STORM SURGE DAMAGES IN A COASTAL POLDER: A CASE STUDY ON CYCLONE AILA

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ABSTRACT

In 2009, cyclone Aila hit the south-western coast of Bangladesh resulting in loss of lives and damages to properties thus rendering half a million people homeless. Although several studies have been conducted for the broader sectoral assessment of the impacts of Aila in different regions, but very few studies involved the damages and impacts in details at the local level in a participatory approach. This paper presents the detailed study of damages and impacts of cyclone Aila in Polder 32 of Dacope upazila of Khulna district. During Aila, the embankment in Polder 32 was breached and overtopped at several points resulting in washing out of agricultural lands, damages to livestock and household properties, etc. Even after receding of the storm surge, saline water was logged in many areas for 2 to 3 years and caused immediate as well as prolonged impacts on agricultural productivity. Data on damages were collected through Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), Individual Interviews and then analyzed and verified with secondary data. Interviews and FGDs were conducted with diverse livelihood groups consisting of both men and women. The study involves participatory GIS (P-GIS) mapping to prepare inundation map of the study area using the information of the local people. The maps show that the high inundation depth in most of the polder area resulted in prolonged sufferings of the local people. Based on economic loss and physical damages, it is found that agriculture is the most severely affected sector. It is also found that some agricultural activities started only in the relatively high lands in the third year after Aila. However, the yield was approximately 60 - 80% of that in the year before Aila. This paper provides an in-depth understanding of the local damages and long-term impacts caused by the storm surge.

Keywords: *Storm surge, damage, agriculture, productivity, polder*

1. INTRODUCTION

The landmass of Bangladesh is connected to the Indian Ocean through a coastline of 700 km to the north and north-eastern part of the Bay of Bengal. So Bangladesh owns a huge coastal region which consists of 19 districts with a total area of 47,203 km^2 and a population of 35 million, which is 28% of the country's total population (Khan & Awal, 2009). Since distant past, people have been settling in the coastal belt of Bangladesh though they remain in a precarious situation of becoming hit by a natural disaster at any time. But still they have been taking risks to live here as the coastal region of Bangladesh has one of the world's largest resources and opportunities as well. The coastal region has experienced frequent cyclones associated with storm surges in the last few decades. Bangladesh is found to experience 40% of the total storm surge events of the world (Murty & El-Sabh, 1992). The low-lying and relatively flat terrain, geographical setting at the tip of the funnel shaped Bay of Bengal, shallow continental shelf, high tidal range, high density of population and fragile coastal protection system are attributed as the major reasons for this disproportional large impact of storm surges on the coast of Bangladesh (Dasgupta et al., 2010). Bangladesh has experienced 36 cyclonic storms in the last four decades resulting in over 450,000 deaths and huge economic loss (UNDP, 2010). Among those, the most disastrous events, Sidr in 2007 and Aila in 2009 hit the southwestern coast of Bangladesh, the most vulnerable region in the country. These cyclones and surges resulted in loss of lives and damages to properties thus rendering millions of people homeless. Aila, the deadliest cyclone at the dawn of the 21st century, hit the Bangladesh coast on May 25, 2009. It severely affected 12 out of 19 coastal districts of Bangladesh which includes Satkhira, Khulna, Bagerhat, Pirojpur, Barisal, Patuakhali, Bhola, Laksmipur, Noakhali, Feni, Chittagong and Cox's Bazar (Roy, Kumar, Mehedi, Sultana & Ershad, 2009). At the time of landfall at the Bangladesh coast, the sustained wind speed of Aila was 75 mph which ranked it as a Category-1 cyclone (Kumar, Baten, Masud, Osman &

Rahman, 2010). Though by definition, it falls into a weak cyclone category but due to its economic cost and long-term sufferings, the impacts of Aila outweigh the impacts of any past cyclone. About 2.3 million people were affected by this event and many coastal inhabitants were stranded in the affected areas since they had no safe alternatives to survive (Kumar et al., 2010). The surge height rose to almost 10-13 ft which caused overtopping of embankments, breaching at several points and inundation of households and croplands (Kumar et al., 2010). The fisheries and croplands were devastated throughout the coastal region due to salinity ingression. Poor communication with the affected embankments, rise in market prices and loss of livestock made the situation even worse. Even two years after Aila, the coastal system did not return to its previous state. Long-term inundation with saline water increased soil salinity, which damaged agricultural productivity in the subsequent years. This paper provides an in-depth participatory study of the local damages caused by Aila in a selected site. Similar participatory local damage assessment will help local level planning for disaster management and design of future interventions.

2. STUDY AREA

Dacope upazila of Khulna district is situated in the southern region of Bangladesh. The upazila consists of three polders, namely Polder 31, 32 and 33. Cyclone Aila severely affected Polder 32. The polder is situated at 22.5722°N latitude and 89.5111°E longitude (Figure 1). The study area has a population of 43,749 with an area of 78.17 km^2 (BBS, 2011), and is enclosed by the Bhadra river on the east, the Shibsa on the west, the Dhaki on the north and the Sutarkhali river on the south side. A number of canals including Jaliakhali, Gulbonia, Mistripara pass through the polder. The mangrove forest Sundarbans starts on the southern part of the study area. Most of the lands in the area are medium high land (inundation depth 0.30-0.90 m). Local occupations include shrimp farming, crop cultivation and wage labour. Common agricultural crops in this area are aman (monsoon rice) and homestead vegetables (winter crops) with small scale sunflower, sesame, boro rice and watermelon. Cropping intensity in the study area is found to be 104%. Dry season cropping is constrained by high soil salinity which ranges from high to very high (13-30 dS/m) during dry season (MoL, 2011). Among the farmers, the landless and marginal are the majority. A good number of people have chosen Sundarbans dependant livelihoods which include fishing and collection of golpata (used locally for roofing), honey, firewood, timber, fries, etc. An extensive field study was conducted during January, 2014 to May, 2015 in Kamarkhola and Sutarkhali unions of Polder 32, in Dacope upazila, Khulna district.

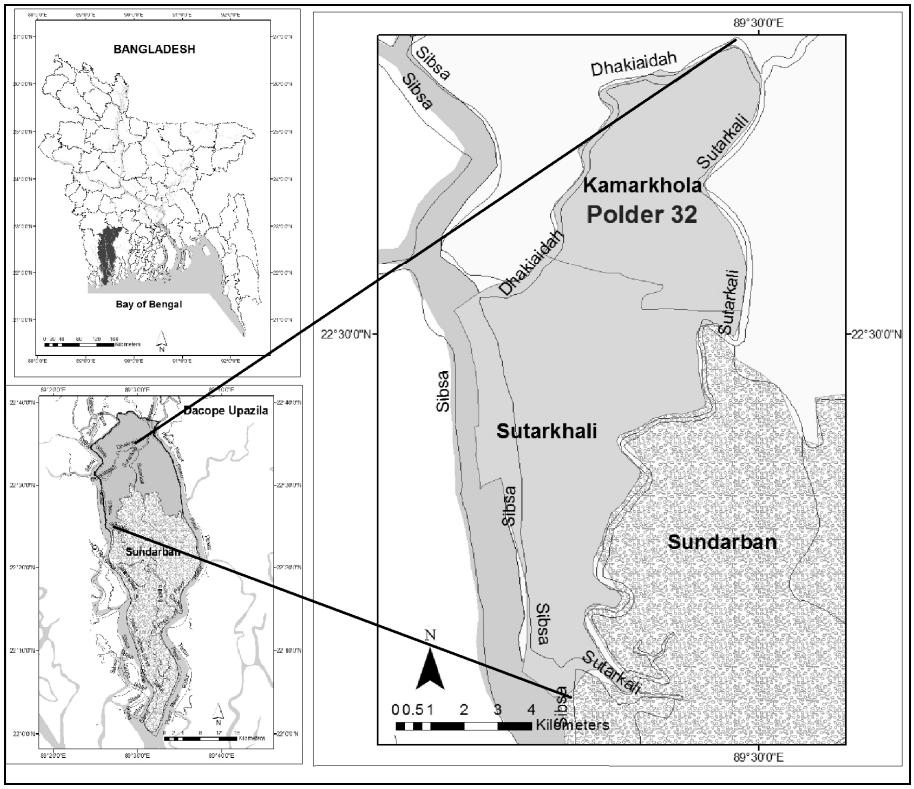


Figure 1: Study area located in the coastal region of Bangladesh

3. METHODOLOGY AND DATA COLLECTION

For this study, the damages and losses caused by Aila are assessed from primary and secondary information. Scientific literatures regarding storm surge propagation characteristics, land-use and cropping pattern, land value, sea level rise, damage due to storm surge, etc., are reviewed, particularly in the context of the southwestern coastal area of Bangladesh, to develop an in-depth knowledge. Physical elements of storm surge (inundation depth and locations of overtopping and breaching of embankments) are identified through participatory GIS (P-GIS) mapping (McCall, 2003; DFID, 2009; Jayasinghe, 2015). P-GIS helps in establishing the links between inundation (both short-term and long-term) within the polder with different factors, including polder overtopping and breaching, creation of new depressed areas (and subsequent water logging) because of scouring and widening of the breaching points during daily high tides using the perception of the local people. The process involves engaging local communities in deriving information on the physical factors associated with storm surge, via Focus Group Discussions (FGDs), with the help of existing map (BWDB canal network map) and Google earth image of the study area. An open source software ArcGIS 10.1 is used to digitize the information on depth of inundation in preparation of the map.

Assessment of potential damage and loss in the agricultural sector focuses mainly on the likely impacts on crop production, livestock and fishery. For crop production, this analysis is restricted to Aman rice in coastal Bangladesh. The crop calendar, or the planting - harvesting dates of aman and winter crops are different. As a result, these crops are exposed to varying degrees of risk of storm surge inundation. This fact has been taken into consideration in the damage assessment.

Relevant data are collected through field observations and visits to relevant governmental and non-governmental organizations. Several Participatory Rural Appraisal (PRA) tools including Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), Individual Interviews, etc., are used to obtain information from the local people on the damages caused by Aila. FGDs are conducted with diverse groups including farmers, fishermen and women while KIIs are conducted with local government officials and prominent local people. The information given by different groups varies slightly because of the difference in perceptions and level of impacts. The information are analyzed and verified with secondary information collected from relevant literature sources.

4. RESULTS

4.1 Loss and Damages of Aila: A Broader Picture

Cyclone Aila caused the death of 190 people, injured 7,103 and rendered another half a million people homeless (Dasgupta et al., 2010). Though the casualties were less according to official reports, but the long term sufferings were beyond description. We find that, during the event in the affected areas, only a small percentage of the affected people managed to move to the nearby cyclone shelters while others took shelter on elevated roads, embankments and rooftops. Aila not only broke down the overall social cohesion, but also resulted in a miserable condition in the area for several years. Beyond the human impacts of the disaster, some 100,000 livestock were killed, over 1300 km^2 of cropland were destroyed, and over 6,000 km of roads and 1,500 km of embankments were damaged (ActionAid et al., 2009; UNICEF, 2010; Shamsuddoha et al., 2013). Local people informed us that the loss and damages caused by Aila had both immediate and long-term significances. The damaged roads were not repaired in time, and houses and agricultural lands were submerged for quite a long time, which significantly hampered the local economy. Consequently, in the wake of Aila out-migration in search of employment and alternate livelihoods, both seasonal and permanent, became predominant in the affected areas, informed the local people.

4.2 Impacts of Aila in Dacope Upazila

Among the affected areas of Khulna district, Dacope Upazila was hit the hardest. In Dacope, 7 out of 9 unions were severely affected (Kumar et al., 2010). Thousands of people of Kamarkhola and Sutarkhali unions in Polder 32 were the worst victims of Aila. People of other two polders (polder 31 and 33) of the upazila also experienced damages of varying levels. Table 1 illustrates the summary of damages in Dacope Upazila.

Table 1: Summary of damages in Dacope Upazila

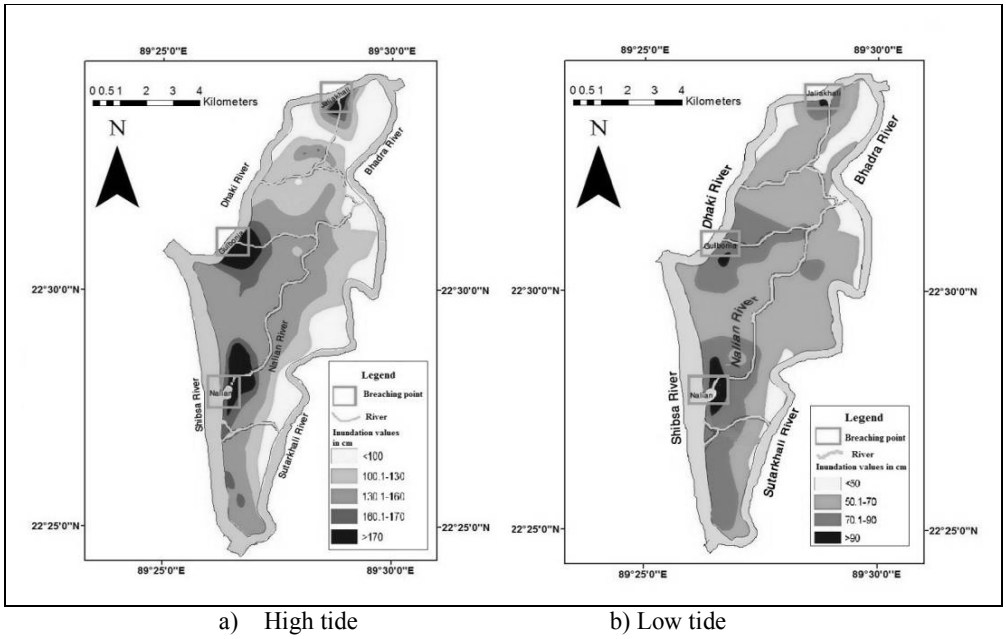
Affected union	Affected villages	Affected people	Displaced people	Destroyed household	Crop damage (acre)	Dead or missing livestock	Damaged shrimp gher
Tildanga	All	26000	10000	2000	500	400	300
Dacope	All	25000	9000	1500	400	300	200
Bajua	All	25000	9000	1800	450	400	250
Sutarkhali	All	21000	8000	2000	500	400	300
Banishanta	All	15000	6000	1300	350	300	300
Pankhali	All	15000	6000	1200	300	250	150
Kamarkhola	All	10000	4000	950	200	200	150
Total		137000	52000	10750	2700	2250	1650

Source: Cyclone Aila Situation Report (USS, 2009)

Many people were displaced immediately to nearby cyclone shelters and elevated road embankments and many other people were stranded in the affected areas finding no other alternatives. Almost all the agricultural land was submerged by cyclonic saline water for different duration depending on the land type. A previous study (Kumar et al., 2010) shows that, 2,700 acres of crop land was initially damaged in Dacope Upazila while field observations showed that almost all the agricultural lands in Polder 32 and some other parts of the upazila were unsuitable for crop production even for 2 years after Aila. Damages in different sectors and the impacts assessed through PRA tools are summarized in the following sections.

4.2.1 Damages of the Embankments

The cyclone washed away the coastal embankments, the only protection to the fragile coastal regions at the first thrust of Aila. During Aila, almost 10% of the 50 km long polder 32 was overtopped with several major breaching at Jaliakhali, Golbunia also known as Vitevanga, Nalian, etc. Breaches in the embankments (Figure 2), which became wider during daily high tides particularly during spring tides, intensified the damages of the event. Local people informed that, during every high tide, water used to rise upto 3.5-6 ft and 1.5-3 ft during ebb tide (Figure 2) within the polder for the first few months and in some points for even longer period until the polder was repaired. This regular and cyclical inundation worsened the damages to other sectors. Figure 2 also illustrates that at the mouth of the breaching points large depressions were created and we attribute the initial strength of Aila and the regular tidal effects as the reasons.



a) High tide b) Low tide

Figure 2: Maps showing depth of Inundation during high tide and low tide

The officials from Bangladesh Water Development Board informed us the detail information about the breaching width and scouring depth in the polder 32 (Table 2). Some depressions were created which were far deeper than the normal bed level of (-) 4 to (-) 5 m, PWD. Though within one year after Aila storm water receded from some relatively high land, but in the natural depression points water was stagnant for even more than one and half year.

Table 2: Summary of the breaching width and Depth

Breaching Point	Initial width (m)	Width during repairing (m)	Average rate of breaching (m/week)	Bed elevation (m, PWD)
Vitevanga	20	120	2.63	(-)15 to (-)16
Jaliakhali	60	80	0.53	(-)12
Nalian	10	60	1.32	(-)8 to (-)9
	2	40	1.0	
	1.5	20	0.49	

Source: Bangladesh Water Development Board, Khulna Office

In the study area, damages to the network of embankments resulted in a prolonged continuation of the immediate aftermath of Aila. Local people informed that intentional breaching of the embankments to lift saline water into ghers (shrimp farm) made the embankments weak and led to breaking down during Aila. Moreover, silting up of the river beds also forced the tidal surge and river flow to put excessive pressure on the embankments to make them even weaker. Field information strongly suggests that, failure of the embankments rather than strength of Aila was more responsible for the sufferings of the people. The damages of embankments cost a huge amount of money to repair the embankments (Table 3). The key informants informed that, the embankment was washed away in some points which were repaired in some cases. But, in most cases the embankment was needed to be shifted due to the conversion of the previous embankment area to river portions. The repairing and shifting of the embankments took huge economic costs.

Table 3: Economic loss due to embankment damage

Points	Length (Km)	Status	Cost (Taka, million)	Authority
South Kalabagi	1.2	Shifted	7.2	CARE
Mistripara	3	Shifted	18	BWDB
Gunari	5.5	Shifted	33	BWDB
Kalibari	2.5	Shifted	15	BWDB
Upside of Kalibari	2.5	Shifted	15	BWDB
Jaliakhali	2	Shifted	12	BWDB
Nalian	22.5	Shifted	135	BWDB
Other	33	Repaired	66	BWDB

Source: Bangladesh Water Development Board, Khulna and CARE Office, Khulna

4.2.2 Loss and Damages in Agriculture

Cyclone Aila struck during the planting season of Aman (Table 5). Table 4 and Table 5 give the crop calendar and cropping period of Aman rice in the study area, prepared on the basis of the information given by the local people. Though short term impacts on agricultural crops were not severe in the study area as it was planting season, the long-term residual impacts were far-reaching (Figure 3) and caused profound negative impacts on local crop production (Dasgupta et al., 2010). For instance, Aman rice harvests significantly decreased in consecutive years following cyclone Alia (Table 6) due to the sudden and drastic increase in soil and water salinity that resulted from storm surges. This whipped the already affected poor people since there was no agricultural production for three years at a stretch. Typical local farmers informed that before Aila they used to get 4.0-4.5 t/ha. For the first two years after Aila, the loss was 100%, and in the third year they were able to cultivate some lands which were relatively high and got 3.75-4.0 t/ha only after reduced salinity in the agricultural land.

Table 4: Crop calendar of the study area based on field interviews

Season	Month	Previous Crop	Present Crop
Kharif-1 (Pre-monsoon)	Mid April-July	Fallow	Fallow
Kharif-2 (Monsoon)	Mid July-Mid November	Aman	Aman
Rabi/winter crops (Post-monsoon)	Mid January-Mid May	Fallow (Small scale homestead vegetable)	Rabi crops (Sunflower, sesame etc.)

Table 5: Cropping period of Aman rice

Month	April-May	June-july	November
Activity	Sow seeds	Seedlings	Harvesting

Table 6: Aman rice production before and after Aila (Typical farmers)

	Amount of land (Acre)	Before Aila (April, 2009)	During 2010, 2011	During 2012[1] (ton)	During 2013[2] (ton)
Farmer-1	0.3	0.65	No Crops	0.45	0.72
Farmer-2	1	2.1	No Crops	1.48	2.30
Farmer-3	1	2.2	No Crops	1.50	2.53
Farmer-4	1.5	3.2	No Crops	2.20	3.6
Farmer-5	2	4.1	No Crops	2.85	4.70

[1] Aman production with the same variety which people used to produce before Aila
[2] Aman production with improved rice variety.

We attribute the sediment deposition after Aila within the poldered area, initiation of improved rice variety for increased crop production in 2014.

Moreover, Figure 3 (a) shows that, about 52% of the impacts in agriculture were long term impacts. Long term inundation resulted in long term agricultural un-productivity. Figure 3(b), 3(c), 3(d) based on the interviews of the affected people, shows comparative agricultural damages to other sectors in the three major damaging locations of the study area where polder breaching caused the worst impacts. In all the locations agricultural sector top the damage list. During field visits, local people also reported that in Kamarkhola and Sutarkhali unions the agricultural land was waterlogged and unproductive for greater period than any other neighboring affected area resulting in a huge agricultural loss. Interviewed people informed that long-term waterlogging changed the soil quality which in consequence affected the immediate cropping season along with the following three year's production.

Field observations and public consultations showed that production of aquaculture (white fish) was not possible for a long time because of salinity and pollution in the water bodies. In the local ponds, storm water intruded that paralyzed white fish culture and in many places ponds and shrimp ghers were flooded through which the fish species escaped into floodplain. Historical practices of shrimp were thus hampered and analysis shows that out of total damages of shrimp ghers in Dacope upazila, 27% occurred in Kamarkhola and Sutarkhali union only. It is also found that after Aila production of shrimp was reduced from a normal year's 2,350 kg/ha to 470 kg/ha (Shamsuddoha et al., 2013). Lately, in many places the shrimp farmers had to abandon shrimp "ghers" in the pressure of local people who blamed shrimp cultivation for the intensification of the damages.

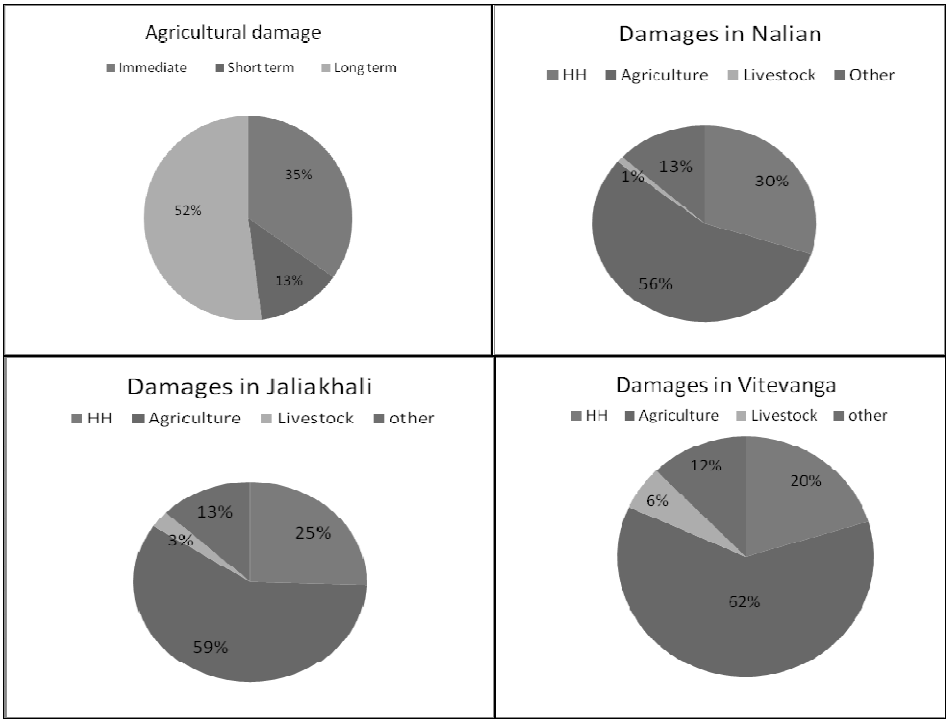


Figure 3: Damage assessment based on FGD, Interviews (a) Agricultural Damage Type (b) Damages in Nalian (c) Damages in Jaliakhali (d) Damages in Vitevanga

Along with crop production and fisheries, livestock like cows, goats, hens, ducks, etc., were major income sources in the study area, which was devastated by Aila. Respondents informed that in the study area Aila damaged 75% livestock which reduced the local people's farm income. Along with the immediate loss of livestock, death toll of the domestic animals continued even after Aila due to food and drinking water shortage. Based on the field consultations with the affected people, Table 7 shows the detail scenario of livestock damages of some typical families in the study area. The statistics implies that poor and affected farmers were compelled to sell their remaining livestock rather than seeing their depletion.

Table 7 : Typical statistics of livestock damages

	Family-1		**Family-2**		**Family-3**	
	Before Aila	**After Aila**	**Before Aila**	**After Aila**	**Before Aila**	**After Aila**
Cow	2	All died	3	1 died, 2 sold	3	1 died, 1 sold, 1 sent to owner's relative's house
Goat	26	19 died, 3 sold, 4 survived	10	2 died, 8 sold	12	5 died, 7 sold
Duck	12	8 died or lost, 4 survived	10	2 died, 6 sold, 4 survived	10	4 died or lost, 6 sold
Swan	6	2 died, 4 sold	-	-	4	2 died or lost, 2 sold
Hen	15	7 died, 5 sold, 3 survived	10	2 died, 8 sold	10	1 died, 7 sold, 2 survived

4.2.3 Loss and Damages in Household Assets

From field observations it has been found that, most of the houses of the study area are earth-made. These earthen houses are very much sensitive to water submergence and even worse to saline water. As a result, most of the houses failed in the first thrust of Aila causing a huge immediate loss in this sector (Figure 4). The results also represent that 75% of the damages in this sector was immediate. It summarizes that, most of the damages in this sector occurred in the early periods of the event. In addition to this, local people confirmed that, the earthen houses those somehow survived the first phase, could not stand tall more than few weeks resulting in short term impacts. During first few months after Aila, the houses were continuously submerged under 1-1.5 ft even during low tide depending on house location. So as a result, most of the houses failed/broke and became unsuitable to further living. In addition to this, 90% of the people of the area lost their houses along with their daily essentials like cooking utensils, furniture, etc. Many of the household furniture and daily accessories were washed away by storm water. Some people were in such a rash during the first stage of Aila that they could barely thought about their household resources and were running for a safe shelter only with their own lives, informed local people. A comparative study mentioned earlier in Figure 3(b), 3(c), 3(d) shows that, out of the total damages, 30%, 25% and 20% was household damages in Nalian, Jaliakhali and Vitevanga respectively. This also implies that, households were the second worst damaging sectors in all the major locations.

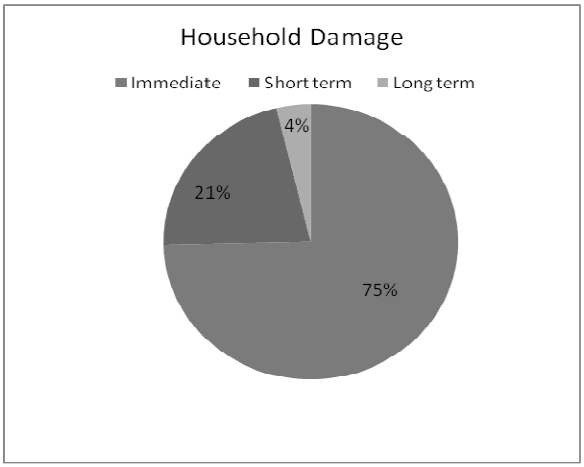


Figure 4: Household Damage Type

4.2.4 Impacts on Livelihoods

Economy of this region was seriously hampered due to Aila. Shrimp farming (40%) was a major occupation along with small holding agriculture (30%) and wage labour activities (30%) in southwestern coastal region of Bangladesh including the Aila affected region (Kumar et al., 2010). About 96% of these livelihood bases were devastated by Aila (Kumar et al., 2010). The most affected sector of livelihood was agriculture. Almost all the productive crop land went under saline water and the land remain unsuitable for further production for three long years. The crop farmers, during this period either sat idly living on relief supports or worked temporarily as day labourer in some embankment reconstruction sites. Some family reported that before Aila they were well to do with their agricultural return which was worth BDT thirty thousand per year but after Aila they were as like as other landless farmers. The fisherman both white fish and shrimp, had to pay a great loss. In a normal year, a mediocre shrimp farmer used to make a profit of BDT 30-45 thousand per year but two year followed by Aila they could hardly come back to their practice. During the study, fishermen informed that, they used to earn BDT 300 to 500 daily before Aila but after losing their equipment (boats and fishing nets) most of the time they had to depend on the support of the NGOs and government reliefs. A previous study (UNDP, 2010) showed that the casual labours found only seven to ten days work per month compared to 20-25 days in a normal year and during the field visit the local people too informed that there were limited working opportunities, the number of workers increased compared to availability of working opportunities in the affected areas immediately after Aila. The wage laborers who used to earn BDT 150 to 300 daily before Aila could earn BDT 100-120 when they could manage some work in some reconstruction sites and the remaining days they had to remain jobless and penniless as well. This changed the occupational pattern of this region. Many non-laborer affected people took jobs in reconstruction programs of the damaged embankments after Aila. Migration increased sharply after the disaster. Maximum working male population migrated from this region to urban areas for seeking jobs. Many people became wage laborers and left for other places in search of jobs. The women staying back at home had to do all the work in the field and at home.

4.2.5 Potential Human Casualty

The number of cyclone shelter was insufficient to meet the demand in the study area. Moreover, some people were reluctant to go to shelters due to distance from the homestead, unwillingness to leave livestock, lack of user-friendly facilities for women and lack of sanitation facilities. Interviewed people informed that many people were hit by tin sheets (roofing material), broken trees, etc., leading to serious physical injuries. Some people died or became disabled due to these injuries. Diseases and ailments like diarrhea, food poisoning and skin diseases broke out after the cyclone throughout the region. During field visits, local people informed that the number of human casualties were less, may be 10 in the polder 32. They also added that, the number was less than it was anticipated as the event took place in daytime.

4.2.6 Distortion of the Local Market

Devastating impacts of Aila on the local production base distorted the local economies and market system. At many points, market places were either washed away or local people lost market access immediately after the cyclone. Demands for goods and other necessities rose and subsequently prices soared while at the same time supply of goods decreased as cost of supply and transportation increased. This created a sole dependency on the relief supports. Local people informed that after Aila in some places price of rice rose to 40-50 taka/kg while the normal price was 25-30 taka/kg. Some people informed that after walking miles after miles they could barely find keorsine oil which they traditionally used for lighting during evening.

4.2.7 Loss of Ecosystem Services

The Sundarbans areas were inundated with approximately 6 meters of water during Aila as per media reports. A large number of trees were uprooted and logs of trees were swept away by the storm surge. A significant decrease in regeneration and growth of mangrove forests was seen in the Sundarbans after Aila. Infrastructures like forest camps were severely damaged. Floral and faunal diversity along with many coastal people's livelihood was also severely damaged. Local people informed that many dead frogs, snakes, etc., were seen floating in the water after Aila. Due to long-term water logging many trees died due to anoxic conditions.

5. CONCLUSIONS

The study summarizes that agriculture was the worst victim of Aila in the study area. Since agriculture was the major livelihood option in the study area the chain of economic loss in the agricultural sector along with the inaccessibility to local food markets in the affected areas, shortage of supply in the markets, and increased prices undermined the food security of the local people in the long term. Immediately after the event, the outbreak of some unexpected problems made the situation worse. For example, scattered local food shops rather than large markets were the main sources of food supply, which limited the availability of various food items. There was a serious scarcity of drinking water and dry food among the affected people. Cooking fuels were short or almost non-existent and dry places were rare in the affected areas. Therefore, Aila had both short and long-term impacts on the study area. This study concludes that adaptation strategies should be formulated based on sectoral priorities- which is also an important message to the policy makers. Also in-depth knowledge of the local damage types of different sectors is essential, which may play an important role in adopting adaptation strategies.

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