system	Potential weather information
Green chilli	Weeding to harvesting	Fog and cold wave Storm at early stage	Damage crop			Potential weather information
Winter vegetables	Weeding and flowering	Fog and cold wave	Less production	Attacks by Insect	Use of organic fertilizer Change in cropping cycle Early and late variety vegetables after and before recession of fog and cold wave	Potential weather information
Potato	Weeding and flowering	Fog and cold wave	Corrode plant root	High investment	Uses of fungicides	Potential weather information

In the floodplains of River Teesta aim to minimize the stress moment of the fishermen community the Department of Fisheries of Government of West Bengal has supported development of a sequence of small ponds on private lands ranging from 1 to 5 bigha. The income per 1 bigha is 10,000Rs to 20,000Rs annually, but fishermen have to get fish spawn from Maldah and sell the produce in Siliguri regulated market where the Government also to provide fish carp of *Boroli* fish for fish cultivation purpose.

Table7: Adaptation in Non-agricultural activity to critical moments in the downstream of Teesta River basin, India.

Non-agricultural activities	Stress moments	Climatic extremes & hazards	Stress by hydrological condition	Other factors leading to vulnerability	Adaptive strategies	Potential adaptive measures
Fishing	Dry season	Lack of water	Less catching	Heat stress and roughness	Work as daily wagers Short term migration to nearby cities for daily workers	Livelihood diversification
	During peak monsoon	Flood (High discharge of water with high velocity)	Unable to go for fishing Less catching	After flood due to inundation catch amount got reduced for some months	Seasonal migration to other cities Fishing net building or take some loans to survive.	Livelihood diversification
Livestock	Dry season	Heat stress	Lacking of fodder	Sell by very low price	Work as daily wagers	Livelihood diversification
	During peak monsoon	Flood	Diseases outbreak every year		Veterinary treatment Seasonal migration	Livelihood diversification

At the same time, with just about enough water to cultivate lands, many people are migrating to other states in India, especially Kerala and Delhi where the wage rate is higher (450Rs. per day whereas in local that is 200 to 250 per day). Young men migrate in groups and some have even migrated to Dubai. Some people work temporarily in nearby town i.e. Jalpaiguri or Siliguri town as masons, rickshaw pullers, and so on. Beside that side local men and women engage as daily wage worker under the MGNREGS (Mahatama Gandhi National Rural Employment Generation Scheme) which empower the women also. So it is very much asserted that Livelihood diversification is continuing in the study area.

7. Conclusion:

The findings from the above research are leading to a number of suggestive approaches to take several potential strategies, actions and policies against the critical stress moments. By the undertaking of socio-economic and bio-physical parameters to understand why and how vulnerability sustain on livelihoods of the communities. Therefore it is found that in the downstream of River Teesta, floods, river bank erosions is common phenomenon as a result of erratic rainfall every year and some anthropogenic activities i.e. dam constructions constitute a critical stress moments attributed to hydrology of the downstream Teesta basin itself. Due to this kind of hydrologic disruption reduction of agricultural production, changing cropping cycle, break of communication, Livelihood diversification and outbreak of livestock diseases are the common result increasing every year. Moreover heavy rainfall, drought, storms, fog and cold waves have large impact on the livelihoods residing at the downstream of Teesta River basin, India.

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