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Extreme Event, Anthropogenic Stress and Ecological Sustainability in Sundarban Islands

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Abstract:

For fifty four densely populated islands surrounding one of the World Heritage Site and a famous tiger reserve in the Ganges delta, called Sundarbans, the main occupations of the residents has been agriculture and catching fish and crab in the delta waters. Cyclone Aila in 2009 had destroyed the islands' agriculture through salt deposits on agricultural fields, resulting from widespread breaching of protective embankments. This paper examines the nature of anthropogenic stress on the river and forest inflicted upon by the disaster. The study finds that fish and crab catching was a supplementary activity for most poor households along with agriculture. When agriculture was temporarily devastated, working adults from many such households opted to move out as migrant labourers. This in turn helped to release some possible pressure on the ecosystem. Climate Change predictions warn of increased frequency of cyclones in the Bay of Bengal and this delta is considered as one of the most vulnerable areas in the country. This paper suggests that in face of such disasters, devising a long term policy of relocation of island people away from forest and rivers is a more ecologically sustainable strategy rather than protecting them locally by erecting costly embankments.

1. Introduction

Existing literature suggests that locally available natural resources has acted as a 'natural insurance' against disaster induced livelihood loss in different parts of the world. It puts additional value to such resources apart from its usual livelihood augmenting role for the local poor. In this paper, the role of surrounding natural resources as a natural insurance for local households against a large scale loss of their main livelihood in the Indian side of Sundarban delta due to a cyclone disaster has been explored. People in this remote low-lying delta are mainly dependent on rain-fed agriculture which produces a single crop of paddy. A large population lives on these islands with very limited livelihood options in absence of infrastructural provisions and power-driven industry. Freshwater agriculture on these islands crucially depends on the protective earthen embankments encircling them. Such embankments stand guard against saline water of the surrounding rivers during high tide. Apart from agriculture, another important livelihood option is to exploit the deltaic natural resources. It mainly takes the form of fishing and crab catching in open rivers and mangrove forest creeks, collection of prawn seedlings from rivers to be sold to commercial prawn farms and occasional honey collection from the reserve forests.

Cyclone Aila, just before the onset of monsoon in 2009[2], had broken many parts of the embankments on almost every island in Sundarban. As a result, the protection against saline water was unavailable for almost all parts of these islands for a varied duration of time. The resultant salt deposits on fields had severely affected agriculture in large areas. Previous local experience showed that such salinity related productivity loss is fully reversible after two normal monsoon showers. The rains gradually wash out the salt from agricultural fields.

In this backdrop, this paper explores the nature of anthropogenic stress on the ecosystem, in the form of increased exploitation of river and forest creeks fish and crab, during the intermediate

period. The study has undertaken a detailed survey of 800 sample households over two years (three repeat visits) to find out the livelihood ramifications in the intervening period, till their agricultural practices are reasonably restored.

2. Background

2.1 Natural resource as natural insurance:

Natural disasters, both extreme events and periodic shocks, usually results in some change in the livelihood mix especially in a rural area. In the backdrop of climate change (CC) scenario, a number of insightful studies across the globe in recent times had analyzed the *ex post* coping behaviour against disaster induced livelihood loss among the rural poor and forest communities. Literature shows that the coping strategies differ considerably with the available natural resources as well as institutional provisions. Also, the distribution of the disaster related burden among the asset classes does not follow a unique pattern.

Such studies had been undertaken against a wide variety of events and locations. They vary from relatively rare extreme events like hurricane Mitch (1998, Nicaragua, Honduras), typhoon Harurot (2003, the Philippines) to great floods (1998, Bangladesh) and recurrent droughts (1982-1995, Zimbabwe; 2002-2003, India) and usual climate related uncertainties in agriculture (Nepal, Brazil). From their findings, it can be said that there is no unique relationship between the nature of the disaster and households' dominant coping strategies against livelihood loss. For most of these studies the primary effect of a natural disaster had been loss of cultivation. They found that households coped with a variety of strategies depending on local circumstances.

There is a strong body of literature that claims, with empirical evidence, that when people are endowed with natural resources like forests in their surroundings, it often acts as a natural insurance against livelihood shocks. In Brazilian Amazon, study found that forest collection is positively correlated with both agricultural shortfalls (consumption smoothing response) and expected agricultural risks (income smoothing response). It shows that households rely on the forest to mitigate the risk inherent to subsistence agriculture (Pattanayak *et al*, 2001). In the Philippines after the typhoon, households living near the edge of the forest were able to cope with their economic loss with income from illegal logging (Huigen *et al*, 2006).

But the role of natural resources to provide insurance against livelihood shocks is largely determined by the prevailing control regime. A post-Mitch study in Honduras (Mcsweeney, 2005) concludes that although reliance on natural resources was predicted to intensify after the hurricane disaster, enforcement of a commercial extraction ban in the forest had actually led to net attrition from forest-based activities. Households that nevertheless continued to sell forest products to self-insure were those that had been unable to recoup their pre-Mitch landholdings. It suggested that household attributes such as land wealth strongly condition how and when forest resources act as safety nets for the rural poor.

Under stricter protection regime of natural resources like forests, one of the most widely observed household coping strategy was seen to be going out as migrant labourers. Using household data from the Chitwan Valley of Nepal, a study found that a decrease in access to firewood increased the likelihood of migration of individuals for work (Shestha *et al*, 2007). It showed that environmental insecurity was a significant predictor for migration regardless of its destination. Migration and remittances as significant livelihood coping strategies are also supported by other post-Mitch studies (Carvajal *et al*, 2009). However, a recent study on households' migration behavior in response to natural disasters in US during 1920s and 1930s has shown that government efforts at disaster mitigation have actually distorted the possible private

self-protection behavior through migration. It found that public investment in rebuilding and protecting flood prone areas had resulted in in-migration in those areas (Boustan *et al*, 2012)

Several livelihood coping strategies are found to be common in varying contexts across the world and there seems to be no general rule for the adoption of a dominant strategy against similar natural disasters. Different case studies stand apart with their own specific geographical and social situation. In this respect, the present study in Sundarban attempts to bring out the regional experience after the disaster by cyclone Aila.

Following several predictions relating to CC threats over short and long run, the Sundarban is among the first set of casualties due to a sea level rise (SLR) scenario as it is a low lying delta region. Even the relative SLR is not uniform across all regions as continental land subsidence is also a slow but sure phenomenon. Conducted over a 14-year period till 1998, one study estimated an average increase in sea level at the rate of 3.14 mm per year (Hazra *et al* 2002) for the region that includes Sundarban, which is larger than the average rate in other parts of coastal India. For more than a million inhabitants on the islands in this delta, the more immediate CC related threat, however, is the forecasted increase in the frequency of cyclones and super cyclones in the Bay of Bengal. There is scientific literature predicting an increase in occurrence of cyclones in the region in the increased GHG scenario (Ali, 1999; Unnikrishnan et al 2006).

Cyclone Aila provided a unique opportunity to study the effect of a disaster on the health of the delicate mangrove ecosystem in Sundarban. In doing so, the study goes beyond capturing the short term story and looks at the long run effect on surrounding natural resources. Sundarban is a World Heritage Site and a biodiversity hotspot. A possible increase in anthropogenic stress on this delicate ecosystem due to climate related disasters calls for appropriately designed interventions from the controlling authority. This study aims to provide crucial scientific evidence in this context.

2.2 Sundarban: Location and geography

In India, the Sundarban is located at the southern corner of the eastern state of West Bengal and on the Gangetic delta. Spread over India and Bangladesh, it is the largest single mangrove forest tract in the world and a declared World Heritage Site for its biodiversity significance. The physiography is dominated by deltaic formations that include innumerable drainage channels. The deltaic islands rise marginally above the sea level with average elevation between 4 to 7.5 meters across them. Tidal saline water, pushed into from the Bay of Bengal, alternately drowns the exposes large parts of the islets twice a day throughout the year.

In the Indian side, out of a total 102 islands, 48 constitute the Reserve Forest that is home to the famous Royal Bengal Tiger. The remaining 54 islands are inhabited and contain a large population on them. The reserve forest and the settlements are on two mutually exclusive sets of islands. There is no human habitation inside the forest. In the Indian part, the forest lies in the eastern corner while the populated islands are located along its western boundary and further towards the mainland.

Officially, Sundarban Biosphere Reserve (SBR) refers to a region that extends beyond these islands and covers some of the area that is part of mainland now. It spreads over two southern districts of West Bengal. The region is densely populated. As per 2001 Census, the total population of SBR was about 3.7.million. The decennial growth rate during 1991-2001 was 17.4% against the state average of 17.77%. The population density as per 2001 census was 845 per sq. km which is more than the average for rural West Bengal.[3]

This paper focuses on that section of the Sundarban population who reside on the islands. In absence of any clear estimate from secondary sources, the study estimated the population on such

islands at around 1.5 million. Due to remoteness and lack of infrastructural development, their livelihood choices and economic conditions are not similar to other people who are generally categorized as 'coastal'. The people on these low lying islands are residents within an important and delicate ecological site and biodiversity hotspot. Their livelihood practices and pattern of exploitation of natural resources have important implications for the sustainability and management of this important ecological site.

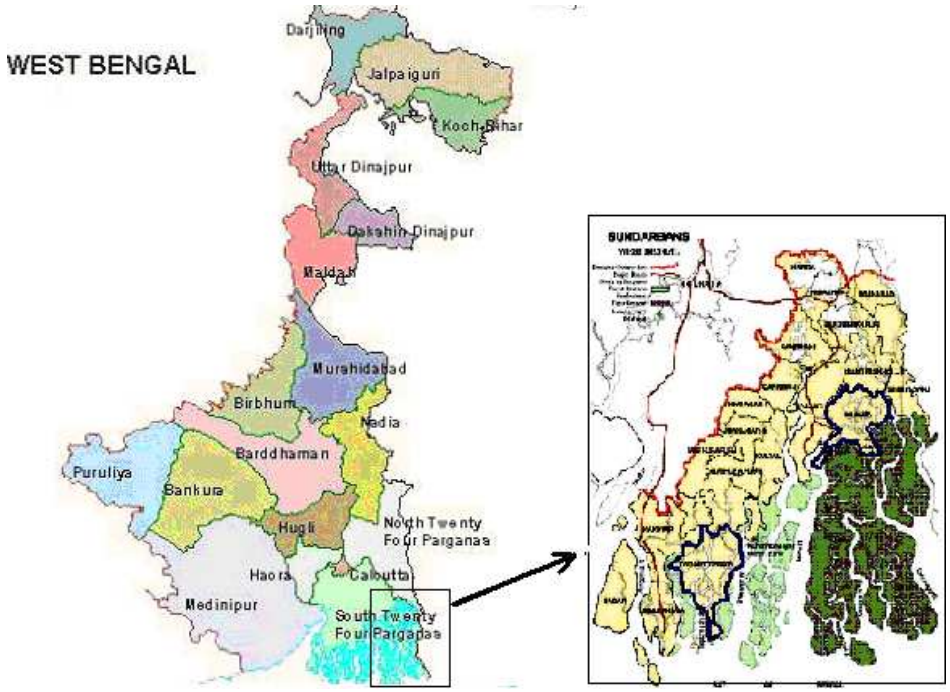

Figure 1: Location of the study area

[The yellow region shows the inhabited parts while the green area represents the reserve forest. The region marked by blue borders represents the two administrative blocks from which households were selected for primary survey]

3. Data and Sampling

The nature and intensity of natural resource exploitation at household level depends on its location vis-à-vis the resource, its location vis-à-vis markets or trading points and households physical and human capital endowments. Since this study intends to analyze the effect of a disaster, it also required enough variability in terms of an appropriate damage indicator. Keeping these requirements in view, selection of sample households in this study has been carefully carried out to ensure reasonable variation in terms of households' remoteness, proximity to natural resources, asset holdings and the extent of damage to their agriculture. A sample of 800 households were selected by a multistage sampling scheme starting from administrative blocks to villages and then to households. In the higher stages (blocks and villages), the selection was

purposive, while at the lowest stage (households within a village), a stratified random sampling scheme has been used. In the first stage, the two administrative blocks were chosen purposefully – *Gosaba* in the north-east and *Patharpratima* in the south (the boundaries of these two blocks are demarcated by blue borders in Figure-1). Gosaba is an entirely island-block, situated on the verge of the reserve forest. Patharpratima, on the other hand, is much away from the reserve forest and close to the sea, with part of it covering the mainland. Apart from differences in their location, these two blocks had also experienced maximum damage by the cyclone following official statistics. It may be noted that these two blocks contain maximum number of islands between themselves.

In the second stage, some primary information from elected representatives of local administrative bodies (village Panchayats) of each village from these two selected blocks were collected. The information contained estimates of the extent of cyclone damage, remoteness and proximity to natural resources[4]. After processing the information, 20 villages from each block were purposively selected ensuring maximum variability in these three aspects. It was also ensured that all the 18 islands covered under these two blocks are represented by at least one village located on it.

In the final stage of sample selection, a first-hand list of all village households had been prepared along with their current landholding data for all the 40 selected villages. Then 20 households from each of these villages have been selected as random samples maintaining a fixed proportion from each landholding strata. This way of selecting 800 sample households ensured sufficient variability in households' socio-economic conditions, exposure to natural resources, remoteness and the extent of livelihood loss due to Aila.

Local experience suggested that such salinity induced productivity loss is reasonably recovered after two monsoon showers. Keeping that in mind, this study aimed to record the households' livelihood choices over two years. Each of the households were visited three times after the monsoon crop starting from the Aila year. The first round of detailed survey of these households was carried out between March-June, 2010. This survey-round collected information on the pre-Aila livelihood activities of the households (by recall), extent of the cyclone damage to its agricultural field, the state of its own agriculture after the cyclone (monsoon of 2009) and other regular socio-economic data.

The second round of survey to the same households was conducted during January-March, 2011. In this round, information on the state of their agriculture in the previous season (monsoon of 2010) was collected along with changes in livelihood practices between the two visits. This round also collected other regular socio-economic information. The Third round of survey recorded similar information for the households during January-March, 2012.

The information was collected through a set of structured questionnaires that recorded many aspects of a household's livelihood and didn't contain itself only with the module of natural resource exploitation. This allowed the possibility to relate natural resource usage with other livelihood choices as well. This design actually proved to be very useful in preparing this paper.

4. Study Findings

4.1 Endowments

The study area hosts a population that had settled on these islands within the last century, migrating in from neighbouring districts. The region, being adjacent to the international border with Bangladesh, had also received a wave of refugees during the partition of Bengal in 1947.

This special historical background explains why big landowning households are almost absent in the area. Though the initial settlers curved out a piece of land for their own cultivation, subsequent division and fragmentation of it had created a significant section of marginal farmers. Survey data shows a heavily skewed distribution of land towards marginal and small-holders. A considerable proportion of households are landless – either getting dispossessed from their inheritance with time or being late arrivals on the islands. Usually such households locate themselves close to the riverbanks and use the rivers and creeks for catching fish and crab. Also, there is little common land on these islands and usually livestock holding, if any, mostly caters to the household's own needs. Table-1 provides an idea of the households' physical endowments obtained from primary survey.

Table 1: Endowments of survey households

Total number of HHs surveyed in all three rounds	778
Average family size	4.9
Average value of livestock holding (US $)*	21
Landless households (in per cent)	32.4
Households with landholding between 0 – 0.2 Hectare (in per cent)	29.4
Households with landholding between 0.2 - 0.4 Hectare (in per cent)	18.8
Households with landholding between 0.4 - 1.0 Hectare (in per cent)	15.7
Households with landholding between 1.0 - 2.0 Hectare (in per cent)	3.3
Households with landholding more than 2 Hectare (in per cent)	0.4

(Source: Primary survey)

* From first survey round. Value calculated at 2009 prices (conversion factor: US $ 1 = INR 55)

4.2 Livelihood practices

The livelihood options on these islands comprise of a small set and there is no manufacturing industry due to absence of conventional power supply. Apart from own cultivation, daily labour, both farm and non-farm, is a significant livelihood. A small section of households had reported salaried employment as a source of earning. Petty trade and artisanship constitute some other local livelihood options.

The other major livelihood, particularly engaging the asset poor, is exploitation of surrounding rivers and forest creeks. Close to a fifth of survey households reported activities like prawn-fry collection and fishing or crab-catching in pre-Aila days. Also, since the region grows only a single monsoon crop in absence of freshwater irrigation, a large number of working adults adopted the practice of going out as agricultural workers in the winter season. In more recent times, working as semi-skilled or unskilled labour in large construction projects in distant parts of India has gained momentum. Such workers usually go out with durations ranging from few months to more than one year. More than one-fifth of the survey households reported working as migrant labourers before the disaster.

The first round of survey, conducted within one year of Aila, had recorded the set of major livelihood practices of the responding households immediately before and after the disaster. Figure-2 gives an idea of the pattern of livelihood changes that were observed within a year of the disaster.

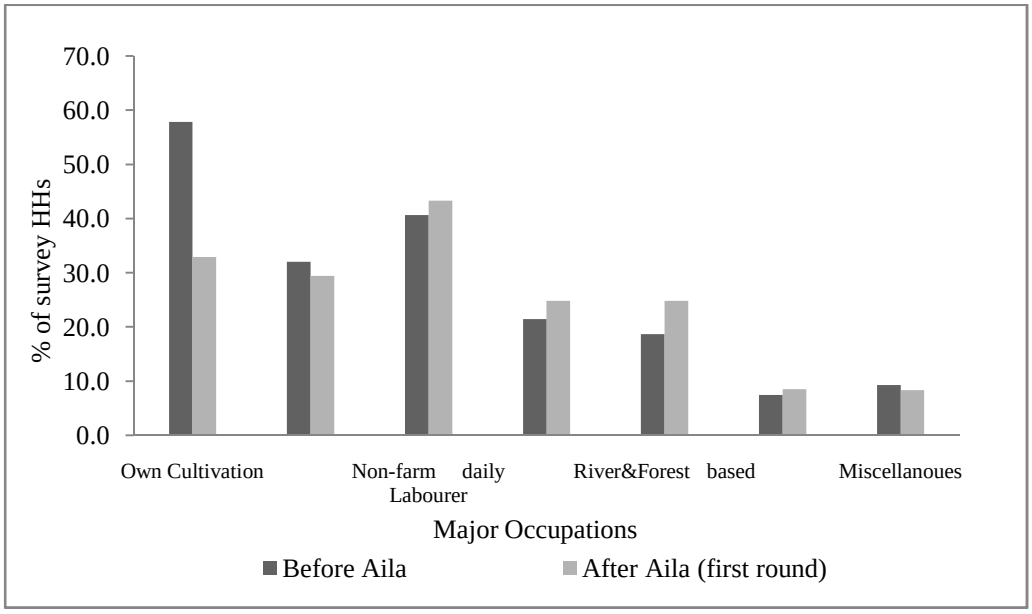

Figure 2: Major livelihood practices before and after Aila

It might be noted that the households often showed a mix of livelihoods. Smallholders mostly augmented their earnings with fishing or other jobs. So, the percentages shown in the above figure add up to more than one hundred.

Figure-2 shows that the disaster had major adverse effect on agriculture. It had also affected farm labour sector. A marginal increase is seen in the 'non-farm daily labour' jobs after Aila. Mostly it was possible due to new job opportunities created by post-disaster spurt in NGO activities and reconstruction works by government sponsored rural employment schemes[5]. Such jobs were mostly of livelihood augmenting nature.

More importantly, the percentages of households depending on river and forest and on migrant labour jobs have increased immediately after Aila. During many group discussions in the field with local affected people, these two livelihood options had been singled out as alternatives against the damage to agriculture.

4.3 Coping with natural resources: descriptive analysis

As mentioned before, the direct anthropogenic pressure on Sundarban's ecosystem is caused mainly by activities such as prawn-fry collection in village-side of the rivers, fishing and crab-catching in the open rivers and forest creeks and seasonal honey collection from the reserve forest. Fuel wood is also collected sometimes illegally from the reserve forest by the fishermen and in most times by the villagers from village-side mangrove covers along the embankments. It is interesting to look at the number of individuals engaged in different components of natural resource exploitation. Since it was a study over a period of two years, such numbers varied marginally in each survey round. To get an idea of the distribution, data from the second round survey (mid-point) has been used to construct the following figure.

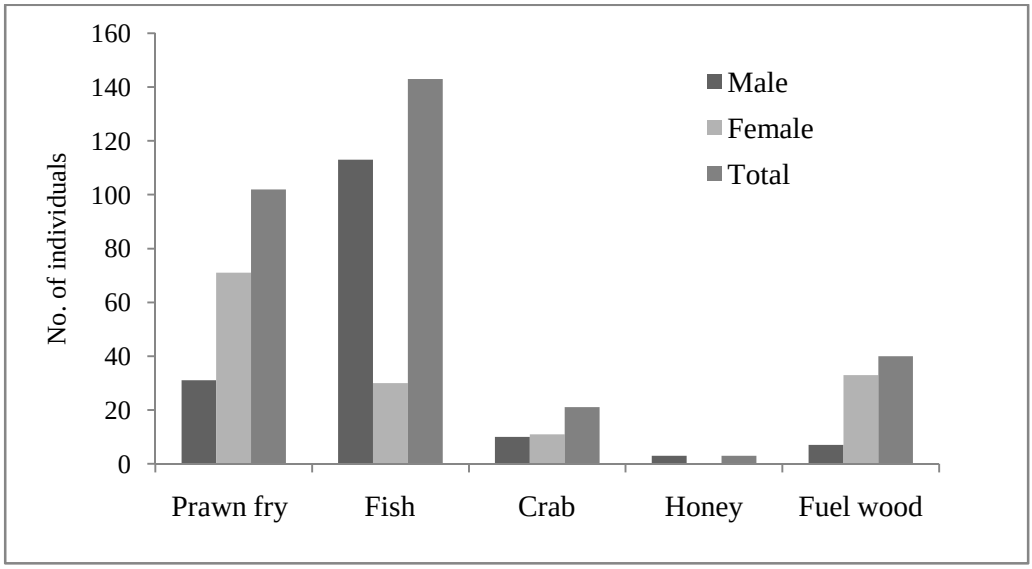

Figure 3: Types of natural resource exploitation across sex

The above figure tells us that prawn-fry collection and catching fish are the two predominant exploitative activities. There is significant difference in sex compositions among people engaged in these two different lines. While mostly women engage in prawn-fry collection, men tend to go out more for fishing. This is natural as prawn-fries are collected near one's home – mostly in stretches of rivers along the village boundary. But fish catching, with its different forms, requires wider area of operation and often needs the help of a boat. This is more challenging work and is mostly taken up by the men folk. It might be noted that these activities are not mutually exclusive for an individual. One often takes up more than one activity. In Figure 3, the total number of individuals engaged in these different activities involves such double counting. The essence of the figure is to give an idea of the intensity of anthropogenic stress on the ecosystem inflicted through different lines of activities.

However, prawn fry collection is potentially the most destructive activity for the ecosystem's health. In the crude process it is done, hundreds of seedlings of other faunal species in the water get perished against collection of few prawn-seedlings. This practice is fast deteriorating the quality and quantity of fish stock in the river waters of Sundarban. The Figure above highlights that this most harmful activity is also a dominant one at present.

Proximity to natural resource is assumed to have a significant influence on the intensity of their exploitation. It implies that so far as poor people are not relocated at some distance from the rivers, the threat to the ecosystem remains high. This understanding gets corroboration when one looks at the survey data in this regard. Against each of the activities, the respondent was asked about the place where primarily he conducts the work. The response was elicited in the form of a closed option set. The result of the responses is shown in Figure-4.

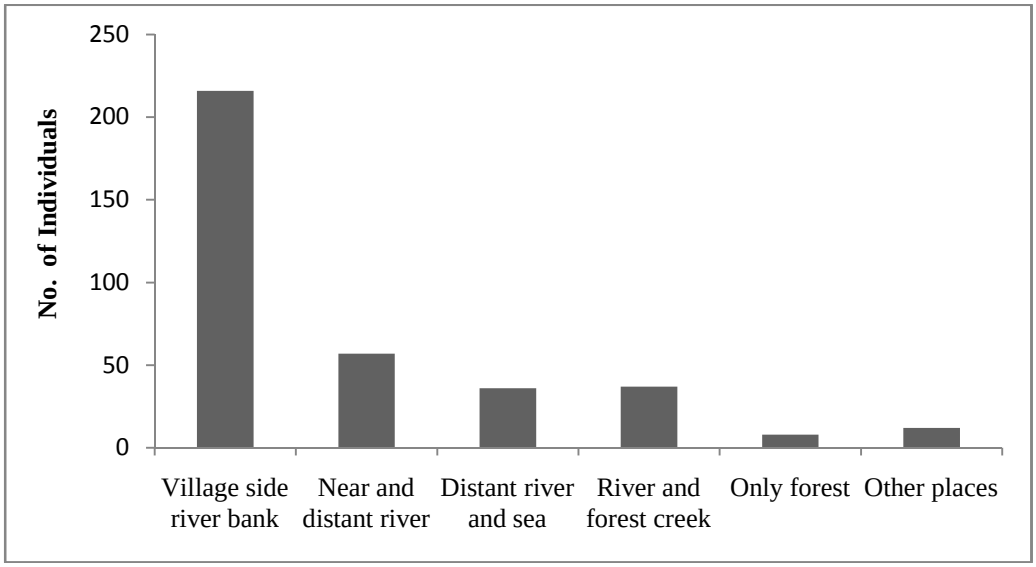

Figure 4: Location of work in natural resource exploitation

The Figure clearly shows that in most cases the exploitation is carried out in the vicinity of the village. It highlights one significant dimension of the problem of sustainability. These people are recent settlers on the islands and the man-nature interaction in Sundarban is not old enough to develop a set of social norms and practices for its sustainable use. So, proximity of a vast population to delicate natural resources seems to be big factor responsible for its over exploitation.

4.4 The cyclone and increased stress on ecosystem: regression result

This section looks at the possible determinants at household level that shaped their choice of depending on rivers and forests during the study period. The status of the household regarding river and forest based activities in each survey round is captured by a dichotomous variable NRES. This binary outcome is supposed to depend on a set of household level variables and attributes such as household's location, exposure to natural resources, physical endowments and human capital. But most importantly, it is assumed to be a function of the cyclone damage intensity also. The more the damage, the more intense and prolonged is the crop loss. It is plausible that the more will also be the probability of the household, *ceteris paribus*, to cope with surrounding natural resources. This crucial variable, representing the number of days of exposure of a household's agricultural land to saline water (WATERSTAY) is treated as a continuous variable in this analysis.

Among the other regressors, location of the household within Sundarban delta and educational qualification of the household head (REMOTENESS and HDEDU) are recorded as categorical variables having pre-decided codes. A household's exposure (proximity and availability) to natural resources (EXP2NRES) is also treated as a categorical variable after processing the survey data[6]. Sex of the head of the household (FEMALE_HEAD) and the area of agricultural land (LAND_HOLDNG) are a binary and a continuous variable respectively among the set of regressors.

The status of a household vis-à-vis its natural resource dependence (represented by NRES) has shown some changes over the survey rounds implying the dynamism in the livelihood adjustment process. However, most other regressors remained time invariant across the rounds. But the complete data is essentially a panel data with a dummy dependent variable. A probit regression with panel data is the most appropriate model to estimate in this case. This has been carried out and the result is shown in Table-2.

Table 2: Determinants of natural resource exploitation: Probit analysis for panel data

Dependent Variable: **NRES**	Marginal effect (dy/dx)	Test Statistic (z)
REMOTNESS	-0.105	-1.15
EXP2NRES	0.331	5.44***
FSIZE	0.047	1.02
HDEDU	-0.326	-3.68***
HDAGE	-0.011	-1.74*
FEMALE_HEAD	-0.750	-1.99**
LAND_HOLDNG	-1.255	-4.02***
WATERSTAY	0.013	5.13***
Regression Diagnostics	Number of obs = 2334 Number of groups = 778 Wald chi2(8) = 82.67 Prob > chi2 = 0.0000	

The regression result shows that location of a household is an important determinant in deciding its natural resource dependence status. Proximity to river banks is a great inducement in this regard. Higher landholding and educational status (human capital) reduces the probability of exploiting natural resources. Age and sex of the household head are also influencing factors. Fish and crab catching are dangerous and arduous jobs in the Sundarban. So, Female-headed households and those with older people tend to keep away from such activities.

The most interesting feature of the regression result above is the high significance of WATERSTAY. This is the variable that captures the intensity of damage (salt deposit) inflicted upon the agricultural fields of the household by the cyclone. It assumed a large positive significance in the above regression exercise, establishing thereby the fact that the cyclone indeed increased the anthropogenic stress on Sundarban's delicate ecosystem.

4.5 Effectiveness of natural resources as natural insurance

The previous section statistically established the fact that rivers and forests indeed acted as an option to depend on, when households faced large scale damage to agriculture. But was it an effective insurance? The answer can be found by comparing the consumption pattern of households identified according to their status with respect to natural resource exploitation. In each of the survey rounds, the aggregate monetary consumption expenditure data (average of last three months) had been collected from all respondent households. With three survey rounds, they

constitute a panel data for households. A panel data regression has been carried out with this expenditure (MCONEXP) as the dependent variable. The set of regressors are similar to what was used in the probit regression before (Table 2). Only a square term for family size (FSIZESQR) has been added as a regressor as it was assumed that family size might be non-linearly related with monthly aggregate consumption expenditure. The result of this regression is given in Table 3.

Table 3: Panel regression of Monthly Consumption Expenditure of households

Dependent Variable: MCONEXP	Marginal effect (dy/dx)	Test Statistic (z)
REMOTNESS	-127.45	-3.3***
EXP2NRES	15.92	0.63
FSIZE	271.21	4.17***
FSIZESQR	0.08	0.02
HDEDU	260.81	7.43***
HDAGE	6.47	2.36**
FEMALE_HEAD	-278.49	-1.77*
LAND_HOLDNG	-51.20	-0.49
NRES	-33.61	-0.51
CONSTANT	447.78	1.6
Regression Diagnostics	Number of obs = 2288 Number of groups = 778 Wald chi2(9) = 308.3 Prob > chi2 = 0.000	

All the significant determinants of household's monthly expenditure hold expected signs in the result. It seems that more remote households are less engaged in monetary exchanges and hence requires less money. Alternatively, they might also be a poorer lot among Sundarban population with lesser exposure to job and earning opportunities. Households with larger family size and higher education spends more, presumably because of their larger human capital base they could utilize better livelihood opportunities. Households with female head (mostly widow) have lesser capability to spend.

What is interesting in Table-3 is that the variable NRES, which is a dummy variable representing the households status for natural resource exploitation (=1 for those households who engage in river/forest based activities), turns out to be insignificant. It means that the households that went for such activities could effectively match their counterparts in terms of capability to spend money. So, it can be said that the rivers and forests in Sundarban delta has been effectively used as a natural insurance against the disaster induced crop loss.

4.6 Anthropogenic stress and labour outmigration

The preliminary understanding of the livelihood dynamics in Sundarban suggested that there is a closely relationship between natural resource exploitation and migrating out for labour jobs. This is because both of these livelihood options are generally adopted by the asset poor. Traditionally, it is the landless or marginal farmers who adapted to either of these activities

(sometimes both of them). The survey in its first round also recorded the livelihood activities that the households were undertaking immediately before Aila. Figure-5 below shows the distribution of households across landholding classes identified with their migrant labour status and natural resource exploitation status before Aila. It is clearly seen that the less a household's landholding, the more is the chance of its adapting to either of these activities.

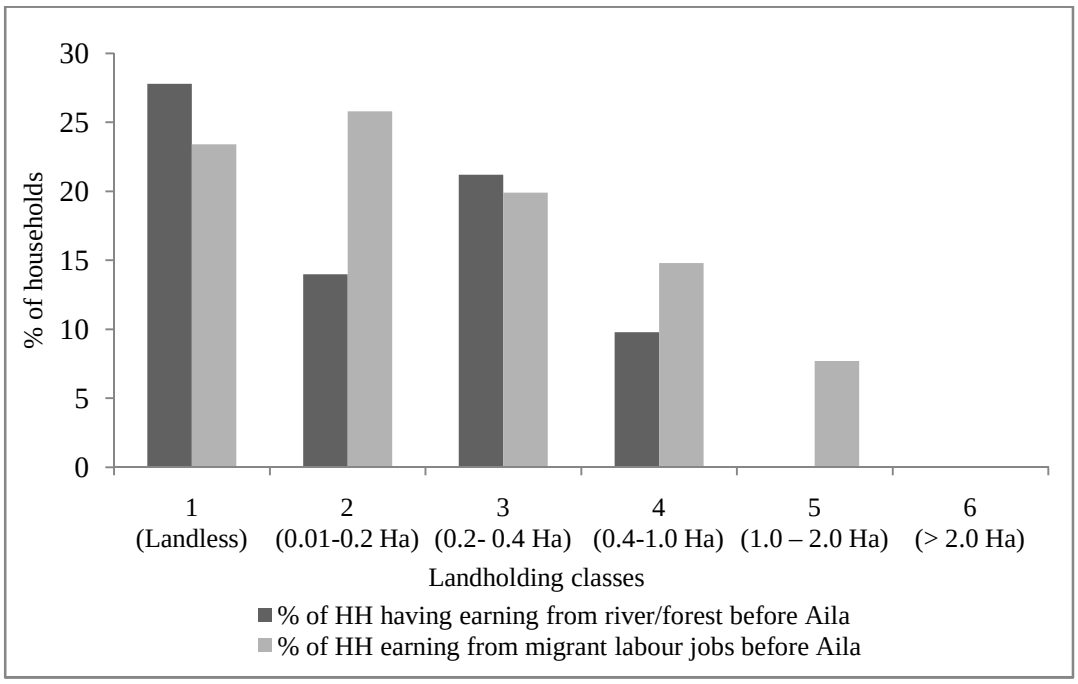

Figure 5: Natural resource dependents and migrant workers across landholding classes

If a member of such a household goes out of Sundarban as migrant labourer for a period, there is obviously a reduction of possible threat to rives and forest creeks for that period. So, after Aila, it was interesting to see whether the decision to enter in these two different lines of livelihood activities had any influence on each other at household level.

This could be analyzed by identifying the 'new-entrants' after Aila. Data collected in survey rounds has been used to identify the households which had *newly* started natural resource exploitation and/or migrant labour jobs after Aila. A household is identified as 'new' in such a livelihood if none of its members was engaged in it before Aila, but at least one of them had started it in the any of the survey rounds.

Then the total set of survey households has been divided into two categories – those which are 'new' in migrant labour jobs and those which are not. Against each of these categories the new entrants in natural resource exploitation are also identified for each survey round. The percentage increase in the number of household in each survey round - increase compared to the number before Aila – has also been calculated for each of these two categories. The result has been described in Table – 4.

It corroborates the fact that migrant labour jobs have a releasing effect on anthropogenic stress in Sundarban's ecosystem. For the group that didn't resort to new migrant labour jobs, there has been over 50% increase in the number of newly entered households before and after the disaster in natural resource exploitation. The corresponding figures for the other group (households that went for new migrant labour jobs) are considerably less and even negative.

Table 4: Incidence of natural resource exploitation vis-a-vis outmigration

Status regarding migrant labour job after Aila	% increase in number of HHs that exploited natural resources (increased compared to the number before Aila)		
	1st round survey (Mar-Jun, 2010)	2nd round survey (Jan-Mar, 2011)	3rd round survey (Jan-Mar, 2012)
HHs that did not start new migrant labour jobs	56	69	59
HHs that started new migrant labour jobs	5	10	-5

For a more conclusive evidence of the above phenomenon, a panel regression has been carried out to find the determinants of 'new entry' in natural resource exploitation separately for the two groups (migrants and non-migrants). The dependent variable (NEW_NRES) is constructed as a dummy variable identifying new entrants in river and forest based activities for every round (=1 for household which is a new entrant). Accordingly the regression is a probit analysis for panel data. The set of regressors is the same as has been described before. Results of the two sets of estimations are given in Table-5.

Table 5: Determinants of natural resource exploitation across migrant status
(Probit for panel data)

Dependent Variable: **NEW_NRES**	**HHs without new migration**		**HHs with new migration**	
	Marginal effect (dy/dx)	Test Statistic (z)	Marginal effect (dy/dx)	Test Statistic (z)
REMOTNESS	-0.0219	-0.91	-0.0222	-0.97
EXP2NRES	0.0156	0.99	0.0297	2.03**
FSIZE	0.0065	0.57	0.0113	0.96
HDEDU	-0.0122	-0.64	-0.0106	-0.42
HDAGE	-0.0005	-0.3	0.0006	0.33
FEMALE_HEAD	-0.1128	-1.19	-0.0592	-0.76
LAND_HOLDNG	-0.1550	.-2.1**	-0.0317	-0.43
WATERSTAY	0.0021	2.67***	0.0004	0.64
Regression Diagnostics	Number of obs = 401 Log likelihood = -198.47 LR chi2(8) = 17.33 Prob > chi2 = 0.0269		Number of obs = 375 Log likelihood = -172.27 LR chi2(8) = 7.47 Prob > chi2 = 0.4869	

It clearly shows that 'new entry' in natural resource sector has been almost completely determined by the cyclone damage intensity (WATERSTAY) for the households without new migrant labour

jobs. But for the other set, this crucial variable failed to assume any significance. So, it can be conclusively said that the cyclone is not a contributor to additional anthropogenic stress on Sundarban's ecosystem if migrant labour jobs are chosen as alternative livelihood strategy against agricultural loss.

5. Conclusion

Efforts are ongoing at national and international level for conservation of Sundarban's ecosystem, which is a World Heritage Site. This study shows that anthropogenic pressure on this ecosystem increased permanently with a climate related disaster and attendant agricultural loss. Survey data show that among the households facing larger damage intensity, those with smaller land endowments and lesser education tended to shift towards natural resource exploitation in the wake of the disaster. It is seen that even after reasonable restoration of damaged agriculture, a significant number of households had continued with this new livelihood option. It is observed that proximity to riverfronts induced some households to permanently shift towards river and forest exploitation.

It is seen that households that are lowly endowed with physical and human capital tend to be more dependent on natural resources. Again, it is the similar types of households that often resort to the alternative option of migrant labour jobs. It was found that if a household opts for sending a household member for such jobs outside, the probability of its falling back on forest and river is significantly reduced.

New entrants in natural resource exploitation are harmful for Sundarbans. Official efforts to protect local agriculture against such future events, in the form of heavy investments in strong embankment building, is not in line with the long term sustainability of this ecosystems in face of predicted increase in such events under climate change scenarios. Instead, helping the local population in getting labour jobs outside can be an alternative way to conserve the ecosystem. It might be helpful to generate greater awareness and information regarding job opportunities outside. Some form of subsidizing private costs of migration would also help to steer the workforce of marginal and smallholder families out of Sundarban. This might improve the long run sustainability of the ecosystem as well as providing them with a more certain livelihood option in face of the climate change threats.

Notes :

1. This paper is a partial outcome of a research project funded by South Asian Network for Development and Environmental Economics (SANDEE), Kathmandu, Nepal and was hosted by SHODH: The Institute of Research and Development, Nagpur, India. an earlier version of the paper has been presented in the Seventh Biennial Conference of INSEE (December 5-8, 2013; Tezpur University)
2. On 25th May, 2009.
3. Sources: Department of Sundarban Affairs: http://www.sadepartmentwb.org/
   Directorate of census operation, West Bengal: http://web.cmc.net.in/wbcensus
4. The indicators are:
   Extent of cyclone damage: *percentage of cultivable land left uncultivated in 2009*
   Remoteness: *time taken to reach the block administrative office from the village by usual mode of transport*
   Proximity to natural resources: *length of river embankment in the village*
5. National Rural Employment Guarantee (NREG) Scheme: a scheme funded by government of India to provide labour jobs to the rural unemployed
6. Please refer to APPENDIX for a detailed description of the categorical variables

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Appendix A1: Description of variables used in regression analyses

Category	Variable Name	Description
Dependent Variables		
NRES	(Binary) =1 if any members of the HH had earning from river and /or forest based activities = 0 otherwise	
NEW_NRES	(Binary) =1 if no member of the HH was engaged in river and /or forest based activities before Aila but at least one member *started doing it after Aila* = 0 otherwise	
MCONEXP	(Continuous) = Monthly monetary expenditure of the household (Rs.)	
Regressors:		
Location/ remoteness	REMOTNESS	Categorical variable (1 to 4) indicating the distance of the household from the Block Administrative Office (in ascending order).
Natural resource availability	EXP2NRES	Categorical variable (0 to 4) indicating the exposure of the HH to natural resource captured by the length of river embankment within the village perimeter divided by the village population (in ascending order; zero indicating not adjacent to a river).
Physical and human capital endowment	LAND_HOLDNG	Area of HH's own cultivable land for landed households (unit = Hectare)
	FSIZE	Number of members in the HH
	HDAGE	Age of the head of the household (in completed years)
	HDEDU	Categorical (1 to 8) indicating the highest educational qualification of the head of the household (in ascending order)
	FEMALE_HEAD	(Binary) Sex of the head of the household 0= Male ; 1=Female
	LIVESTOCK	Money value of HH's livestock holding in US $; (conversion rate: US $ 1 = INR 55)
Aila damage indicator	WATERSTAY	The number of days through which saline water stayed on the HH's agricultural land (reported by the HH in first survey round)

Appendix A2: Summary statistics of the variables used as regressors

Variable	Type/Unit	Obs	Mean	Std. Dev.	Min	Max
REMOTNESS	Categorical	778	2.75	0.89	1	4
EXP2NRES	Categorical	778	2.30	1.38	0	4
FSIZE	Integer	778	4.91	1.87	1	15
LAND_HOLDNG	Hectare	778	0.26	0.38	0	5.6
HDEDU	Categorical	778	2.68	1.05	1	8
HDAGE	Integer	778	46.2	13.3	20	89
FEMALE_HEAD	Binary	778	0.05	0.22	0	1
WATERSTAY	Integer	530	17.05	27.10	0	180

APPENDIX A3: Construction of categorical variables used in regression

1. REMOTENESS: Within the delta region with a labyrinth of rivers, people mostly commute by boats. In such a context, the distance between places could be meaningfully captured only by measuring the commuting time between them. In the sample selection process, remoteness of a village was recorded in terms of options representing the average time taken to reach the Bock Development Office from that village using usual mode of transport. The four options were – (i) less than one hour (ii) between one to two hours (iii) between two to three hours and (iv) more than three hours.

The appropriate option has been recorded by the corresponding number and later this information is used to represent the remoteness of all the households belonging to that village. So, REMOTENESS is an integer between 0 to 4.

2. HDEDU: Highest educational qualification of the household's head has been recorded as one of the eight given options starting from 'illiterate' (lowest, recorded as '1') to 'post-graduate and above' (highest, marked as '8'). So, this is a categorical variable with ascending values representing higher human capital endowment for the household.

3. EXP2NRES: This is a variable constructed after the collection of survey data. It is invariant for all households within a village and essentially a village level characteristic. It is intended to represent two dimensions of natural resource availability to the villagers. Firstly, it captured the proximity to natural resources by the length of riverfront (equivalently 'length of embankment', as riversides are invariably guarded with embankments) within a village. Secondly, it considered the degree of competition within the villager for use of that riverfront.

At the village selection stage, data has been collected on embankment length and voter number (adult population) for all villages in the two study Blocks. Then, the ratio of embankment length and corresponding voter strength has been calculated. This ratio, representing 'per-adult embankment length', has been used as a proxy for villagers' exposure to natural resources.

There are villages for which this value is zero, as they are located in the interiors of an island. The non-zero values, however, represented a continuous variable. It needed to be transformed into a discrete one to arrive at some finite categorization before selection of sample villages. It was accomplished by calculating quartiles of the non-zero values of that ratio. These quartile numbers were used as categories representing the exposure to natural resource (river) for the village as a whole (i.e., category '1' village representing least exposure to riverfront). So, EXP2NRES had five possible values (0,1,2,3 and 4; with '0' representing 'no embankment'). The value of this categorical variable for a village has later been assigned to every household from that village.