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Assessing the Impacts and Livelihood Vulnerability of River Bank Erosion: A Case Study in Chakdah C. D. Block of Nadia District, West Bengal

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ABSTRACT

River bank erosion due to channel oscillation and lateral migration of the Bhagirathi-Hugli river is one of the most hazardous hydrological events in the Gangetic West Bengal. In contemporary times, the increased frequency of bank erosion is attributed to the controlled hydrological regime of this river by the Barrage on the Ganga River at Farakka. In the present study, an attempt has been made to understand the nature of channel oscillation and frequent river bank erosion of the Hugli river and its impact on the livelihood mechanism of the local population in the selected study units. The findings reveal that land loss due to bank erosion for 1921 to 2019 in Chakdah block is 27.42 sq. km. It also shows a highly inconsistent and unpredictable pattern of channel migration except along some portions of the river course. This increases the vulnerability of the agrarian economy that economically supports over 80% of the resident population. As far as livelihood stress is concerned, the findings reveal that erosion induced frequent relocation of home and hearth is prevailing in the area. This is leading to a forced change in occupation from agriculture to other non-agricultural economic pursuits. The only strategy to cope with this hazard is frequent relocation in the absence of viable rehabilitation packages. At the end, suitable suggestion for better management and erosion hazard planning for the study area has been proposed.

Introduction:

River flood plains are the most sought-after landscape for agricultural activities that form the source of the economic livelihood of the majority of the world population. Despite their initial advantages as areas with great potentials for agricultural activity, the natural dynamics of the river hydrological regime (lateral channel migration; concomitant erosion and accretion of the concave and convex bank, respectively) pose certain hazards when encroached upon for humanhabitation. The hazards, chiefly emanating from bank erosion, cause loss of life and property and livelihood vulnerability.Several workers have done studies related to the various dimensions of this research problem in different areas of the world.The river bank erosion by lateral channel migration is one of the common geomorphic hazards in the floodplain rivers (Lawler, 2004).The impact of bank erosion is comparatively more hazardous than the phenomena of flood and soil erosion (The, 2003; Pimentel, 2006). Spatio-temporal shift and morphological analysis and channel shifting have been analyzed by different authors (Pati et al.,2008; Momin et al., 2020). Channel oscillation and shift in Kalindri river (Malda, West Bengal), Brahmaputrariver (Barpeta, Assam) and Ganga–Pagla interfluves (West Bengal) have been studied (Das, 2016; Ahmed, 2016 Majumdar & Mandal,2020). The authors discussed the inundation and displacement of riparian communities and the different strategies for identifying alternate suitable human habitation sites.Gurnell et al. (1994) investigated the

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channel plan-form changes along an 18 km section of Dee river and found decreasing channel mobility downstream, indicating its transformation into a moribund state.Mistri et al. (2012) discussed the changing channel pattern of the flood-prone Damodarriver to investigate the surface expression of hidden geomorphic changes. They used the sinuosity index as a tool.Banerjee (1999), Parua(2009) andRudra(2010, 2018) opined in their work about the hydro geomorphologic and socio-economic impact of the Farakka Barrage project in both the upstream and downstream areas. These studies have concluded that natural processes transforming into disasters are a product of human intervention into the natural order of things. The impact of such hydrogeomorphic disaster causes huge destruction of property and loss of lives also. It may be noted that Banerjee (1999) studied the region of Malda and Murshidabad and the present study site, Nadia district, is not covered. Likewise, Parua(2009) and Rudra(2010, 2018) dealt principally with the fluvial dynamics of the river system and the negative impact of the fluvial dynamics on the life and livelihood of the local population has not been discussed based onthe database.Islam et al. (2011) highlighted the impact of bank erosion in Bangladesh along withthe Padma, Jamuna and Meghna and also focused on the vulnerability of the local refugees of river bank erosion.Haque et al. (1989) analyzed the survival strategies of the population affected by river bank erosion hazards and displacement in Bangladesh. The sufferers of river bank erosion migrate to nearby or distant places to cope with the vulnerable situation (Islam et al., 2014; Hutton and Haque, 2004; Iqbal, 2010). The agricultural production, cropping pattern, and total agricultural scenario of the erosion-affected areas are badly impacted by river bank erosion (Islam et al., 2014; Uddin and Rahman, 2011). Islam et al. (2015) studied the severity of bank erosion of the lower reach of the Bhagirathi-Hugliriver and social vulnerability due to occupational change of the victims and gave valuable suggestions for managing the situation.They highlighted the river bank erosion-induced displacement that forced them to shift from the original occupation of agriculture to other non-agricultural activities. They identified two tiers of the vulnerability of the victims of bank erosion; the first one is due to river bank erosion and the second one is due to occupational change of the victims.Das (2011) studied the perception of the riparian communities regarding the causes and consequences of bank erosion and also opined that their perception gap is the main reason for their backwardness.

Remote Sensing and Geographical Information System helps to display spatio-temporal changes of the area under observation. Sarkar et al. (2012) and Yang et al. (2015) detected the past and current channel courses of Brahmaputra and Yangtze rivers with the help of RS and GIS tools. Gogoi et al. (2014) analyzed the pattern of channel shifting and other changesof the Subansiririver in Assam with the help of RS-GIS technology. They found continuous changes in the channel pattern leading to huge discharge and heavy sediment load rendering the river fluvially unstable. Issues of population displacement and consequent livelihood stress are not discussed.

Bag et al.(2019) and Deb et al. (2015) used the linear regression method for predicting bank lines and identified the hazard-prone areas in the Bhagirathi and the Manu river in the north-eastern zone of Bangladesh, respectively,for the period 1975 to 2013. They reported irregular shifting patterns of the river and shifted along withthe bank, showing a linear trend.Coleman et al. (2005) andPal et al. (2016) stated the lower reach of the Bhagirathi river in West Bengal is extremely dynamic. Islam et al. (2017)discussed the impact of increasing discharge on bank erosion and channel oscillation in different areas. The impact of dams and barrages upon the hydro geomorphology of the upstream and downstream sections of river control structures have been analyzed by different authors (Ghosh et al., 2014; Thakur, 2014). Islam et al. (2017)studiedthe impact of the Barrage at Farakka on the river Bhagirathi. They reportedthat in the pre-Farakka barrage period, large-scale bank erosion was only during the monsoon months and for the rest of the year, erosion was minimal because of low discharge through the river Ganga. However, in the post-barrage period, discharge was uniform in the monsoon and lean periods due to the presence of the feeder canal. High discharge in the lean months following the construction of the Barrage accelerated bank erosion downstream of the Barrage.From 1905 to 1913, there was very little discharge in Jangipur, Berhampore and Katwa gauge stations, but the discharge increases in the monsoon period in all these stations (Hirst,1915). The literature review reveals that livelihood stress due to river bank erosion in floodplain areas has not been discussed elaborately. Therefore, in the present study, an attempt has been made to generate a database through perception survey on livelihood stress and analyze it scientifically.

2. Theme of the present study

The central theme of the present study is to assess

the magnitude of river bank erosion along the left bank of Hugli in Chakdahand the concomitant impacts on the livelihood vulnerability of the local population. Firstly, to assess the magnitude of river bank erosion,the present study has analyzed the pattern of channel oscillation and spatio-temporal changes of river bank for 1921 to 2019 with the RS-GIS techniques.The simultaneous impacts on livelihood vulnerability have been studied.

3. Study area

Chakdah community development block is located in the southern part of the Nadia district, West Bengal(22° 56' 31" N to 23° 07' 04" N latitude and 88° 24' 29" E to 88° 32' 36" E longitudes).There are 137 villages spread over 17 Gram Panchayats. The study area is well connected with the metropolitan city Kolkata by rail and bus services. In the north, the district shares its boundary with Murshidabad. The Hugli district lies in the west. In the south, there is the North 24 Pargana district. In the east, the district has an international boundary with Bangladesh. The study area is located on the left bank of river Hugli and corresponds to the moribund deltaic section of the regional geomorphic divisions of West Bengal (Fig. 1).Bhagirathi-Hugliriver in the GangeticWest Bengal takes off from the Ganga near Mithipur in Murshidabad district of West Bengal and flows 500 km southward and falls into the Bay of Bengal at Gangasagar (Rudra, 2010). The non-tidal part (220 km) of the river from the off-take at Mithipur up to Nabadwip is known as Bhagirathi, while the tidal part (280km) of the river starts from Nabadwip (from the confluence of Jalangiand Bhagirathi Rivers) to the Bay of Bengal known is known as Hugli (Rudra, 2010; Garret, 1910). The region is characterized by a gentle slope, very low relief, natural levees, meander scrolls, etc. Sand, silt and clay dominated the Bhagirathi and its tributaries deposit alluvium soil. The channel here is extremely dynamic and characterized by avulsion, meandering and lateral migration. The region experiences frequent floods and therefore, fertile alluvium covers the agricultural land (Parua, 2009; Bagchi,1944). However, despite these natural advantages for agricultural activities, bank erosion in this region causes large-scale displacement of riparian communities, loss of crops, livestock, land, property

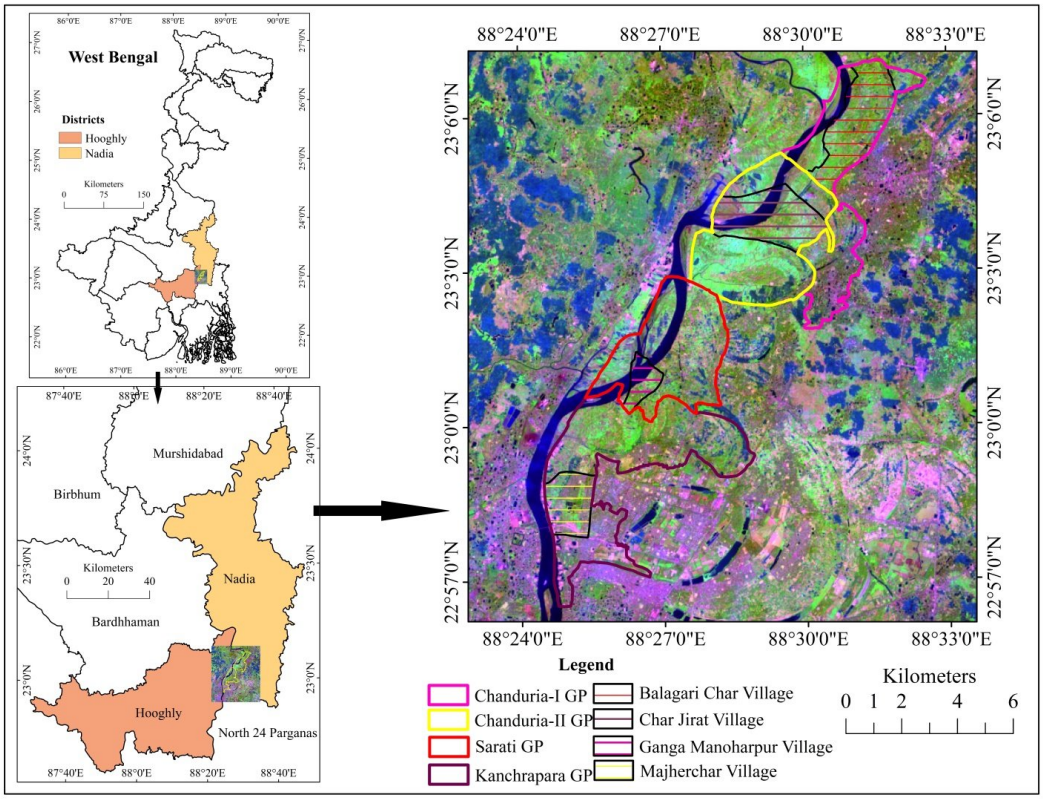

Fig. 1: Location Map of the Study Area

and human lives. An inquiry into these problems is the main research issue of this paper. According to the Disaster management plan of Government of West Bengal (2018-2019), Chakdah is the only block of Nadia district affected by both flood and bank erosion phenomena, while the other blocks (17 in number) do not suffer bank erosion (Table 1). In Chakdah, there are three affected gram panchayats, as shown in table 1. The villages selected for a detail survey corresponding to these GPs are also shown in the table.Besides, a study on the length of the erosion zones along the left bank of Hugli is reported to be the maximum (2.50 km.) at Zirat (Parua, 2009). Since Zirat coincides with the Chakdah community development block, the selection of the study area stands justified.

4. Database description

The study is based on secondary and primary databases. The former is for the generation of relevant maps and the latter for the generation of socio-economic data.The description of the secondary database is given in the table below (Table 2).From the table, it is evident that the data availability for the study pertains to the period 1921 to 2019.The river Hugli in Chakdah block traverses through four-gram panchayats out of the 17-gram panchayats. One village from each of these panchayats has been chosen for the primary survey and for primary data collection. The selected GPs and their corresponding villages are coincident with the erosion zones identified and mapped on the basis of channel oscillation from cadastral maps and satellites imageries (Fig. 2).As shown in table number 3, four villages have been surveyed, among which, Balagari Char, Char-Jirat and Ganga-Manoharpur villages coincide with the erosive bank while Majherchar coincides with the zone of accretion.Twenty-five households from each village affected directly by bank erosion have been chosen purposively to survey their perception regarding bank erosion and corresponding livelihood stress.Primary data has been collected on the aspects of the economic status of the respondent households and livelihood stress with the help of a perception survey. The perception survey is very helpful for collecting socio-economic information and their perception regarding the vulnerable river bank erosion (Sudarmadi, 2001).

4.1 Economic status of the respondent households

It is a fact that the economically vulnerable groups of the population mostly feel the impact of livelihood stress due to natural or man-made calamities. Therefore to assess the livelihood stress of the people residing along the erosive left bank of river Hugli in the study area, the economic status of the surveyed population becomes imperative. Since the economic

Table 1: Gram panchayats affected by bank erosion

Affected Gram Panchayats	Corresponding village chosen for survey	Year of recording magnitude of disaster	Number of affected people
Chanduria-II	Balagari Char	2015	1898
Chanduria-I	Char Jirat	2016	1150
Sarati	Ganga Manoharpur	2014-2015	3500

Source: Disaster management plan of Nadia district, 2018-2019

Table 2: Secondary database used in the study

A: Maps

Data	Source
Police Station Map, Chakdah, 1917-1921	Revenue Survey 1917-21, Govt. of West Bengal
Landsat Imageries (1973 and 2019)	USGS Earth Explorer

B: Satellite imageries used in the study

Satellite	Sensor	Path/Row	Acquisition Date	Spatial Resolution (Meter)
Landsat 1	MSS	148/44	11.12.1973	60
Landsat 8	OLI TIRS	138/44	21.01.2019	30

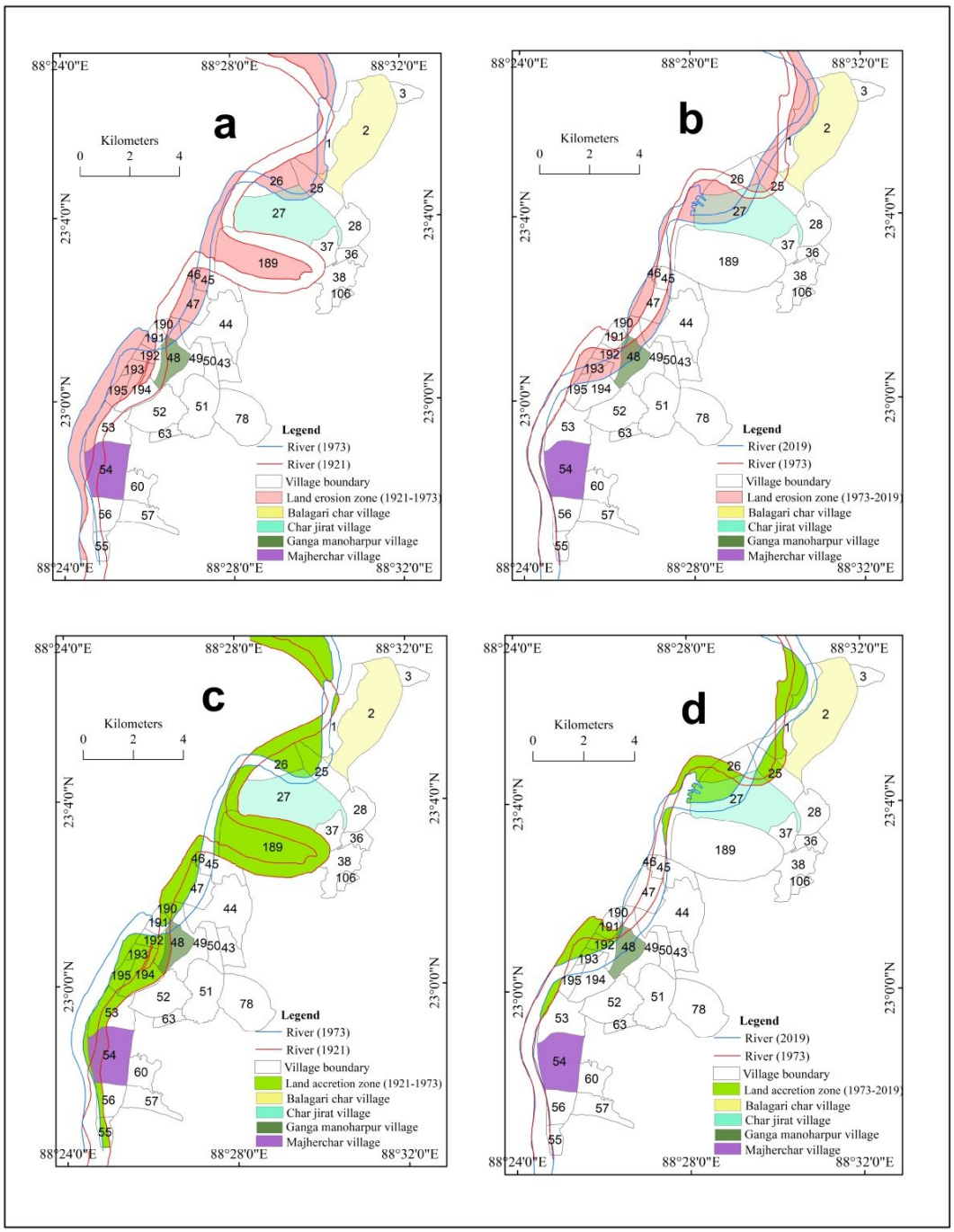

Fig. 2: Erosion zones and study sites**a** Land erosion zones (1921-1973) **b** Land erosion zones (1973-2019) **c** Land accretion zones (1921-1973) and **d** Land accretion zones (1973-2019)

Table 3: Primarysurvey design

Sl. No.	GP	Village/Mouza	No of households surveyed
1	Chanduria-I	Balagari Char	25
2	Chanduria-II	Char Jirat	25
3	Sarati	Ganga Manoharpur	25
4	Kanchrapara	Majherchar	25

pursuits are informal, composite indicators of economic activities have been used to assess the economic status of the surveyed household. The indicators chosen for the assessment of the economic status of the respondents are the status of landownership, housing condition, present occupation and the monetary income per month from current occupation.

4.2 Indicators of livelihood stress

Livelihood stress in areas characterized by the hazard of bank erosion revolves around the oscillating pattern of home and hearth of the affected population. The indicators of spatial displacement chosen for the nature and frequency of displacement in the present area are detailed in table 4. All of these are complementary indicators of the same theme to assess forced relocation of the resident population.

5. Methods

5.1 Temporal scheme of secondary data analysis

The scheme has been chosen to understand the impact of FarakkaBarrage on bank erosion in the study area as the large scale interference in the natural hydraulic regime of a river causesenforcing changes in the dynamics of the river,especially in terms of channel shift, changes in channel geometry, the magnitude of erosion and accretion. The entire study period is divided into two phases: from 1921 to 1973 and from 1973 to 2019.

5.2 Methods of Measurement of area eroded and accreted

The Hugliriver during 1921 and 1973 was digitized, mapped and superimposed. Thereafter, the area along the left bank of the river during 1921 and that of 1973 were digitized and mapped. The same exercise was undertaken along the right banks of the river during the same period. The digitized mouza map was then overlaid on the map of the erosion and accretion zones. These brought out the mouza wise land erosion and deposition zones (Fig. 2) and the same process was applied in the next time phase for 1973 to 2019.

Table 4: Indicators of livelihood stress

Sl. No.	Indicators	Justification
1	Period of residence in the present locality	To assess displacement frequency
2	Number of generations of the present resident population residing here	do
3	Displacement pattern: frequency of displacement of home and hearth in the last thirty years	Strict adherence to structured questionnaire often leads to missed information. Under such circumstances some unstructured questionnaire are canvassed in the field. During one such interaction with respect to question related to indicators 1 and 2 above the respondents informally reported that before 30 or 35 years they were residing in some other nearby locality. From this the author concludes that the maximum period of residence of the local population is 30 to 35 years on an average.
4	Past and present occupation/ occupational change of the working population	To assess displacement induced occupational shift

5.3 Analysis of data extracted from secondary and primary sources

With the help of SPSS software, multiple linear regression analysis has been used in this study to understand the relationship between the dependent and independent variables. The multiple linear regression model explains the degree of relationship between the variables and how a single response variable depends on a number of predictor variables (Uyanik et al., 2013).

$$y = \hat{a}_0 + \hat{a}_1 X_1 + \ldots + \hat{a}_n X_n + \mathring{a}$$

Where, y= Dependent variable, X_1= independent variable $\hat{a}_1$= parameter and $\mathring{a}$ = error

6. Results and discussion

6.1 Findings on the extent of land erosion and accretion

The measurement of land erosion and accretion is done in two phases, 1921-1973 and 1973-2019, as shown in table 6. During 1921-1973,the area under erosion and accretion is 18.01 km² and 23.188 km², respectively. The annual rate of erosion and deposition is 0.35 km² and 0.45 km², respectively, indicating greater accretion than erosion due to the neck cut-off near Srikrishnapur Char village.During the next period (1973-2019), the area eroded and accreted is 9.41 km² and 4.95 km², respectively andthe annual rate is 0.20 km² and 0.11 km², respectively. For the total period (1921-2019), the total area eroded is 27.42 km² while 28.14 km²of land has been aggraded (Table 5). Frequent erosion in the study area due to the oscillating nature of river Hugli causes large-scale loss of agricultural land, decreased production, huge displacement, fall in income level and occupational shift of the local population. Therefore river bank erosion has direct and indirect negative effects on the lifestyle and socio-economic condition of the inhabitants of erosion-prone areas, thereby increasing their levels of livelihood stress. The trend of river bank erosion during the two periods (pre and post-Farakka) of observation is decreasing, but nevertheless, this does not mitigate the problem of bank erosion. It is persisting and livelihood vulnerability of the local population is reported and observed. It would be pertinent to assess the situation of decreasing erosion along the left bank in the backdrop of the discharge through the Feeder Canal because the hydrological regime of a river is an important control factor on fluvial dynamics.

6.2 Reasons for accelerated bank erosion in the left bank: Discharge from FarakkaBarrage through feeder canal as a factor for bank erosion

Although the maximum discharge has not changed over the pre and post-Farakka periods, an increase in the average discharge is noted in the post-Farakka period for the same gauge stations under consideration. For example, minimum discharge for Katwa never drops below 500 cumecs after FBP, while it recorded as low as tencumecs in the pre-Farakka period (Islam et al., 2017). This implies that the discharge in the lean period is increasing because no corresponding increase in discharge is noted for the maximum discharge during the monsoon period in all the gauge stations as stated above. Therefore, the role of Farakka Barrage in inducing erosion in the lower reaches cannot be ruled out altogether, although its effectsmay be indirect in nature.

Analysis of discharge data as given by Islam (2017) reveals inconsistency in the discharge in both the pre and post-Farakka period. One important thing that emanates from the work is that increase of lean period discharge has accelerated the pace of erosion, channel instability and oscillating meander behavior, especially in the lean period once marked with very minimal discharge and erosion.

6.3 Economic status of the surveyed households

6.3.1 Landownership

Out of the surveyed household, 67% of the families do not have ownership of either cultivable or homestead land. They occupy vested (*Khas*) land. They eke out a living mainly as marginal agricultural labourers, rickshaw pullers and other wage labourers. The remaining 33% of the total surveyed population have ownership rights on the land they occupy and cultivate. (Fig. 3a)

6.3.2 Housing condition

This has been assessed based on the structural description of the respondents' dwelling units and household amenities. 37% of the surveyed population have a permanent structure of dwelling units, while the remaining 67% have a non-permanent (Kutcha) structure of dwelling units.On a broader scale, after the last displacement, 67% of the population who do not have a permanent structure of dwelling units were forced to relocate to roadside locations where their living conditions are highly substandard. 37% of the surveyed population who have a permanent dwelling

Table 5: Amount of land erosion and accretion along the left bank in all villages from 1921 to 2019 (Villages are listed from north to south)

Gram Panchayats	Villages with J. L. number	1921-1973		1973-2019		1921-2019	
		Erosion (Sq. km.)	Accretion (Sq. km.)	Erosion (Sq. km.)	Accretion (Sq. km.)	Total Erosion (Sq. km.)	Total Accretion (Sq. km.)
Chanduria-I	Gournagar (1)	0.91	0.49	1.53	0.87	2.44	1.36
	Balagari Char (2)	0.08	0	0.18	0.08	0.26	0.08
Chanduria-II	Raninagar (25)	1	0.76	0.63	0.65	1.63	1.41
	Durllabhpur (26)	1.31	0.93	0.57	0.82	1.88	1.75
	Char Jirat (27)	0.85	0.51	2.5	1.53	3.35	2.04
Sarati	Srikrishnapur chak (189)	3.93	8.76	0	0	3.93	8.76
	Char Raghunathpur (193)	0.39	0.4	0.4	0.13	0.79	0.53
	Naosari Char (192)	0.49	0.72	0.65	0.49	1.14	1.21
	Ganga Manoharpur (48)	0.57	0.92	0.51	0.06	1.08	0.98
	Sarati (49)	0.79	0.57	0.3	0	1.09	0.57
	Tarinipur (44)	0.17	0	0.29	0	0.46	0
	Dumurdaha Char (190)	0	0.21	0.02	0	0.02	0.21
	Durgapur (47)	1.42	0.7	1	0	2.42	0.7
	Kalipur (45)	0.42	0.008	0.12	0	0.54	0.008
	Sukhsagar (46)	0.18	0.13	0.11	0	0.29	0.13
	Raninagar Char (191)	0.23	0.16	0	0.32	0.23	0.48
	Char Madhusudanpur (195)	0.64	0.66	0.18	0	0.82	0.66
	Char Jajira (194)	0.63	1.68	0.4	0	1.03	1.68
Kanchrapara	Char Kanchrapara (56)	0.29	0.29	0.02	0	0.31	0.29
	Char Nandanbati (55)	0.17	0.31	0.001	0	0.171	0.31
	Char Jadubati (53)	0.83	1.39	0	0.002	0.83	1.392
	Majherchar (54)	0.4	1.28	0	0	0.4	1.28
	Birpara (52)	2.28	2.28	0	0	2.28	2.28
	Muratipur (51)	0.03	0.03	0	0	0.03	0.03
	Total	18.01	23.188	9.411	4.952	27.421	28.14
	Annual Rate	0.346	0.446	0.200	0.105	0.280	0.287

Source: Measured by the authors

unit structure have modern sanitation facilities and electricity connections.

6.3.3 Present occupation

The occupational categories and the percentage of respondents in each of these categories is presented in figure 3b. The figure reveals that approximately 45% of the respondent population is directly engaged in agricultural activities. Among the remaining categories, fishing and van rickshaw pullers comprise 13% and 20% of the population. Ferryman comprises 11% and 6% are non-workers.

6.3.4 Monetary income per month from the present occupation

The income ranges from rupees 1001-26000 per month. Only a minuscule percentage of the respondents fall in the high-income group of rupees 16001 to 26000. (Fig. 3c)

6.4 Livelihood stress of the surveyed population

The major indicators of livelihood stress are frequent relocation of the home and heart of the affected population. These are discussed in detail below as

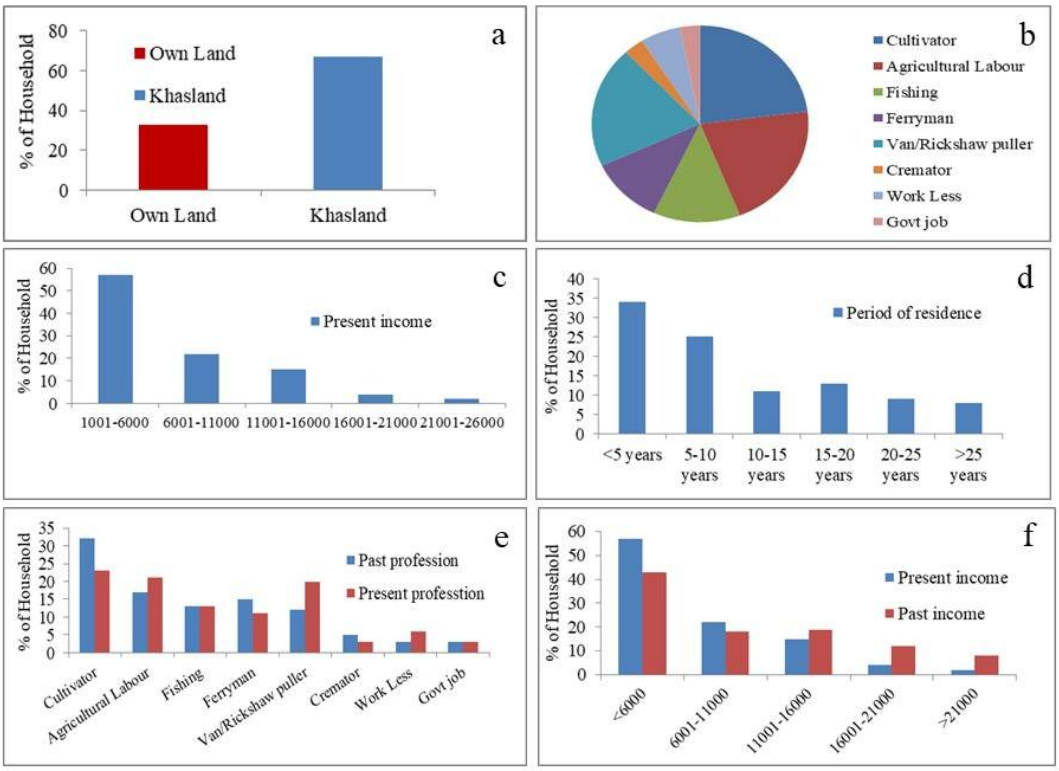

Fig. 3: a Landownership status**b** Present occupation **c** Present income status**d** Period of residence **e** Past and present occupation **f** Past and present income

per indicators mentioned in section 4.2. Only 8% of the local people are residing here for more than 25 years.About 59% of the people reside for only less than ten years, out of which 34% stay for less than five years. This indicates frequent relocation of home and hearth of the majority of the local population (Fig. 3d). Since the maximum period of residence is 30 to 35 years approximately.

6.4.1 Displacement pattern

Due to the massive land loss in the left bank (study area), the occupant population is forced to relocate at regular intervals. For the assessment of the situation, the frequency of displacement has been examined through the primary survey. The results show that five times displacement in 26% household, four times displacement in 14% household, three times displacement in 12% household, two times displacement in 20% household, 1-time displacement in 14% household and 14% household have not been displaced yet.A detailed study of this phenomenon has been attempted for one of the study sites Balagari Char.

In the case of Balagari Char village, the victims resided at Mukundanagar village in 1980 and then they had been shifted to Poradanga village in 1990 due to bank erosion. In the year 2000, they shifted to a nearby site in GournagarGhat and in 2018, they shifted beside the roadside of Gournagar Ghat. This is the present settlement site of the victims. Some of the affected people have got rehabilitation in Jhautala and Doardanga village. One notable feature of the pattern of displacement of the residents of Balagari Char is that their path of movement has been along with the erosion-prone left bank zone only (Fig. 4). The reason for choosing the left bank along was enquired into, and the respondents reported that the accreted right bank falls in the jurisdiction of Hugli district. Therefore their shift into the right bank is not officially feasible. Because their official papers related to their domiciliary status are issued and recorded in favor of their present site of settlements/address. Besides, they reported that the chars in the opposite bank, which fall in the category of *khasland* are not distributed among the vulnerable groups who are socially and economically disadvantageous. Instead, they are distributed among

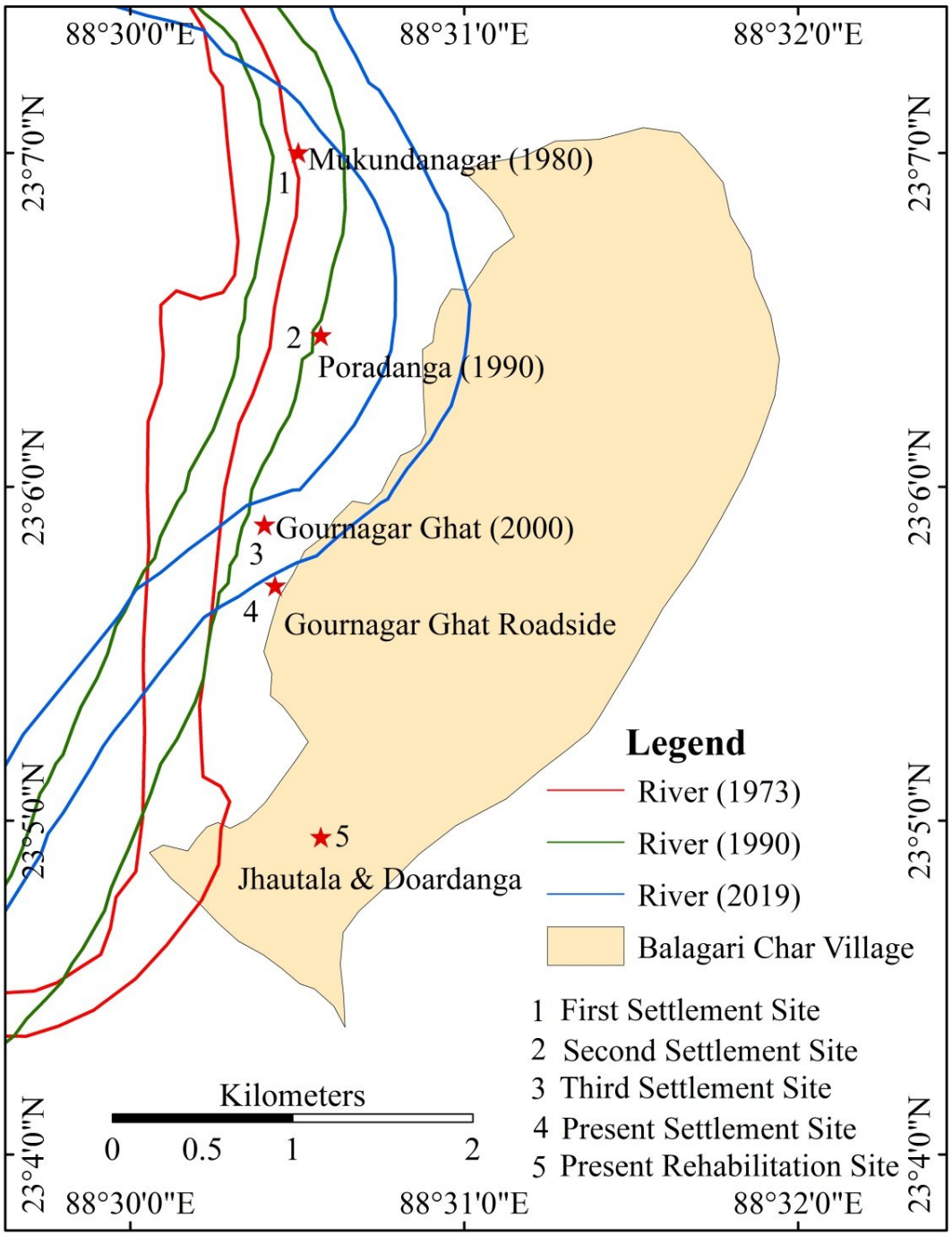

Fig. 4: Displacement pattern of the surveyed households in Balagari Char village

the economically and socially advantageous groups' for cultivation alone. However, alternative dwelling units are provided to households with ownership rights along the left bank only through the *IAY* scheme. Households without ownership rights of homestead land do not qualify for grant of *IAY* funds and hence their vulnerability increases. Temporary residential rights along the roadside were, however, granted to the disadvantaged groups of the population. Das (2011) also investigated this phenomenon, the frequency and volume of migration of inhabitants and the nature and mode of adjustment to hazard upstream and downstream of the FarakkaBarrage, connecting the riverbanks in the Malda and Murshidabad districts. She also highlighted the importance of *charland* in her study area for the local habitants, mainly the victims, to cultivate profitably. Due to accretion in the convex bank, new Chars originate. The chars are inherently extremely fertile and become the bone of contention for appropriation in view of the profitable economic opportunities they offer. There is always a problem of ownership in the newly created chars as these are very fertile and productive. This feature of ephemeral lands in the form of river islands is common in the entire stretch and applicable for the present study area.

6.4.2 Occupational change of the working population

The study area victims have lost a huge amount of movable and immovable property due to river bank erosion. They have changed their income so many times to cope with the situation and adjust to the hazardous erosion phenomena. In the study area out of the total worker, 32% populations were engaged in cultivation in past, and in present it declines to 23%. The percentage share of workers in non-land-based activities has been increased considerably (Fig. 3e).In case of Balagari char, Char Jirat and Ganga Manoharpur villages the percentage of cultivator has declined around 20%, but in case of Majherchar, the percentage of cultivator have increased to 24% as there is no erosion affected area in the last several years. The scenario of occupational diversification of the selected villages is shown in fig. 3(e). Main cultivators are diverted to agricultural laborers and other occupations (Table 6). Some of them opined that they have no other options except land-based activities for income generation, but they have no opportunity for farming practices due to land loss. Due to the loss of agricultural land of big farmers, who had a vast amount of land become agricultural laborers andwere forced to migrate to other places. So there is the obvious declination of income opportunities of those landless people. Per capita monthly agricultural income has been declined for all the villages except Majherchar as this village has had no effect of land erosion in the last several decades. Figure 3(f) shows the past and present income of the households and it is seen from the figure that the present income is higher than the past income in the low-income group. In the case of the high-income group, the past income is higher than the present income.

7. Findings

In meandering river plains, like the Bhagirathi-Hugli in GangeticWest Bengal, erosion and accretion in the concave and convex banks, respectively, are

Table 6: Past and present occupation

	Balagari Char		Char Jirat		Ganga Manoharpur		Majherchar	
Occupation	past	present	past	present	past	present	past	present
Cultivator	9	3	8	2	10	7	5	11
Agricultural Labour	3	4	3	5	5	9	6	3
Fishing	4	3	3	4	3	2	3	4
Ferryman	3	2	4	3	2	2	6	4
Van/Rickshaw puller	3	7	4	7	3	4	2	2
Cremator	2	3	3	0	0	0	0	0
Work Less	1	2	0	3	1	1	1	0
Govt. job	0	1	0	1	1	0	2	1

Source: Field survey, 2019

complementary phenomena. They are not hazards per se; they are transformed into hazards and disasters only when they impact human life through loss of life and property. Traditionally preferred settlement sites are on upland areas which are not liable to floods. Floodplains are therefore uninhabitable because of the cyclical inundation and ephemeral nature of the land. However, in recent times, following the population explosion, either due to natural growth of population or migration, these uninhabitable areashave been encroached upon by marginalized groups of the population. Such examples abound in the riverine islands of Damodar river of India (Bhattacharyya, 2011) and along the entire Bhagirathi-Hugli floodplain (Das, 2011). It is a fact that control of the hydraulic regime of a river accelerates the erosive capacity of rivers in the concave bank. Thereby posing a hazard to the resident marginalized group of the population and irreversibly damaging the hydraulic system of the river as a whole. In the study area, the construction of the Farakka Barrage at Jangipur on the river Bhagirathi is an important interference into the hydraulic regime of the river. Therefore, to understand the nature and extent of river bank erosion in the study area, the locale and areal extent of erosion along the left bank for the pre and post-Farakka periods has been mapped.

The result shows that the annual rate of erosion and accretion in the pre-Farakka period was 0.35 km^2 and 0.45 km^2, respectively. In the post-Farakka period, the annual rate of erosion and deposition was 0.20 km^2 and 0.11 km^2, respectively. This implies that in the pre Farakka period, although the annual rate of erosion and accretion was more than the post-Farakka period, accretion was dominant. In the post-Farakka period, the annual rate of erosion and accretion has decreased. Still, erosion is more prevalent than accretion, possibly because the maximum discharge has not changed over the pre and post-Farakka periods and an increase in the average discharge is noted in the post-Farakka periods for the same gauge stations under consideration. This implies that the discharge in the lean period is increasing because no corresponding increase in discharge is noted for the maximum discharge during the monsoon period in all the gauge stations, as stated above.Erosion impacts the livelihood of the resident population, chiefly the economically marginalized groups.Therefore, to assess the livelihood stress of the people residing along the erosive left bank of river Hugli, the economic status of the surveyed population becomes imperative. A study on the economic status of the surveyed population revealsthat approximately 70 percent of the population are economically vulnerable and at the receiving end of livelihood stress.This is also reflected in the income groups of the surveyed households. It is seen that almost 60% of the population falls in the income group of rupees 1001-6000 per month. While around 20% fall in the income category of rupees 6001-11000. Therefore approximately 80% of the population fall in the low-income group of rupees 1001-11000 per month indicating higher economic vulnerability. Therefore livelihood stress impacts almost 80% of the surveyed population in the study area. Economic vulnerability is reflected in the physical parameters of quality of life like housing conditions and availability of other amenities of life. The findings reveal that 37% of the surveyed population who belong to the higher economic status have a permanent dwelling unit structure with modern sanitation facilities and electricity connections. Occupationally about 45% of the respondent population are directly engaged in agricultural activities, but ironically approximately 70% of the people do not have ownership of either agricultural or homestead land.

Livelihood stress emanates from homelessness arising out of the hazard of bank erosion. It is reflected throughthe spatial displacement of the home and hearth of the affected population. Thefindings of the analyses of the indicators discussed above indicate frequent relocation of home and hearth of the majority of the local population rendering them transitory/semi-permanent resident population.More than 90% of the population report that the cause of the transitory resident status is due to loss of land caused by river bank erosion.Multiple linear regression analysis was conductedto understand the nature and magnitude of livelihood stress and the factors causing them.Here, the frequency of displacement was taken as the dependent variable and average per capita monthly agricultural income,the average amount of land loss (bank erosion), and the total duration of homelessness as independent variables. In the model summary (Table 8), the choice of the dependent and independent variables seems justified because the adjusted 'R^2' is 0.658 and 'R^2' is 0.668, which means about 67 percent variance of the dependent variable can be explained by this model. The dataset fits multiple linear regression analysis as the ANOVA (Table 9) shows that the significant level (p-value) is less than 0.05. The results show that the beta value is lowest for the first independent variable; it is moderate for the second independent variable and very high for the third independent variable (Table 10). The variable with the highest beta value is the comparatively most important

Table 7: Different Satellite data and Ward maps are used in the study.

Correlations					
		Frequency of displacement	Average amount of land loss	Average per capita monthly agricultural income	Duration of homelessness
Frequency of displacement	Pearson correlation	1	.612**	-.522**	.777**
	Sig. (2-tailed)		.000	.000	.000
	N	100	100	100	100
Average amount of land loss	Pearson correlation	.612**	1	-.539**	.561**
	Sig. (2-tailed)	.000		.000	.000
	N	100	100	100	100
Average per capita monthly agricultural income	Pearson correlation	-.522**	-.539**	1	-.424**
	Sig. (2-tailed)	.000	.000		.000
	N	100	100	100	100
Duration of homelessness	Pearson correlation	.777**	.561**	-.424**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8: Model summary table

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.817[a]	.668	.658	.710

a. Predictors: (Constant), Duration of homelessness, Average per capita monthly agricultural income, Average amount of land loss

Table 9: ANOVA table

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	97.539	3	32.513	64.407	.000[b]
	Residual	48.461	96	.505		
	Total	146.000	99			

a. Dependent Variable: Frequency of displacement

b. Predictors: (Constant), Duration of homelessness, Average per capita monthly agricultural income, Average amount of land loss

inde-pendent variable (Uyanik et al.,2013). It means that the total duration of homelessness (independent variable number 3) is the major factor for the higher frequency of displacement (beta value=0.603, r=0.777). The next important factor relating to the high frequency of displacement is the average amount of land erosion (beta value= 0.184, r=0.612). The per capita agricultural income is an insignificant factor is to be reckoned with because of a negative correlation of -0.522 (beta value=.167). All these correlations are significant at a 99 percent level of confidence (Table 7).Land loss caused by bank erosion is the

Table 10: Coefficient table

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.364	.258		5.285	.000
	Average amount of land loss	.303	.128	. 184	2.370	.020
	Average per capita monthly agricultural income	-.001	.000	-.167	-2.361	.020
	Duration of homelessness	.236	.028	.603	8.352	.000

a. Dependent Variable: Frequency of displacement

leading cause of homelessness and consequent population displacement,leading to large-scale vulnerability to livelihood stress.

To obtain a deeper inside into the phenomena, correlation analysis among some additional variables like agricultural and non-agricultural income and expenditure hasbeen attempted below (Table 11). The correlations between the average per capita monthly agricultural income and agricultural expenditure (Table 11) have strong positive relation (r=.888) at 99 percent significant level of confidence. Likewise, non-agricultural income is also positively correlated (r=.788) with average per capita monthly non-agricultural expenditure and the correlation is significant at 99 percent significant level of confidence.Therefore, income earned from agriculture is spent. Similarly, income earned from non-agriculture is also spent. In the former, it appears that income

Table 11: Correlation among the agricultural and non-agricultural income and expenditure

correlations

		Average per capita monthly non-agricultural income	Average per capita monthly non-agricultural expenditure	Agricultural expenditure	Average per capita monthly agricultural income
Average per capita monthly non-agricultural income	Pearson correlation	1	.788**	-.382**	-.406**
	sig. (2-tailed)		.000	.000	.000
	N	100	100	100	100
Average per capita monthly non-agricultural expenditure	Pearson correlation	.788**	1	-.411**	-.439**
	sig. (2-tailed)	.000		.000	.000
	N	100	100	100	100
Agricultural expenditure	Pearson correlation	-.382**	-.411**	1	.888**
	sig. (2-tailed)	.000	.000		.000
	N	100	100	100	100
Average per capita monthly agricultural income	Pearson correlation	-.406**	-.439**	.888**	1
	sig. (2-tailed)	.000	.000	.000	
	N	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

earned from agriculture is reinvested in agriculture. In the latter case, income earned is spent for material belongings that may be value added like purchase of van rickshaw, etc. On the contrary, the average per capita monthly agricultural income has a moderate negative correlation (r=-.439) with an average per capita monthly non-agricultural expenditure at 99 percent significant level of confidence. So it can be stated that their expenditure for food and luxury purposes is met by non-agricultural income and the agrarian economy cannot fulfill all the needs for healthy living.

8. Conclusion

Bank erosion, consequent homelessness and spatial displacement of homes and hearth are endemic to the resident population of the study area. Accelerated bank erosion following the construction of a barrage at Farakka (Murshidabad district) on the river Ganga is one of the major causes of this livelihood stress. The economic backwardness of the population inhibits self-ameliorative capacity and therefore, livelihood stress is perpetual and therefore, the population is trapped in a vicious cycle of livelihood stress. Rehabilitation packages from the government and other public institutions can be a source of relief, but these steps are not forthcoming. New residential units should be distributed among the vulnerable groups with cultivation rights at their present locale of agricultural activity. Since erosion and accretion are complementary, the accreted *charlands* (river islands) should be distributed among the vulnerable groups of populations for the sustainable development of society. Although the *charlands* are ephemeral, yet their agricultural efficiency, productivity and yieldare very high.The government needs to work out of the land not to be occupied repeatedly by economically and politically powerful people. This can go a long way in achieving equity of economic opportunities. This will also prevent social and political instability, which is generally seen among the contending stakeholders to occupy the newly emerged *charlands*.

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