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Sectoral and Temporal Damage Variation Due to Cyclonic Storm Surge: The Case Study of Aila

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The coastal region of Bangladesh is protected from tidal actions by 139 polders. During cyclone Aila in 2009, several polders failed, causing immense sufferings to the coastal inhabitants. This article presents the results of investigations of the nature of damages and their variations in different sectors in a selected coastal polder of the south-western Bangladesh during Aila. The study was carried out involving the application of various Participatory Rural Appraisal (PRA) tools including Focus Group Discussions (FGDs), Key Informant Interviews (KIIs) and Individual Interviews to obtain information such as damages caused by Aila, cropping pattern, and planting and harvesting time of the crops. The study explored the spatial and sectoral variation in cyclonic damage. The impact of inundation depth and duration on aman rice production was assessed in the study area. In sectoral damages, agriculture was the worst affected. Household and livestock sectors experienced the worst immediate impacts while agriculture faced the most severe long term impacts. The study also reveals that the coincidence of the timing of the cyclonic event with the cropping season will cost the largest amount of loss and damage. The findings of the study will help the policy makers to decide on the appropriate adaptation measures to minimize the impacts of any severe cyclonic disaster in future.

Field of Research: Water Resources Engineering

1. Introduction

Along the north and the north-east part of the Bay of Bengal, Bangladesh is connected to the Indian Ocean through a coastline of 700 km. The coastal zone of Bangladesh has an area of 47201 km^2, which is 32% of the total area of Bangladesh (Khan & Awal 2009). 48 upazilas in 12 coastal districts are defined as exposed coasts due to their high exposure to the sea and the remaining 99 upazilas are termed as interior coasts (PDO-ICZMP 2003a). The coastal zone of Bangladesh is characterized by a wide network of rivers and canals, and the Ganges-Brahmaputra-Meghna estuarine system shared with India, Nepal, Bhutan and China. The coastal areas are protected by polders from tidal actions. There are 139 coastal polders in Bangladesh (Khan 2014). 49 of them are sea facing and all of the polders were constructed in the 1960s under the Coastal Embankment Project (CEP). In 1964, 37 polders with almost 1566 kilometers of coastal embankment and 282 sluice gates were constructed in the south-western region of Bangladesh (Kibria 2005). Lunkapis (1998) describes that coastal belt is a dynamic zone where cyclonic storm surges, coastal erosion, accretion, flooding, tsunamis, etc., are common features. Since 1960, approximately 5 million people have been killed worldwide in cyclonic

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disasters and the greatest numbers of deaths occurred in Asia in the last 20 years (Cropper & Sahin 2009). The reason behind the above statement is the increasing number of hydro meteorological events due to climate change (ISDR 2009). In the recent past, Cyclone Aila hit the coastal belt of Bangladesh on May 25, 2009. It caused death of 190 people, injured 7,103 and rendered another half a million people homeless (Dasgupta et al. 2010). Aila not only broke down the overall social cohesion, but also resulted in a miserable condition in the area for several years. Consequently, in the wake of Aila out-migration in search of employments and alternate livelihoods, both seasonal and permanent, became predominant in the affected areas. Some damages were acute immediately after the event and some others were perceived severe in the long term basis. Although several studies have been conducted for the broader sectoral assessment of the impacts of Aila in different regions, since then very few studies involved the damages and impacts in details at the local level. Previous studies determined the broader sectoral impacts, but this study was conducted to assess local level damages and damage behaviors in a participatory approach.

This study focuses on the detailed assessment of the damage nature of different livelihood sectors of the coastal people, which will help the policy makers to design adaptation measures in local level. Scientific literatures relevant to coastal areas of Bangladesh and cyclonic disasters in Bangladesh have been discussed in the following section 2, reasons for selecting the study area have been provided in section 3, detailed methodology of the study has been mentioned in section 4, findings and necessary discussions have been provided in section 5 and finally, conclusions and summary of the study have been mentioned in section 6.

2. Literature Review

Since 1994, two thirds of the recorded tropical cyclonic disasters have affected the coastal zone of Bangladesh (UN 2005). A previous study of Nicholls et al. (1995) estimated that in the last two centuries, more than 40% of the 1.9 million disaster related deaths occurred in Bangladesh. 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). McBride (1995) stated that every year almost 80 storm surge events with wind speed of equal to or greater than 17 m/s take place around the world. Supporting the previous statement Neumann (1993) estimated that 6.5% of the events form in the North Indian Ocean. Among the tropical cyclones formed in the Bay of Bengal during the period 1877 to 1995, it is seen that Bangladesh is hit by about 1% of the world's total tropical cyclones, India by 3.34%, Myanmar by 0.51% and Sri Lanka by 0.22% (Ali 1999). Considering the tropical cyclones with a death toll in excess of 5000, it is found that 16 out of 35 disasters occurred in Bangladesh, 11 in India (Ali 1999). A disaster causes sufferings not only to human lives, but also to their homes and properties. Compared to cyclone Sidr that hit Bangladesh in 2007, Aila might not put a heavy death toll, but the aftermath of the cyclone was beyond description. 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 et al. 2009). It left half a million people on the verge of migration due to permanent waterlogged conditions in the affected areas (Kumar et al. 2010). 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 (Action Aid et al. 2009; UNICEF 2010; Shamsuddoha et al. 2013). Aila caused a huge loss and damages to agricultural crops and fisheries. Many other studies have already been conducted on the post Aila impacts. All of the studies assessed the broader sectoral impacts. Very few studies involved the local level losses and damages. No other studies assessed the sectoral distribution of impacts in a participatory approach in a specific coastal polder. This study depicted the sectoral and temporal variation of different losses and damages caused by Aila in a specific polder of Bangladesh.

3. Study Area

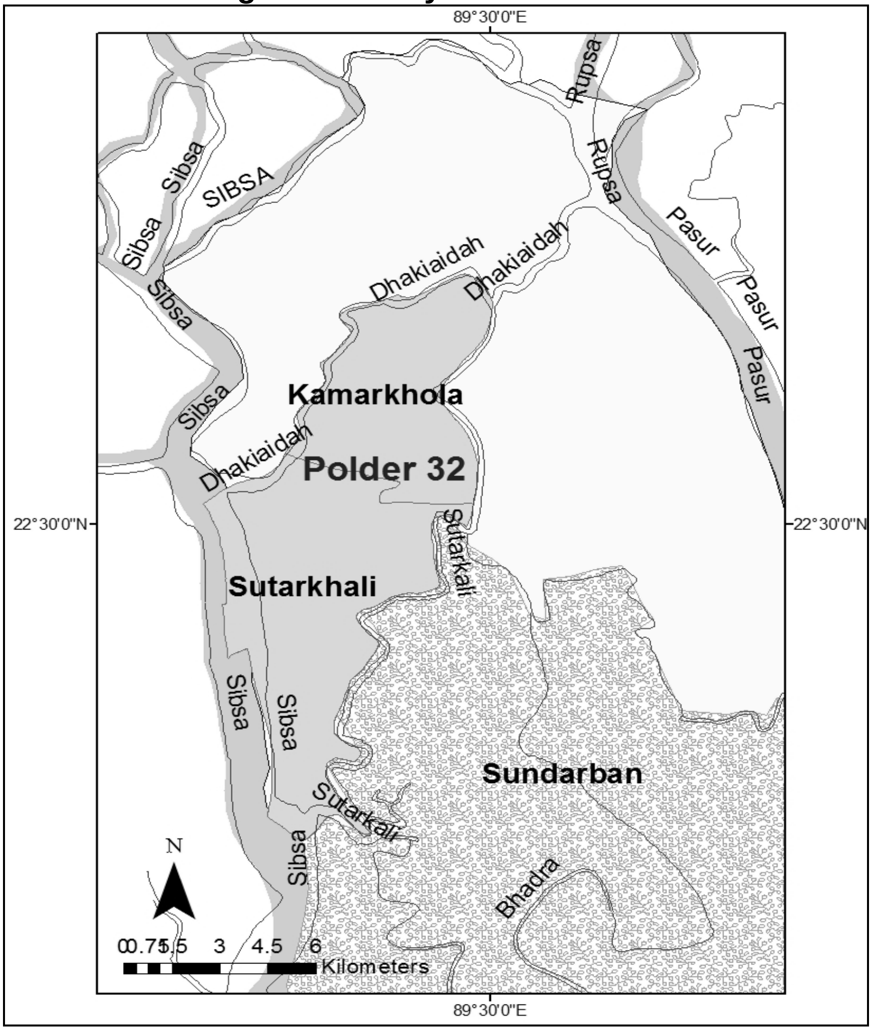
The study has been conducted in a south-western coastal polder of Dacope upazila in Khulna district, Bangladesh. Dacope upazila of Khulna district is situated in the southern region of Bangladesh. The upazila consists of three polders, namely Polder 31, 32 and 33. Cyclone Aila severely affected Polder 32 which has been selected for this study. Polder 32 was selected for this study as this area was closest to the landfall location of Cyclone Aila. This area was one of the worst victims of the past cyclonic events especially, Aila. Polder 32, consisting of Kamarkhola and Sutarkhali unions 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 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. 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.

4. Methodology

For this study, damages and losses caused by Aila were assessed from primary and secondary information and relevant Scientific literatures regarding land-use and cropping pattern, land value, damage due to storm surge, etc. Crop calendar and planting - harvesting dates of aman and winter crops were taken into consideration for assessment of potential damages and losses in agriculture sector. The crops are exposed to varying degrees of risk due to storm surge inundation. This fact was considered in damage assessment.

Relevant data were 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., were used to obtain information from local people on the damages caused by Aila, cropping pattern, planting and harvesting time of the crops. FGDs were conducted with diverse groups, including farmers, fishermen and women while KIIs were conducted with local government officials and prominent local people. Information given by different groups varied slightly because of the difference in perceptions and level of impacts. The information was analyzed and verified with secondary information collected from relevant literature sources.

Figure 1: Study Area Location



5. Results

5.1 Damage Variation

The devastating cyclone Aila was classified as a category-1 (Saffir-Simpson scale) cyclone for its sustained wind speed of 120 km/hr. Official reports showed that the death toll stood on 45 as of 3 June, 2009 (USS 2009) but its chain of loss and damage stayed active for a longer period even up to three years after the event. The amount of losses and damages and their nature were not same throughout the coastal areas. Losses and damages varied from place to place depending on the depth and duration of inundation and types of land use. Local people informed that Polder 31 was water logged only for 17 days after Aila. Due to short term saline water inundation, only one cropping season was missed in that polder. But in Polder 32, water was stagnant in many places for more than a year. After rehabilitation, water receded from most of the polder after one year except some natural depression type areas. But long term inundation resulted in deposition of salts and sandy sediments in agricultural lands. Hence, agricultural crop production was missed for more than three long years within Polder 32.

For a better understanding of damage nature and variations, a detailed study was conducted in three major breaching points, namely Nalian, Jaliakhali and Vitevanga in Polder 32. In the study area, aman rice was the major crop during the monsoon. From consultations with local farmers, it was found that damage due to inundation is a function of two factors e.g. (a) whether the water is fresh or saline and (b) whether the depth of inundation is greater or less than the plant height. If the water is fresh, then for any depth less than the plant height and for duration of less than 3 days there are no considerable damages to aman rice (Table 1). But, for ripened crop there are some degree of losses for the above mentioned depth and duration. If the depth is greater than the plant height or the duration is above 3 days, then in all stages of the plant growth there are considerable amount of losses. Local farmers concluded that if the plant height is around 4 ft, then the plant is vulnerable to a depth above than 4 ft and duration of more than 3 days.

Table 1: Aman Rice vs Inundation

Depth	Duration	Results
2 ft	2 days	Seedlings: will be damaged for full submergence for quite a long time Matured: no damage Ripened: damage increases with time
4 ft	3 days	Matured: No considerable losses Ripened: considerable losses
Above 4 ft	Above 3 days	Considerable losses in all growth stages

But in case of saline water, irrespective of the duration and depth, even if saline water resides for 1 hour, then there will be heavy losses as aman rice is very sensitive to salts. After Cyclone Aila, farmers could not grow any aman rice or any other crops due to salinity in the soil and water of the study area. This phenomenon resulted in a huge long term losses in agriculture sector of the affected area. Most of the earthen houses were damaged in the early period of the event. The earthen houses which were submerged in saline water could not stand tall any longer than 5-7 days. Local people informed that those houses which were submerged above the plinth level failed within the first week after the event. The marketplaces which were under submergence of less than 2 ft were operational during the emergency situation i.e. immediately after Aila. But, the marketplaces which were under submergence of more than 2 ft or was under threat of being washed away, remained closed for a few days until the recession of the surge water from the marketplaces.

It is found that all the sectors of an affected area were not equally affected by Cyclone Aila. Based on the interviews of the affected people, the distribution of the total damages in different sectors of the study area was assessed (Figure 2). The assessment shows that overall damage in the agriculture sector was far reaching compared to other sectors. The high share of the distribution in agriculture sector was due to both immediate and massive long term impacts in this sector while other sectors experienced less long term impacts. The study also finds that the nature of the occurrence of the damages in different sectors varied from sector to sector.

Some of the sectors experienced much immediate impact while some other sectors did not exhibit much immediate impacts but rendered huge long term impacts. The details have been illustrated in Table 2. Our qualitative analysis based on the interviews of individual people from different livelihood groups shows that immediate impacts of Aila on households, fisheries and livestock were very high while the long term impacts were very high on agriculture. Most of the houses and livestock were washed away in the early period of the event which constituted the immediate impacts, but agricultural lands were submerged for a couple of years which resulted in long term impacts in this sector.

Figure 2: Distribution of Damages Due to Aila in Different Sectors in the Study Area

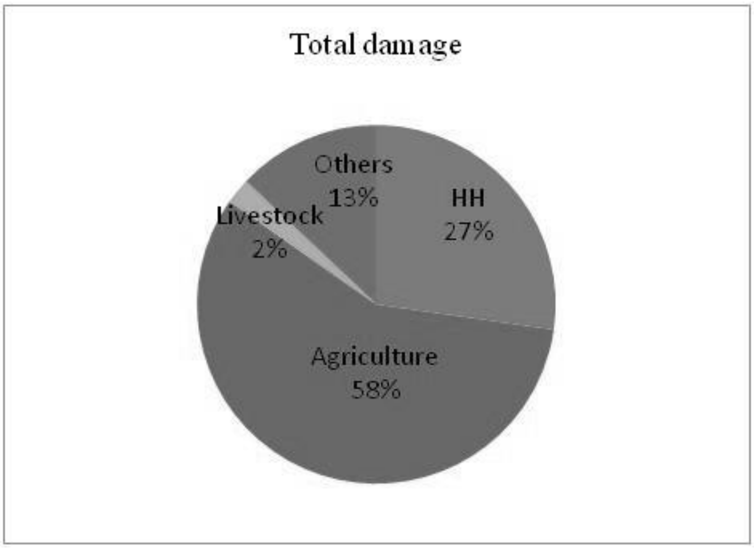


Table 2: Nature of the Damages during Aila in Different Sectors of the Study Area

Sector	Immediate impact	Short term impact	Long term impact
Household	++	+	- -
Crop	-	-	++
Fisheries	++	-	+
Livestock	++	+	- -

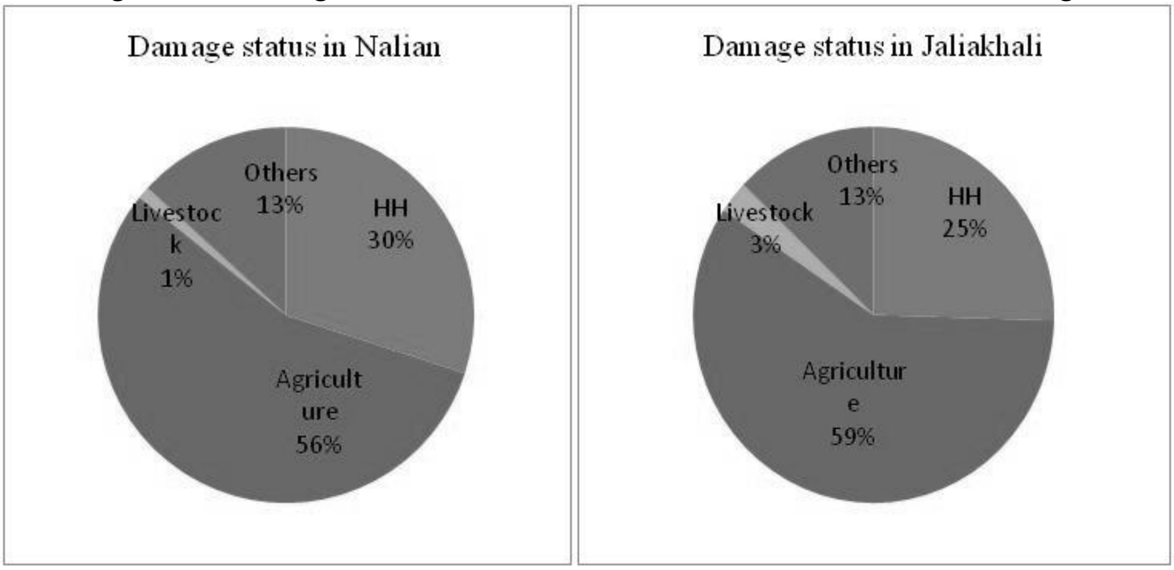
Note: + for high, ++ for very high, - for low, -- for very low.

It is found that all the locations in Polder 32 were not equally affected. In this study, we assessed the total damages of the interviewed people from the study area and then we ranked the degree of impacts (Table 3). Considering Nalian to be the base, the degree of impacts were 1, 0.26 and 0.33 for Nalian, Jaliakhali and Vitevanga, respectively. So it is obvious that the severity of the impacts of Cyclone Aila was the highest in Nalian followed by Vitevanga and Jaliakhali in the study area. Figure 3 shows the damage levels of three major breaching points in different sectors. It shows that agriculture, household, livestock, etc.; were not equally affected by an event. In the vicinity of Nalian breaching point, there were human settlements along with agricultural lands. Moreover, agriculture sector experienced huge long term losses along with immediate impacts. So, agriculture was the worst victim (56%) along with considerable amounts of losses in household properties in Nalian and surrounding areas. In Jaliakhali and Vitevanga, there were mainly agricultural lands with sparse human settlements at a small distance from the breaching face. As a result, the impacts on agriculture (59% and 62% in Jaliakhali and Vitevanga respectively) in those areas were far reaching compared to households and other sectors. In a nutshell, agriculture seems to be the worst victim in all the locations due to long term inundation of agricultural lands which are comparatively lowlands than those of homesteads.

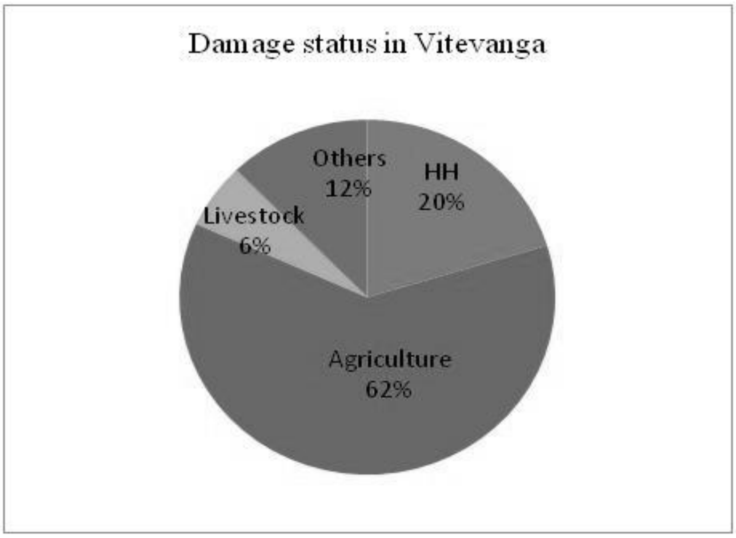
Table 3: Ranking of the Degree of Impacts Based on the Information of Local People

Sector	Nalian (BDT, million)	Jaliakhali (BDT, million)	Vitevanga (BDT, million)
Household	2.73	0.605	0.61
Agriculture	5.075	1.4	1.85
Livestock	0.0924	0.065	0.178
Other properties	1.2	0.305	0.37
Total	9.0974	2.375	3.008
Scale	1	0.26	0.33

Figure 3: Damage Status in a. Nalian, b. Jaliakhali and c. Vitevanga



(a) (b)



(c)

5.2 Damage Variation with Time of Occurrence of a Cyclonic Event

The south west coastal region of Bangladesh is very much vulnerable due to its frequent experience of natural hazards. The dense poor communities living in this region increase its susceptibility to hazards. During field visits, local aged people informed that migration of working people in the southern part is noteworthy in the month of April, May, October and November since the distant past. The reason they put forward is, these are the favorable months for securing jobs in aman fields. The details of crop calendar and aman production are mentioned in Table 4 and Table 5. These crop calendars are important to show the coincidence of the timing of natural disasters with crop seasons. The above mentioned months coincide with the two cyclone seasons as illustrated in Figure 4. Most of the cyclones occur during these four months. Previously, there was only one cropping season (aman in the monsoon) in the coastal region of Bangladesh. So, coincidence of the aman season with the cyclone season used to have devastating results. From field observations and local people's experiences, it was found that damages to the households and other sectors except agricultural crops would be the same for an event of any time of the year. But the damages to the agricultural crops, more specifically the immediate losses to crops would vary depending on the time of occurrence of the event. Field observations showed that Aila hit the coastal belt of Bangladesh on May 25, 2009 which was the sowing time of aman rice (Table 5). Most of the lands were fallow at the time of the landfall of Aila. So, the immediate impacts of Aila on crop production were not much. But, the net cultivable land in polder 32 was almost 4,450 hectares, according to BBS (2011). Dacope agriculture office informed that in more than 80% of the cultivable land, farmers used to produce aman during the monsoon. So, in the aman season any event like Aila would result in an immediate loss of 18,460 ton rice only in Polder 32 which is worth 34.50 million BDT.

Figure 4: Monthly Distribution of the Cyclonic Events in Bangladesh (Compiled From Islam & Peterson 2009; Dasgupta Et Al. 2010)

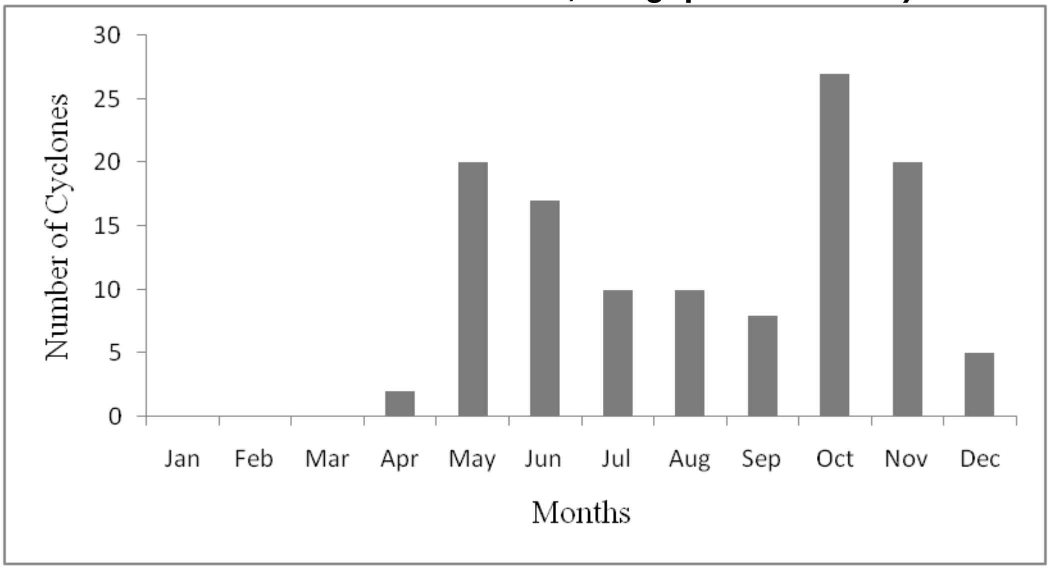


Table 4: Crop Calendar of the Study Area

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

6. Conclusions

Sectoral impacts of a cyclonic event depend on local factors such as land use, cropping pattern, crop type and the time of occurrence of the event. Different previous studies assessed the total impacts of Cyclone Aila in different coastal regions but very few showed the damage variations from sector to sector. This study finds that damages in households, livestock and fisheries sectors vary only spatially, and are found to be the most in Nalian, followed by Vitevanga and Jaliakhali. On the other hand, damages in crop production show both spatial and temporal variation. An Aila like event would cost more losses and damages if it occurs in October-November in the future. In an agriculture-dominated area, under all conditions, the overall impacts of a cyclonic disaster will be the maximum in this sector. The study also concludes that immediate impacts are dominant on households, livestock, fisheries, etc., while long term impacts are high on agriculture. This study recommends that, while taking adaptation measures in the coastal belt of Bangladesh, agriculture sector should be paid more attention by the policy makers. Documentation of inundation depth and duration during Cyclone Aila confined the impact assessment of Aila. Future studies can be conducted taking the impacts of inundation depth and duration into consideration while assessing the sectoral and temporal damage variation.

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