Field Investigation on the Impact of Cyclone SIDR in the Coastal Region of Bangladesh






January 2008

Bangladesh University of Engineering and Technology (BUET)
Dhaka-1000, Bangladesh

Table of Contents

List of Figures

List of Photographs

Acknowledgement

We like to acknowledge Prof. A.M. M. Safiullah, Vice chancellor of BUET to take initiatives to conduct such study in the SIDR affected area. We also like to thank Prof. Anisul Haque, Director of Institute of Water and Flood Management (IWFM), BUET and Prof. Rezaur Rahman to help the study team with encouragement and support. We also grateful to Dr. Hamidul Huq, coordinator of Crossing Boundaries project of IWFM, for providing valuable suggestions and information about the study area. We finally like to thank Japan Asian Friendship Society (JAFS) to provide partial financial support for field visit in the study area.

Chapter 1: Introduction

1.1. Background

Bangladesh often suffers from many climate induced disasters such as flood, drought, and cyclone. Among those natural hazards, cyclone is a tropical storm or atmospheric turbulence involving circular motion of winds, occurs in Bangladesh almost every year. About one tenth of the global tropical cyclone occurs in the Bay of Bengal (GOB, UNDP, World Bank, 1993). About one sixth of tropical cyclones developed in the the Bay of Bengal had landfall on the Bangladesh coast. The Bay cyclones also move towards the eastern coast of India, towards Myanmar and occasionally into Sri Lanka. But they cause the maximum damage when they come into Bangladesh, west Bengal and Orissa of India. This is because of the low flat terrain, high density of population and poorly built houses.

On November 9, an area of disturbed weather developed southeast of the Andaman Islands, with a weak low-level circulation near the Nicobar Islands (Wikipedia, 2008). On November 11 while located a short distance south of the Andaman Islands, the India Meteorological Department (IMD) designated the system as Depression BOB 09. The Joint Typhoon Warning Center (JTWC) upgraded it to Tropical Cyclone 06B after Dvorak estimates indicated winds of 65 km/h (40 mph). Later that day, it intensified into a deep depression as it moved slowly north-westward. The IMD upgraded the system to Cyclonic Storm SIDR early on November 12. The name SIDR was contributed by Oman; it is an Arabic name of a tree belonging to the genus *Ziziphus*, specifically the *Ziziphus spina-christi*. There is another saying that it is derived from the Sinhalese Language where "SIDR" means 'hole' or 'eye. On the morning of November 15, the cyclone intensified to reach peak winds of 215 km/h (135 mph) according to the IMD, and a peak of 250 km/h (155 mph) according to the JTWC. SIDR officially made landfall around 1700 UTC later that day, with sustained winds of 215 km/h (135 mph). It weakened quickly after landfall and the final advisories were issued early on November 16.

The damage in Bangladesh was extensive, including tin shacks flattened, houses and schools blown away and enormous tree damage. Some local officials have described the damage as being even worse than that from the 1991 cyclone. At least 3,447 deaths have been reported. The entire cities of Patuakhali, Barguna and Jhalokati District were hit hard by the storm surge of over 5 meters (16 ft). About a quarter of the world heritage site Sunderbans were damaged. Researchers said mangrove forest Sunderban will take at least 40 years to recover itself from this catastrophe. Electricity and water service were cut and significant damage was reported there due to winds and flooding. The local agricultural industry was also devastated, as many rice crops - which have a December harvest - were lost. Initial assessment of damage is come close to $450 million.

Recently, BUET took initiatives to collect necessary information about the damage of the infrastructures and vegetations. A study team of several faculty members of BUET was formed to visit the SIDR cyclone area.

1.2. Objectives

The main objectives of the study can be stated as follows:

- to identify damages of the infrastructures such as rural roads, electric poles, houses, embankments, polders, cyclone shelters etc.
- to study the performance of the cyclone shelters and present management practices.
- to investigate performances of coastal embankment and polders.
- to identify damage of vegetation such as trees, crops etc.
- to assess water quality and environmental condition after the cyclone.

1.3. Methodology

The investigation was conducted through field visit by a team consists of five faculty members of Bangladesh University of Engineering and Technology (BUET). During the field visit the major emphasis was given on the following points while interviewing local people.

- Accessibility to the cyclone shelter.
- Location and capacity of the shelter.
- Socio-economic condition.
- Operation throughout the year.
- Operation during the disaster.
- Dissemination of cyclone warning.
- Radius of coverage of people gathering.
- Water supply and sanitation.
- Power supply, fuel and energy source.
- Damage, surge height and wind direction.
- Activity during disaster.
- Occupation of local people
- Damage to livelihood.
- Damage to environment.
- Modes of local transport.
- Pattern of local household.
- Damage to vegetation.
- Location of neighboring cyclone shelter.
- Signal system.
- Food availability.
- Livestock.
- Reasons for not going to the shelter.
- Post disaster activities.
- Conclusions from the field interview.

Chapter 2: Literature Review

2.1. Characteristics of Cyclone in the Bay of Bengal[*]

2.1.1 Introduction

Cyclone is a tropical storm or atmospheric turbulence involving circular motion of winds, occurs in Bangladesh as a natural hazard. The tropics can be regarded as the region lying between 30°N latitude and 30°S latitude. All the tropical seas of the earth with the exception of the south Atlantic and southeast Pacific give birth to deadly atmospheric phenomena known as tropical cyclones. On an average, 80 tropical cyclones are formed every year all over the globe.

The term cyclone is derived from the Greek word 'kyklos' meaning coil of snakes. The British-Indian scientist and meteorologist Henry piddington coined the word 'Cyclone' to represent whirling storms expressing sufficiently the tendency to circular motion in his book *The Sailor's Horn-book for the Law of Storms*, published in 1848. Other meteorologists of the world immediately accepted the term and it is still current today. Satellite pictures of cyclones show that the nomenclature is very appropriate. Technically a cyclone is an area of low pressure where strong winds blow around a centre in an anticlockwise direction in the Northern Hemisphere and a clockwise direction in the Southern Hemisphere. Cyclones occurring in the tropical regions are called tropical cyclones and those occurring elsewhere are called extra tropical cyclones.

Tropical cyclones are usually destructive and affect Bangladesh and its adjoining areas. Tropical storms are called hurricanes in the American continent, typhoons in the Far East and cyclones in the South Asian subcontinent. In the West, hurricanes are identified with human names such as Mitchel, Andrew, Carol, Dorothy and Eve. In the South Asian region no such nomenclature is in use. The term 'cyclone' is at times applied to a mid-latitude depression but is now increasingly restricted to a tropical depression of the hurricane type, especially when it occurs in the Indian Ocean. A cyclone is called *Tufan* in Bangla, from the Chinese 'Tai-fun'.

Bangladesh is part of the humid tropics, with the Himalayas on the north and the funnel-shaped coast touching the Bay of Bengal on the south. This peculiar geography of Bangladesh brings not only the life-giving monsoons but also catastrophic cyclones, Northwesters, tornadoes and floods. The Bay of Bengal is an ideal breeding ground for tropical cyclones. Cyclones are usually formed in the deep seas and hence their study has been very difficult. It is only with the advent of the Space age that weather satellites have provided valuable information about them. Direct studies of cyclones with aircraft reconnaissance are also being carried out by advanced countries. However, only a beginning has been made in Bangladesh towards the understanding of cyclones.

[*] Banglapedia at http://banglapedia.search.com.bd/HT/C_0397.htm

2.1.2 Classification

Cyclones in Bangladesh are presently classified according to their intensity and the following nomenclature is in use: depression (winds upto 62 km/hr), cyclonic storm (winds from 63 to 87 km/hr), severe cyclonic storm (winds from 88 to 118 km/hr) and severe cyclonic storm of hurricane intensity (winds above 118 km/hr).

2.1.3 Formation

A tropical cyclone needs more than 27°C sea temperature for its initial formation. Such a high surface temperature is necessary to produce a steep lapse rate for maintaining the vertical circulation in a cyclone. This condition is met throughout the year in regions of the Bay of Bengal where cyclones are formed, mostly near the Andamans. They usually occur at latitudes greater than 5°N or 5°S. It is thought that the Inter-tropical Convergence Zone has something to do with the formation of a cyclone. The Inter-tropical Convergence Zone is the region where winds from the two hemispheres meet near the equator, but its position varies with the season. A cyclone derives its spinning motion from the Coriolis Force arising out of the earth's rotation. This force is virtually zero (0) at the equator. Hence, cyclones do not usually form at the equator. They are formed slightly north of the equator in the Northern Hemisphere, where they can acquire the necessary spin. It is probable that the easterly waves also play some part in the process of cyclone formation.

Among all the atmospheric disturbances, cyclones are the most destructive. The diameter of a cyclone may range from 300 km to 600 km. A cyclone is accompanied by winds with speeds in excess of 118 km/hr, which flow toward the centre of a very strong low pressure. Pressure at the centre of the low may be 50-60 hPa (Hexa Pascal) less than in its outskirts. Cyclones are also accompanied by storm surges. Strong winds bring in enormous amounts of moisture and latent heat toward the centre of the low, which supply the necessary energy to the cyclone. The spiralling winds converge toward the centre of the low pressure where they rise at a tremendous speed.

The most striking feature of a cyclone is its 'eye'. The eye can be seen clearly in satellite pictures in the case of a well-developed cyclone. The eye is small and almost circular; it coincides with the area of lowest pressure and has a diameter ranging from 8 km to 50 km. The eye is warmer than the rest of the storm area. The more violent the storm, the warmer the eye. The winds are very light in the eye, usually not more than 25 to 30 km/hr and rain is practically absent. In contrast, the strongest winds and the heaviest rain occur just outside this central eye.

Wind speed gradually diminishes as one moves away from the region of strongest wind. The main core of the cyclone is circular or nearly circular, having a diameter ranging from 100 km to 800 km. The main cyclone is often accompanied by a long tail having more than one band. The whole thing has a spiral structure, and looks like a comma. The tail may extend up to a few hundred kilometres. The tail usually crosses the land well before the main core of the cyclone and as a result the sky becomes overcast with clouds

and rain often sets in before the onset of a cyclone. Such symptoms can serve as a warning for the possible approach of a cyclone.

The right-hand side of a traveling cyclone has more destructive power than its left-hand side. The duration of a cyclone, from the beginning to the end, may range from 7 to 10 days and it may produce 25 cm to 50 cm of rainfall. The life cycle of a cyclone ends soon after the cyclone reaches land ('landfall'), because it is cut off from its moisture source.

2.1.4 Cyclone track

Cyclones in their initial stages move at a rate of 5 to 10 km/hr. In their final stage they may move at a rate of 20 to 30 km/hr or even up to 40 km/hr. Cyclones in the Bay of Bengal usually move northwest in the beginning and then curve eastwards. But this pattern is not uniform as seen from the tracks of various cyclones. Cyclones accompanied by heavy rains and sea swells are called storm surges. If this occurs during high tide, the storm surge is reinforced considerably and can rise as high as 12m. This deadly wall of water does most of the damage to life and property.

In cyclone forecasting, it is often assumed that a cyclone follows the direction of the upper atmospheric current. SPARRSO (Space Research and Remote Sensing Organization) in collaboration with Dhaka University has undertaken an investigation of the problem and it has been found that there seems to be a steering current for every cyclone, but the level differs from cyclone to cyclone and there does not seem to be any relationship with the intensity of the cyclone. Moreover, the upper atmospheric current is as variable as the tract of the cyclone. SPARRSO has installed the model TYAN for predicting the track of a cyclone based on the climatology of the Bay of Bengal cyclones for the last one hundred years. The model has shown promising results in forecasting a cyclone's movement twenty-four hours ahead of landfall.

2.1.5 Storm surges

In addition to the waves associated with winds, abrupt surges of water known as storm surges are associated with cyclones. They strike the coast nearly at the same time that the centre of the storm crosses the coast. In Bangladesh the maximum value of this storm surge has been reported to be as high as 13m. Most of the damage during a cyclone is done by the storm surges, which sometimes wash over entire offshore islands and large areas on the coast.

The most destructive element of a cyclone is its accompanying surge. There is little that can withstand a great mass of onrushing water often as high as 6m. In Bangladesh, cyclones occur in April-May and also in September-December. On an average, five severe cyclonic storms hit Bangladesh every year and the accompanying surge can reach as far as 200 km inland. Surge-heights increase with the increase of wind speed. Astronomical tides in combination with cyclonic surges lead to higher water levels and hence severe flooding.

Storm surges accompanying cyclones hitting Bangladesh have been noted to be 3m to 9m high. The 1970 cyclone (12-13 November) with a cyclonic surge of 6m to 10m and a wind speed of 222 km/h occurred during high tide causing an appalling natural disaster that claimed 0.5 million human lives. The cyclone of 29 April 1991 hit Chittagong, Cox's Bazar, Barisal, Noakhali, Patuakhali, Barguna and Khulna along with a tidal bore (6.1m to 7.6m), killing 140,000 people.

2.1.6 Cyclones in the Bay of Bengal

Cyclones in the Bay of Bengal Because of the funnel shaped coast of the Bay of Bengal, Bangladesh very often becomes the landing ground of cyclones formed in the Bay of Bengal. The Bay cyclones also move towards the eastern coast of India, towards Myanmar and occasionally into Sri Lanka. But they cause the maximum damage when they come into Bangladesh, west Bengal and Orissa of India. This is because of the low flat terrain, high density of population and poorly built houses. Most of the damage occurs in the coastal regions of Khulna, Patuakhali, Barisal, Noakhali and Chittagong and the offshore islands of Bhola, Hatiya, Sandwip, Manpura, Kutubdia, Maheshkhali, Nijhum Dwip, Urir Char and other newly formed islands.

From 1981 to 1985, 174 severe cyclones (with wind speeds of more than 54 km/hr) formed in the Bay of Bengal. The month-wise occurrence is as follows: 1 in January, 1 in February, 1 in March, 9 in April, 32 in May, 6 in June, 8 in July, 4 in August, 14 in September, 31 in October, 47 in November and 20 in December. It is apparent from the above figures that severe cyclones occur mostly during pre-monsoon (April-May) and post-monsoon (September-December) periods and they are the ones which cause the most destruction. A detailed list of historical records of tropical cyclones made landfall at the Bangladesh Coast is given in the appendix of this report (SMRC, 1991).

2.1.7 Chronology of major cyclonic storms

The following is a partial list of the tropical cyclones in Bangladesh or the historical region of Bengal in general. Some of the years and dates may be slightly incorrect. Most of the information has been taken from Banglapedia (2008) web site. The tracks of the major cyclones occurred in the past over the Bay of Bengal is shown in Figure 2.1.

1584 Bakerganj (presently Barisal) and Patuakhali; hurricane with thunder and lightening continued for five hours; the houses and boats were swallowed up, leaving only Hindu temples on a height; about 2,000,000 living creatures perished.

1585 Mouth of the Meghna estuary; severe storm wave swept up the eastern side of Bakerganj; number of living creatures perished, standing crops destroyed.

1797 (November) Chittagong; severe cyclonic storm; every hut leveled to the ground and 2 vessels sunk in chittagong port.

1822 (May) Barisal, Hatiya Island and Noakhali district; severe cyclonic storm with storm wave; Collectorate records swept away, 40,000 people killed and 100,000 cattle lost.

1831 (October) Barisal; storm-wave; many lives lost and cattle destroyed (exact figures not available).

1872 (October) Cox's Bazar; cyclonic storm; exact figures of the loss of lives and cattle are not available.

1876 (31 October) Meghna estuary and coasts of Chittagong, Barisal, Noakhali; most severe storm-surge of about 12.2m (40 ft) height; about 200,000 people died during the storm, but perhaps more people died from the after-effects of the storm, such as epidemic and famine, and enormous properties destroyed by tidal bore. Considering the population at that time, a death figure of 200,000 was indeed too heavy.

1897 (24 October) Chittagong; hurricane reached maximum intensity with series of storm-waves; Kutubdia Island and coastal villages were swept over, 14,000 people killed and 18,000 died in epidemics (cholera) that followed.

1898 (May) Teknaf; cyclonic storm-waves; exact figures of damage not available.

1904 (November) Sonadia; cyclonic storm; 143 killed and fishing fleet wrecked.

1909 (16 October) Khulna; cyclonic storm-waves; killed 698 people and 70,654 cattle.

1913 (October) Muktagachha upazila (Mymensingh); cyclonic storm; demolished many villages killing about 500 persons.

1917 (24 September) Khulna; hurricane; 432 persons killed and 28,029 cattle lost.

1941 (May) Eastern Meghna estuary; cyclonic storm with storm-wave; exact figures of the loss of lives and cattle aer not available.

1942 (October) Sundarbans; severe cyclonic storm; number of human lives, exact figures of the loss of wildlife and boats are not available.

1948 (17-19 May) Between Chittagong and Noakhali; cyclonic storm; about 1,200 persons killed and 20,000 cattle lost.

1958 (16-19 May) East and west Meghna estuary, east of Barisal, Noakhali; cyclonic storm along with surge; 870 persons killed, 14,500 cattle lost and standing crops destroyed.

1958 (21-24 October) Chittagong coast; cyclonic storm; about 100,000 families lost their homes and government had to provide house-building loans.

1960 (9-10 October) Eastern Meghna estuary (Noakhali, Bakerganj, Faridpur and Patuakhali); severe cyclonic storm, maximum wind speed 201 km/hr, maximum storm wave 3.05m; considerable damage to Char Jabbar, Char Amina, Char Bhatia, Ramgati, Hatiya and Noakhali; 3,000 lives lost, 62,725 houses damaged, crops on 94,000 acres of land were fully damaged and thousands of cattle perished.

1960 (30-31 October) Chittagong, Noakhali, Bakerganj, Faridpur, Patuakhali and eastern Meghna estuary; severe cyclonic storm, maximum wind speed 210 km/hr, surge height 4.5-6.1m; about 10,000 persons killed, 27,793 cattle lost and 568,161 houses destroyed (especially 70% of houses in Hatiya blown off), two large ocean liners washed ashore, 5-7 vessels capsized in Karnafuli river.

1961 (9 May) Bagerhat and Khulna; severe cyclonic storm with a wind speed of 161 km/hr, surge 2.44-3.05m; rail track between Noakhali and Harinarayanpur damaged, heavy loss of life in Char Alexander, 11,468 people killed and about 25,000 cattlehead destroyed.

1962 (26-30 October) Feni; severe cyclonic storm with a wind speed of 161 km/hr, surge 2.5-3.0m; heavy loss of life; about 1,000 people died and many domestic cattle perished.

1963 (28-29 May) Chittagong, Noakhali, Cox's Bazar and the offshore islands of Sandwip, Kutubdia, Hatiya and Maheshkhali were badly affected; severe cyclonic storm with storm-wave rising 4.3-5.2m in Chittagong, maximum wind speed 203 km/hr and at Cox's Bazar 164 km/hr; more than 11,520 people killed, 32,617 cattle lost, 376,332 houses, 4,787 boats and standing crops destroyed.

1965 (11-12 May) Barisal and Bakerganj; most severe cyclonic storm, maximum speed 162 km/hr with storm-wave rising 3.7m; total loss of life 19,279; in Barisal alone 16,456 people killed.

1965 (14-15 December) Cox's Bazar along with adjacent coastal area and Patuakhali; severe cyclonic storm with storm-wave rising 4.7-6.1m; maximum speed 210 km/hr in Cox's Bazar, hoisted danger signal #10 at Cox's Bazar and along the coast of Sonadia, Rangadia and Hamidia islands, and Patuakhali; 40,000 salt beds in Cox's Bazar inundated and 873 people killed.

1966 (1 October) Sandwip, Bakerganj, Khulna, Chittagong, Noakhali and Comilla; severe cyclonic storm with storm-waves of 4.7-9.1m, maximum wind speed 146 km/hr; affected 1.5 million people, loss of human life and livestock were 850 and 65,000 respectively in Noakhali and Bakerganj.

1969 (14 April) Demra (Dhaka district); tornado locally known as Kalbaishakhi with wind speed of 643 km/hr; 922 people killed and 16,511 injured; estimated loss Tk 40 to 50 million.

1970 (12-13 November) The most deadly and devastating cyclonic storm that caused the highest casualty in the history of Bangladesh. Chittagong was battered by hurricane winds. It also hit Barguna, Khepupara, Patuakhali, north of Char Burhanuddin, Char Tazumuddin and south of Maijdi, Haringhata and caused heavy loss of lives and damage to crops and property. Officially the death figure was put at 500,000 but it could be more. A total of 38,000 marine and 77,000 inland fishermen were affected by the cyclone. It was estimated that some 46,000 inland fishermen operating in the cyclone affected region lost their lives. More than 20,000 fishing boats were destroyed; the damage to property and crops was colossal. Over one million cattlehead were reported lost. More than 400,000 houses and 3,500 educational institutions were damaged. The maximum recorded wind speed of the 1970 cyclone was about 222 km/hr and the maximum storm surge height was about 10.6m and the cyclone occurred during high-tide.

1971 (5-6 November) Chittagong coast; severe cyclonic storm; exact figures of the loss of lives and cattle are not available

1971 (28-30 November) Sundarban coast; cyclonic storm with a wind speed of 97-113 km/hr and storm surge of less than 1m; Khulna district experienced stormy weather and low lying areas of Khulna town inundated.

1973 (6-9 December) Sundarban coast; severe cyclonic storm accompanied by storm surge; low-lying coastal areas of Patuakhali and adjoining offshore islands inundated.

1974 (13-15 August) Khulna; cyclonic storm with a wind speed of 80.5 km/hr; about 600 lives lost and number of cattlehead destroyed.

1974 (24-28 November) Coastal belt from Cox's Bazar to Chittagong and offshore islands; severe cyclonic storm with a wind speed of 161 km/hr and storm surge of 2.8-5.2 m; 200 people killed, 1000 cattle lost and 2,300 houses perished.

1975 (9-12 May) Bhola, Cox's Bazar and Khulna; severe cyclonic storm with a wind speed of 96.5 to 112.6 km/hr; 5 persons killed and a number of fishermen missing.

1977 (9-12 May) Khulna, Noakhali, Patuakhali, Barisal, Chittagong and offshore islands; cyclonic storm with a wind speed of 112.63 km/hr; exact figures of the loss of lives and cattle are not available.

1983 (14-15 October) Offshore islands and *chars* of Chittagong and Noakhali; severe cyclonic storm with a wind speed of 122 km/hr; 43 persons killed, 6 fishing boats and a trawler lost, more than 150 fishermen and 100 fishing boats missing and 20% aman crops destroyed.

1983 (5-9 November) Chittagong, Cox's Bazar coast near Kutubdia and the low lying areas of St Martin's Island, Teknaf, Ukhia, Moipong, Sonadia, Barisal, Patuakhali and Noakhali; severe cyclonic storm (hurricane) with a wind speed of 136 km/hr and a storm surge of 1.52m height; 300 fishermen with 50 boats missing and 2,000 houses destroyed.

1985 (24-25 May) Chittagong, Cox's Bazar, Noakhali and their offshore islands (Sandwip, Hatiya, and Urirchar); severe cyclonic storm, wind speed Chittagong 154 km/hr, Sandwip 140 km/hr, Cox's Bazar 100 km/hr and storm surge of 3.0-4.6m; about 11,069 persons killed, 94,379 houses damaged, livestock lost 135,033 and road damaged 74 km, embankments damaged.

1986 (8-9 November) Offshore island and *chars* of Chittagong, Barisal, Patuakhali and Noakhali; cyclonic storm hit 110 km/hr at Chittagong and 90/hr at Khulna; 14 persons killed, damaged 97,200 ha of paddy fields, damage to schools, mosques, warehouses, hospitals, houses and buildings at Amtali upazila in Barguna.

1988 (24-30 November) Jessore, Kushtia, Faridpur, offshore islands and *chars* of Barisal and Khulna; severe cyclonic storm with core wind speed 162 km/hr, storm surge of 4.5m at Mongla point; killed 5,708 persons and lot of wild animals - deer 15,000, Royal Bengal Tiger 9, cattle 65,000 and crops damaged worth about Tk 9.41 billion.

1991 (29 April) The Great Cyclone of 1991, crossed the Bangladesh coast during the night. It originated in the Pacific about 6,000 km away and took 20 days to reach the coast of Bangladesh. It had a dimension of more than the size of Bangladesh. The central overcast cloud had a diameter exceeding 600 km. The maximum wind speed observed at Sandwip was 225 km/hr. The wind speeds recorded at different places were as follows: Chittagong 160 km/hr, Khepupara (Kalapara) 180 km/hr, Kutubdia 180 km/hr, Cox's Bazar 185 km/hr, and Bhola 178 km/hr. The maximum wind speed estimated from NOAA-11 satellite picture obtained at 13:38 hours on 29 April was about 240 km/hr. The cyclone was detected as a depression (wind speed not exceeding 62 km/hr) on the 23rd April first in the satellite picture taken at SPARRSO from NOAA-11 and GMS-4 satellites. It turned into a cyclonic storm on 25 April. The cyclone in its initial stage moved slightly northwest and then north. From 28 April it started moving in a north-easterly direction and crossed the Bangladesh coast north of Chittagong port during the night of the 29th April. The cyclone started affecting the coastal islands like Nijhum Dwip, Manpura, Bhola and Sandwip from the evening of that day. The maximum storm surge height during this cyclone was estimated to be about 5 to 8m. The loss of life and property was colossal. The loss of property was estimated at about Tk 60 billion. The death toll was estimated at 150,000; cattlehead killed 70,000.

1991 (31 May to 2 June) Offshore islands and *chars* of Patuakhali, Barisal, Noakhali and Chittagong; cyclonic storm, maximum wind speed 110 km/hr and surge height of 1.9m; people killed, cattlehead perished, boats lost and standing crops destroyed.

1994 (29 April 3 May) Offshore island and *chars* of Cox's Bazar; severe cyclonic storm with maximum wind speed of 210 km/hr; people killed about 400, cattle lost about 8,000.

1995 (21-25 November) Offshore island and *chars* of Cox's Bazar; severe cyclonic storm with maximum wind speed of 210 km/hr; about 650 people killed, 17,000 cattlehead perished.

1997 (16-19 May) Offshore islands and *chars* of Chittagong, Cox's Bazar, Noakhali and Bhola; severe cyclonic storm (hurricane) with a wind speed of 225 km/hr, storm surge of 3.05m (similar strength to that of 1970 cyclone); only 126 people killed because of better disaster management measures taken by the government and the people.

1997 (25-27 September) Offshore islands and *chars* of Chittagong, Cox's Bazar, Noakhali and Bhola; severe cyclonic storm (hurricane) with a wind speed of 150 km/hr, storm surge of 1.83 to 3.05m.

1998 (16-20 May) Offshore islands and *chars* of Chittagong, Cox's Bazar and Noakhali; severe cyclonic storm (hurricane) with a wind speed of 150 km/hr, storm surge of 1.83 to 2.44m.

1998 (19-22 November) Offshore islands and *chars* of Khulna, Barisal and Patuakhali; cyclonic storm with maximum wind speed of 90 km/hr, storm surge of 1.22 to 2.44m.

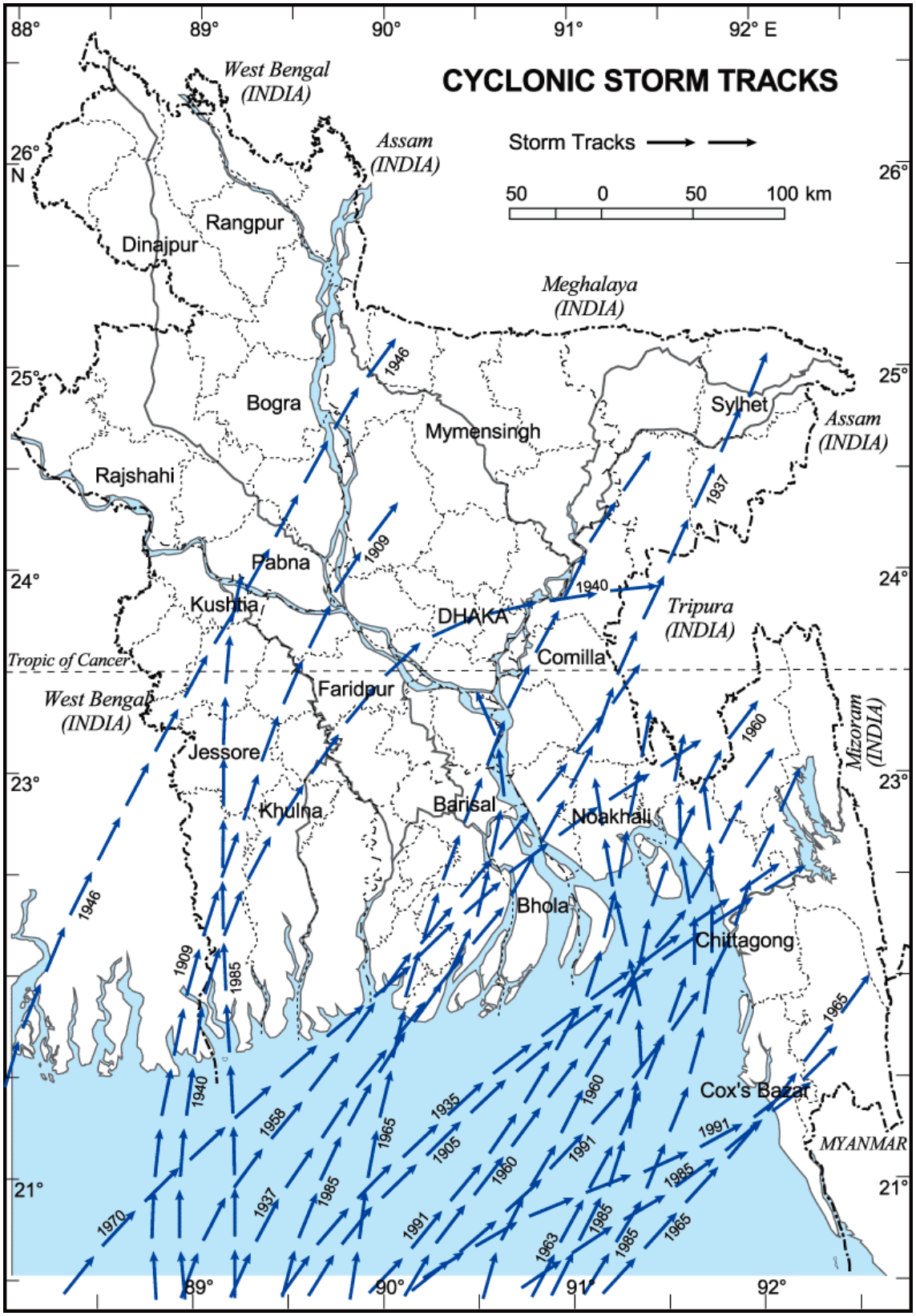


Figure 2.1. Cyclone storm tracks over Bangladesh (Banglapedia, 2008)

2.2. Characteristics of SIDR Cyclone[†]

2.2.1 Introduction

Cyclone SIDR (JTWC designation: *06B*, also known as Very Severe Cyclonic Storm SIDR) is the fourth named storm of the 2007 North Indian Ocean cyclone season. The storm formed in the central Bay of Bengal, and quickly strengthened to reach peak sustained winds of 215 km/h (135 mp/h), which would make it a Category-4 equivalent to tropical cyclone on the Saffir-Simpson Scale. The storm eventually made landfall near Bangladesh on November 15, 2007. As of January 20, 2008, about 3,447 deaths have been blamed on the storm.

Synopsis of Cyclone SIDR	
• **Formed**	November 11, 2007
• **Enter to land**	November 15, 2007
• **Dissipated**	November 16, 2007
• **Highest winds**	215 km/h (130 mph)
• **Lowest pressure**	944 hPa (mbar)
• **Fatalities**	≥3,447
• **Damage**	$450 million (2007 USD)
• **Areas affected**	Bangladesh and West Bengal, India

2.2.2 Storm history

On November 9, an area of disturbed weather developed southeast of the Andaman Islands, with a weak low-level circulation near the Nicobar Islands. Initially moderate upper-level wind shear inhibited organization, while strong diffluence aloft aided in developing convection. Vertical shear decreased greatly as the circulation became better defined, and a Tropical Cyclone Formation Alert was issued on November 11 while located a short distance south of the Andaman Islands. Around the same time, the India Meteorological Department (IMD) designated the system as Depression BOB 09. The Joint Typhoon Warning Center (JTWC) upgraded it to Tropical Cyclone 06B after Dvorak estimates indicated winds of 65 km/h (40 mph). Later that day, it intensified into a deep depression as it moved slowly north-westward.

The IMD upgraded the system to Cyclonic Storm SIDR early on November 12. The system then began to intensify quickly as it moved slowly northwestward, and the IMD upgraded it to a severe cyclonic storm later that day and a very severe cyclonic storm

[†] **Source:** Wikipedia, the free encyclopedia http://en.wikipedia.org/wiki/Cyclone_Sidr

early the next day. On the morning of November 15, the cyclone intensified to reach peak winds of 215 km/h (135 mph) according to the IMD, and a peak of 250 km/h (155 mph) according to the JTWC. SIDR officially made landfall around 1700 UTC later that day, with sustained winds of 215 km/h (135 mph). It weakened quickly after landfall and the final advisories were issued early on November 16. The name SIDR was contributed by Oman; it is an Arabic name of a tree belonging to the genus *Ziziphus*, specifically the *Ziziphus spina-christi*. There is another saying that it is derived from the Sinhalese Language where "SIDR" means 'hole' or 'eye.

Remote sensing satellite images of the cyclone SIDR are presented in the figure 2.2, 2.3, 2.4 and 2.5.

2.2.3 Preparations

As it intensified to a Category 4-equivalent cyclone on November 15, thousands of emergency officials were put on standby in eastern India and Bangladesh in advance of the storm's arrival. Massive evacuations of low-lying coastal areas also took place. A total of 2 million people in Bangladesh evacuated to emergency shelters. The Indian Metrological Department (IMD) also issued a cyclone alert for Orissa and West Bengal on November 14. In Bangladesh, an emergency cabinet meeting decided to withdraw weekly leave for the government officials to join the evacuation process. Over 40,000 Red Cross volunteers were deployed to order residents in the 15 affected provinces into special cyclone and flood shelters. The main ports have been closed.

2.2.4 Impact

Coastal districts of Bangladesh faced heavy rainfall as an early impact of the cyclone. Dhaka and other parts of Bangladesh experienced drizzle and gusty winds. Total damages came close to $450 million.

Tidal waves reaching up to a height of 3 meters (9.8 ft) were reported in the coastal areas of north Chennai in southern state of Tamil Nadu in India, triggering panic among the fishing community.

The damage in Bangladesh was extensive, including tin shacks flattened, houses and schools blown away and enormous tree damage. Some local officials have described the damage as being even worse than that from the 1991 cyclone. The entire cities of Patuakhali, Barguna and Jhalokati District were hit hard by the storm surge of over 5 meters (16 ft). About a quarter of the world heritage site Sunderbans were damaged. Researchers said mangrove forest Sunderban will take at least 40 years to recover itself from this catastrophe. Much of the capital city of Dhaka was also severely affected, as electricity and water service were cut and significant damage was reported there due to winds and flooding. The local agricultural industry was also devastated, as many rice crops - which have a December harvest - were lost.

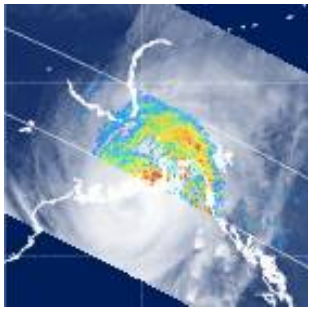
At least 3,447 deaths have been reported. The hardest-hit area was Barguna, where 423 people were reported to have been killed according to local officials. Patuakhali was also hard-hit, with 385 deaths reported. Most of the deaths confirmed thus far were due to the winds, although 13 of them have been as a result of capsized boats in the Faridpur district of Bangladesh. The head of the Red Crescent in Bangladesh expects the death toll to reach as high as 10,000. Over 3,000 other fishermen were reported missing on over 500 fishing boats.

2.2.5 Aftermath

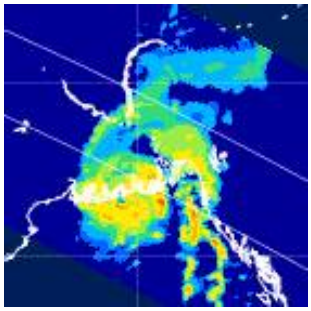
After the storm, five Bangladesh Navy ships were immediately dispatched with food, medicine, and relief supplies for the hardest-hit areas. Saudi Arabia also donated US$100 million to the relief effort as the country's largest relief sum ever. The European Commission also released €1.5 million (US$2.4 million) in emergency relief to Bangladesh. The United States, through the U.S. Agency for International Development, has pledged more than US$14.4 million in emergency assistance, including more than US$10 million in food assistance from the U.S. Food for Peace program. The United States Navy also released over 3,500 Marines aboard USS *Kearsarge* and USS *Wasp* (located in the Gulf of Oman) and USS *Tarawa* (located in Hawaii) to aid in the recovery efforts.

Other agencies quickly followed in providing aid. World Vision released volunteers to help house more than 20,000 people left homeless. The Red Cross also brought a significant presence, while assessments of the damage were underway. Bangladesh Red Crescent Society initally asked 400 million Bangladeshi Taka to the international community.

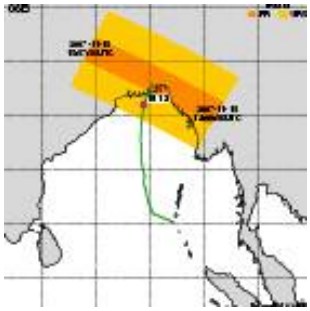
People of the cyclone affected area are having severe health problems as diseases like diarrhea spread due to shortage of drinking water. The landfall of SIDR had followed the devastation caused by consecutive floods earlier in 2007.



PR/VIRS Image



TMI Image



Observation Area

Figure 2.2. TRMM real time monitoring of SIDR cyclone (TRMM, 2008). [Note: Satellite Obs. Date/Time: Nov. 15, '07, 1359Z Lat/Lon: 15.9N -27.8N 84.5E-96.3E Info. (Nov. 15, '07, 1200Z) Pressure: - hPa Winds: 130 kt]

Figure 2.3. Tropical Cyclone SIDR was gathering strength when the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured this photo-like image on November 12, 2007 (NASA, 2008).

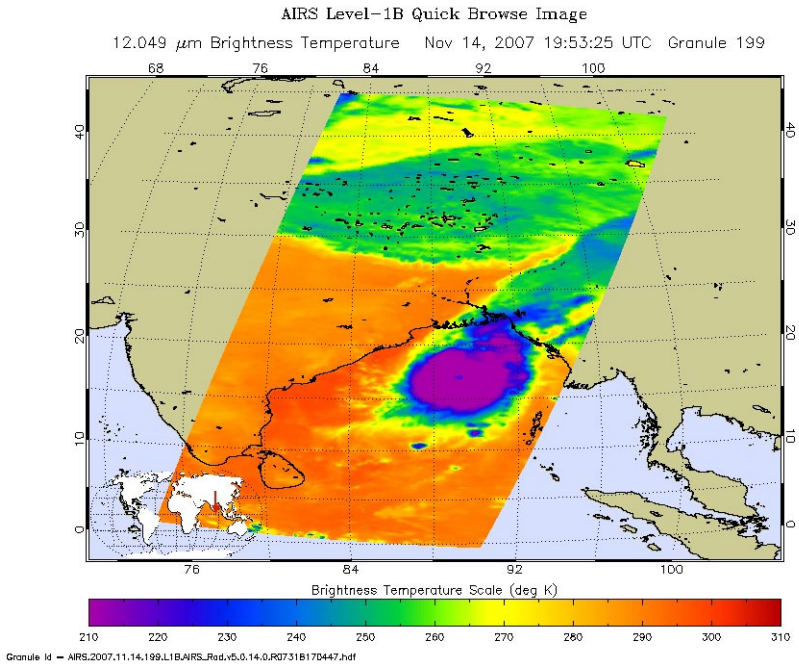


Figure 2.4. On Tuesday, Nov. 13, at 1:30 p.m. local time, the Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua satellite captured this image of the temperatures in SIDR's clouds. At that time, SIDR was located near 12.5 degrees north latitude and 89.8 degrees east longitude, or 605 nautical miles south of Calcutta, India (NASA, 2008).

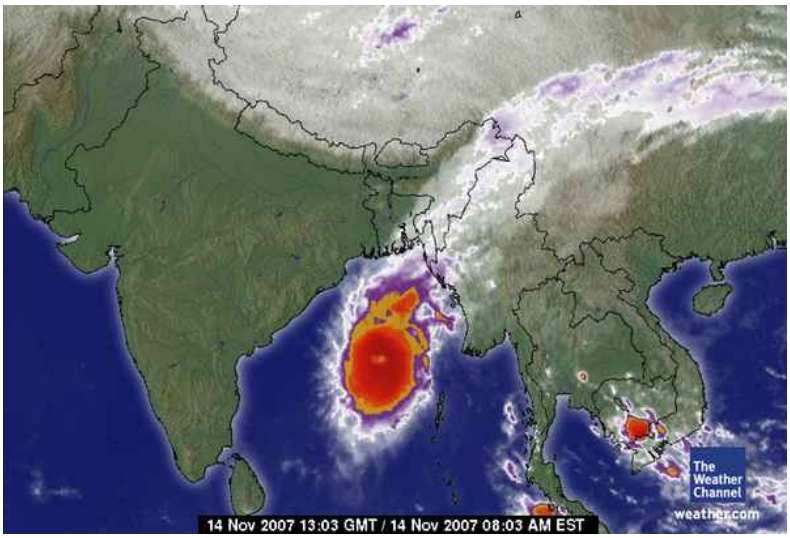


Figure 2.5. As of 7 am Eastern Time Wednesday, Tropical Cyclone SIDR was located about 465 miles to the south of Calcutta, India, with top winds of 150 mph (category 4 on the Saffir-Simpson Scale of hurricanes) (Zafnoor, 2008).

2.2.6 Tidal Surge predictions[‡]

Hassan Mashriqui, an assistant extension professor of coastal engineering with NOAA's Louisiana Sea Grant and Louisiana State University (LSU), simulated tidal surge model before SIDR hits the coast of Bay of Bengal as shown in the Figure 2.6. Since 2003, Mashriqui has been involved in using the Advanced Circulation (ADCIRC) model to predict storm surge from hurricanes in the Gulf of Mexico. As work in the Gulf progressed, he decided to develop models for Bangladesh and neighboring countries.

It is called "Bay of Bengal Cyclone Surge Modeling Program to use of Supercomputer Technology and GIS for Early Warning. The storm forecast of the surge model was delivered to Bangladesh Emergency management officials in time to warn and evacuate people in the path of Cyclone SIDR.

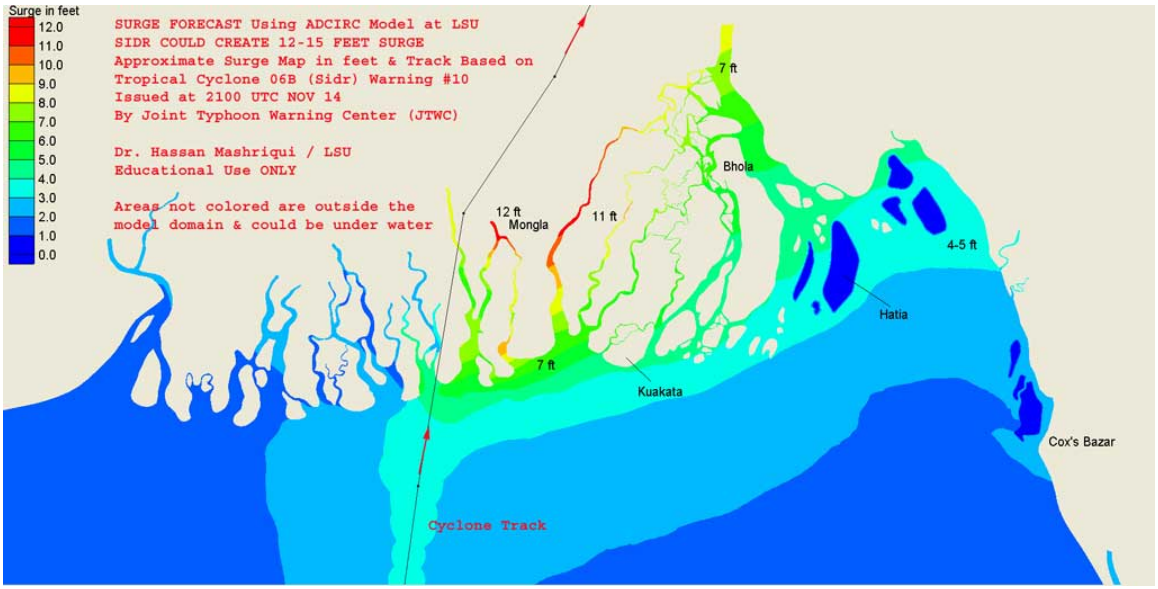


Figure 2.6. Advanced Circulation (ADCIRC) model predicting Storm surge. Model is developed by a Bangladesh scientist, Dr. Hassan Mashriqui, an assistant extension professor of coastal engineering with NOAA's Louisiana Sea Grant and Louisiana State University (NOAA, 2008)

[‡] NOAA (2008) NOAA Researcher's Warning Helps Save Lives in Bangladesh at http://www.oar.noaa.gov/spotlite/2007/spot_cyclone.html

Chapter 3: Field visits to SIDR affected area

After the devastation of the SIDR cyclone, BUET took initiatives to collect necessary information about the damage of the infrastructures and vegetations. A study team of several faculty members of BUET was formed to visit the SIDR cyclone area. Major emphasis of the field visit was given on the following environmental parameters:

1. Structures: water control, cyclone shelters, embankments, polders, road networks
2. Eco-systems: aquatic (water quality, quantity), terrestrial (vegetation)
3. Socio-economic: social and economic damages and recovery

3.1. Study Area

Study area was selected in the vicinity of the Sundarbans area where cyclone caused major damages. Two locations were identified; one in the Mongla, Khulna district and another is Sarankhola, Bagerhat district as shown in the Figure 3.1.

Figure 3.1. Shows study area Mongla, Khulna and Sarankhola, Bagerhat of the field visit with red circles. The path of SIDR is shown by dashed line in the figure.

3.2. Team members

The initial team was formed from faculty members of civil engineering department and institute of water and flood management (IWFM) of Bangladesh University of Engineering and Technology (BUET). A list of the members of initial team is given below.

- **Civil Engineering Department**

    1. Prof. Mehedi Ahmed Ansary (Coordinator)
    2. Prof. Md. Mafizur Rahman

- **Institute of Water and Flood Management (IWFM)**

    1. Dr. Munsur Rahman (Coordinator)
    2. Dr. Sujit Kumar Bala
    3. Dr. A.K.M. Saiful Islam
    4. Dr. Asad Hussain
    5. Dr. Abed Hossain

3.3. Field visit

The above team paid visit to the stud area during January 7-10, 2008. The team has interviewed local people, NGOs and government officials during the visit. The following four case studies are conducted.

- **Case study-1: Performance of a cyclone shelter located outside storm surge area.**
- **Case study-2: Performance of a cyclone shelter affected by heavy storm surge.**
- **Case study-3: Performance of a coastal embankment and polder.**
- **Caste study-4: Assessment of vegetation damage in the study area.**

3.4. Case study-1: Performance of a cyclone shelter located outside storm surge area.

Cyclone center located in village Kanai nagar, union chandpai, Mongla. People started gathering at 3:00 p.m. on November 15, 2007 stayed till 10:00 a.m. of the next morning. There are more than one thousand people stayed in the shelter during that night. The population of the surrounding villages is about five to six thousands. The devastation was caused mainly by the wind which was around 220 km/hr. No storm surge was reported in that place. A brief summary of the various aspects and performance of this cyclone shelter during the cyclone is presented below.

3.4.1 Accessibility to the Cyclone Shelter

Most of the people walk along the access roads near the shelter. Some locally available tri-wheeled non motorized vans and some motorized vans were observed to be the major modes of transporting the heavier goods. The local road in the vicinity of the shelter was not paved and might pose serious threat to access the shelter during the rainy period. The width of the access roads near the shelter is about 15 feet at most and this varies along its course and is not uniform all along.

3.4.2 Location and capacity of the shelter

The shelter is located close to the Mongla port of Khulna district. The latitude is $22^0$26.811' and longitude is $89^0$36.219'. As per local peoples information about one thousand people could take shelter within the facility.

3.4.3 Socio-economic condition

Socio-economic condition of the locality near the shelter in general is below the poverty level. Around 90% can be accounted for as poor. Muslim, Hindus and Christen are the three major religion found.

3.4.4 Operation throughout the year

This multipurpose shelter is used as elementary school through out the year. Many kids are seen studying in the school during our field visit. School is located on the second floor of the shelter. Condition of the class rooms in the shelter is found reasonably well.

3.4.5 Operation during the disaster

This shelter was full of people during the cyclone. More than one thousand people were gathered at night and stayed till next morning of the cyclone. No damage was happen to

the shelter during the cyclone. Wind direction was from the north to the south which was opposite to the facing of the shelter.

3.4.6 Dissemination of cyclone warning

Mode of delivery of the warning is mainly the announcement from radio and television and announcement through hand-microphones in the locality. The local announcement of eminent disaster was from Government employees, NGO workers and volunteers although it was inadequate as per the peoples' opinion.

3.4.7 Radius of coverage of people gathering

Though the cyclone shelters were basically designed with an assumption that people from two km radius will take shelter but reality was different as observed during the study. During the cyclone SIDR the people gathering within the studied cyclone shelter were from an aerial extent having a relatively shorter radius which was approximately around one km within the vicinity of the shelter.

3.4.8 Water supply and sanitation within the vicinity of the cyclone shelter

Water supply system for drinking water in the centre was at site storage of rainwater in the monsoon which was a sort of variant of traditional rainwater harvesting system. They could not confirm the quality of drinking water but the overall health situation of the people was good. Due to the inadequate rain and storage of water available in the local tank, people reported about storing drinking water which was collected from a nearby pond which reportedly had sweet water which was acceptable for drinking by people taking shelter there. The shelter has sanitation system of its own. There were two latrines which were observed to be in operation. Supply of water to the latrine was observed to be provided from the local tube well.

3.4.9 Power supply, fuel and energy source

The shelter area was found to have connection to the electricity. Cooking was observed to be supported by the biome as the major source of energy.

3.4.10 Damage, surge height and wind direction

Damage was done to households and trees. No storm surge occurred. Damage caused due to rain and strong wind only. The damage to road infrastructure could not be confirmed and even if occurred can be taken as minimal. The obstruction to communication was reported by the people to be caused by fallen trees only.

3.4.11 Activity during disaster

During the cyclone, the local disaster management committee run by Caritas (a NGO) actively participated in disseminating warning among the people. The shelter was full of people and it reaches it capacity. The relief operation comes on the next day since this shelter is located very close to Khulna city. During the disaster, people get food (water and biscuit) from their own.

3.4.12 Occupation of local people

The major source of income in the locality is from fisheries. A part of the population is employed as laborers in culture fisheries industry with seasonal involvement in open water fishing. Some part of the population is dependent on forest resources of the Sundarbans.

3.4.13 Damage to livelihood

The major affect on the livelihood took place due to damage to properties rather than direct damage to profession/occupational setup. Destruction of household properties was the major one. The livelihood of people depending on Sundarbans forest resources was badly affected.

3.4.14 Damage to environment

No serious deterioration of water quality was observed. However, the change or damage to environment can be assessed only from long term observational data which is not possible from local information. The possible sources of deterioration can be from fallen trees or litter which was much more compared to normal situation.

From the field observation and the information provided by the local people, the shrimp culture industry has posed major threat to the local agriculture and soil fertility. As reported by the local people, the diversion of salt water through the artificial canals to the former agricultural land caused serious decrease of paddy harvest. The decrease is so severe that from an area which was capable of harvesting about 35 tons of rice has the potential of harvesting about 100 kgs of the same. The reduced growth of other plants in the vicinity is also visible due to the same reason.

3.4.15 Modes of local transport

Mostly non-motorized vehicles (e.g., Rickshaw vans) ply in the area. Public transport such as bus and car are also available as mean of transport to connect this shelter with Khulna city.

3.4.16 Pattern of local household

Locally built houses use the locally available material. ***Golpata*** is the material very commonly used for fencing and roofing the houses. There are however some houses with tin roofs but the number are very small.

3.4.17 Damage to vegetation (type and extent)

This team found serious damage to the paddy field due to excessive wind speed during the cyclone. The long trees are also damaged and uprooted by the cyclone.

3.4.18 Location of neighboring cyclone shelter

The close cyclone shelter is located about two km from this shelter. Local people report that the nearby shelter was also full of its capacity during the cyclone.

3.4.19 Signal system

The present signal system was not found suitable for the people. This system was designed for the navigation purpose. People demanded more understandable signaling methods and more accurate warning system.

3.4.20 Food availability

Normally people are living by producing their own food such as rice and vegetables. During the disaster people eat dry food such as *muri*, *chira* and *gur* which they have bought by themselves. After the disaster, the relief operation was started immediately on the next day.

3.4.21 Livestock

The lack of adequate scope for the shelter for the livestock poses to be a major cause for the villagers to be reluctant to take shelter prior to the disaster.

3.4.22 Reasons for not going to the shelter

Disregard to the signal system due to recent past memory of improper or false disaster warnings lead to the people to neglect cyclone warning. Feelings of insecurity of loosing household belongings from robbery or stealing were another reason to stay at home.

3.4.23 Post disaster activities

Food, livestock, agriculture and fisheries, materials available for house building, employment opportunity, damage and maintenance to the shelter

3.4.24 Conclusions

1. No fatality was reported around this shelter since it was beyond storm surge area.

2. But most of the crops and a few livestock are destroyed due to excessive wind. Some houses are destroyed by the cyclone.

3. Local disaster management body performed very well to provide warning.

4. The capacity of the shelter is inadequate.

5. NGO and government officials reached immediately after the cyclone. Post relief activities were found continuing for the cyclone victims.

Photo 3.1. Cyclone center Kanainagar where no storm surge occurred

Photo 3.2. Students of the elementary school of the multipurpose cyclone center

Photo 3.3. Some structural damages due to lack of operation and maintenance

Photo 3.4. Damage gates of the cyclone shelter caused by cyclone SIDR

Photo 3.5. BUE team interviewed local people during their field visit

Photo 3.6. Group discussion among BUET team while visiting cyclone shelter

3.5. Case study-2: Performance of a cyclone shelter affected by heavy storm surge.

Cyclone center located in village Maddha Kadamtola, union Rayenda, Shoronkhola, Bagerhat. The shelter is very near to the Balwaser River and tidal surge of ten feet was reported by the local people. This shelter was a bit away from nearby city (Bagerhat) which causes delaying of post cyclone relief activities. Many casualties were found in the nearby villages of the shelter. Livestock and crops are also heavy damages from the cyclone.

3.5.1 Accessibility to the cyclone Shelter

This shelter is located along a paved road which comes from Rayenda bazaar. People can easily come to the shelter. Rayenda is well connected with Khulna and Bagerhat district by national highways.

3.5.2 Location and capacity of the shelter

This shelter is located in Kaadamtola village under Reyanda union of Bagerhat district. The latitude is $22^0$15.84' and longitude is $89^0$50.33'. The capacity of the shelter is approximately 1500 persons.

3.5.3 Socio-economic condition

Majority of the people are Muslims and a minority are observed. Most of the people are poor and living below poverty level. Some people are rich those who have their own boat to collect woods and honey from the Sundarbans.

3.5.4 Operation throughout the year

A private primary school, a mosque and a madrasha were located with the compound of the cyclone shelter. A local NGO called Muslim Aid, UK is supporting this activates.

3.5.5 Operation during the disaster

This shelter was full of people during the cyclone. More than one thousand people were gathered at night and stayed till next morning of the cyclone. No damage was happen to the shelter during the cyclone. Wind direction was from the north to the south which was opposite to the facing of the shelter. The maximum storm surge water level was about the eight steps of the stair of the shelter.

3.5.6 Dissemination of cyclone warning

Mode of delivery of the warning is mainly announcement from radio and television and local announcements through hand-microphone. The local announcement of eminent disaster was from Government employees, NGO workers and volunteers were reported not very active.

3.5.7 Radius of coverage of people gathering

The radius of coverage of the shelter is approximately one km. We have found four cyclone shelters from Rayenda bazaar to Tafayel. The density of the shelters is not sufficient to support all the people of the coverage area.

3.5.8 Water supply and sanitation within the vicinity of the cyclone shelter

This shelter has its own hand tube well installed to supply fresh drinking water. There were two sanitary latrines in the shelter although its condition was not found very neat.

3.5.9 Power supply, fuel and energy source

The shelter area was found to have connection to the electricity. Cooking was observed to be supported by the biome as the major source of energy.

3.5.10 Damage, surge height and wind direction

The surge height reported by the local people was about ten feet from the ground. The shelter was not affected or damaged by the cyclone. But the nearby tin-shed Madarasha was fully destroyed. The roof of the primary school built by tin-shed was also found damaged.

3.5.11 Activity during disaster

During the disaster, people of the village helped each other. It takes one and half days to start of the relief operations from government officials. During that time, people share each other's food voluntarily and help the poor to survive.

3.5.12 Occupation of local people

Most of the people of the nearby village are living by fishing, farming and acting as daily labor. This place is very close to the Sundarbans and some of the villagers are living by collecting woods and honey from the forest.

3.5.13 Damage to livelihood

Destruction of houses and tress are observed every where in the nearby villages and roads. Crops and shrimps farms are completely destroyed by the storm surge water. Huge damages of the live stocks were also observed.

3.5.14 Damage to environment

Serious damage to the environment occurred from the polluted water of the storm surge. This cause skin diseases and mosquitoes in some areas. The scarcity of fresh water also was a problem after the cyclone surge.

3.5.15 Modes of local transport

Boat rural roads and paved roads are observed in the villages. People use buses, rickshaws, cycle and motor cycles in those roads depending on condition. This shelter is close to Baleswar river and many boats are seen in the river. Communication through boats is convenient and cheap.

3.5.16 Pattern of local household

Most of the houses are made of woods and leafs. A few houses are also constructed by tin-sheds. Many roofs of those tin-shed houses were damages by heavy wind during the cyclone.

3.5.17 Damage to vegetation

Serious damage to crops and vegetation was observed due to excessive winds. Rice fields were found completely destroyed and other crop fields also damages. Many trees were seen uprooted along the side of the road while this team was traveling. Trees with deeply rooted in the ground are survived from this cyclone.

3.5.18 Location of neighboring cyclone shelter

Location of neighboring shelter is around 2 kilometers. The density of the cyclone shelter is not adequate to provide shelters of the designed area. Most of the shelters were constructed during 1993 after the devastating cyclone occurred on 1991.

3.5.19 Signal system

The present signal system was not found suitable for the people. This system was designed for the navigation purpose. People demanded more understandable signaling methods and more accurate warning system.

3.5.20 Food availability

Right after the disaster, the food supply was mainly from the local people. Everyone helped each other with their limited food supply. The location of the shelter was away from the Khulna city and during the cyclone connecting roads are blocked by the fallen trees. These are main causes of the delay of reaching relief material to the affected people.

3.5.21 Livestock

No livestock shelter was found in the villages. Many cattle, buffalos, goats died from the storm surge. People report that some livestock survived due their untied rope.

3.5.22 Reasons for not going to the shelter

Some people did not go to the cyclone shelter even if they got warning from television, radio and local hand held microphone. The reasons behind neglecting the warning are found as follows:

a. There was warning of Tsunami a few days ago but no Tsunami occurred. During that warning many people went to the cyclone shelter. This false warning was stayed a longer time than it should be and it misleads people.

b. Last devastating cyclone was occurred in 1991, which was about 16 years from now. That may make people a bit lavish and neglect to take precautions.

c. Some people are afraid of steeling of their daily household goods such as bedding, cooking pots and cloths. They remain home to avoid chances of steeling.

d. There was no shelter for livestock and that makes people also resultant to leave their home.

e. The cyclone shelter was over crowded during that night and some people were not able to enter the shelter.

3.5.23 Post disaster activities

About four days people stayed on the major road because their houses were under polluted water. The post disaster activates were delayed since this area is remote from local city. After two and half days of the cyclone, relief supply reached in the shelter. Government army supplies bottle water to the affected people.

3.5.24 Conclusions

This team proposes a number of recommendations based on the interview with the local people. A summary of recommendations are given below.

1. About 37 people died in that village due to storm surge about 8 to 10 ft. height above ground level.

2. Most of the crops and livestock were destroyed due to excessive wind. Many houses are destroyed by the cyclone.

3. Local disaster management body was performed fairly well to provide warning.

4. The capacity of the shelter is inadequate.

5. NGO and government officials and army reached after one day of the cyclone due to inaccessibility of the region. Post relief activities were found continuing for the cyclone victims.

Photo 3.7. Cyclone center where severe storm surge occurred

Photo 3.8. Primary school and mosque of the multipurpose cyclone center

Photo 3.9. Surge water level was about 8 steps of the stairs shown by local people

Photo 3.10. SIDR completely destroyed a local madrasha within the compound of the cyclone shelter

Photo 3.11. BUE team interviewed local people during their field visit

Photo 3.12. Water supply of the shelter is mainly by hand tube-well

3.6. Case study-3: Performance of a coastal embankment and polder.

Coastal embankment and polder located at Rayenda village near the Baleswar River were visited by the BUET team. Storm surge about 8 feet above the embankment was observed during the cyclone. The embankment was damaged in many places and breach shown the degree of devastation caused by the severe cyclone. Many casualties were found closed to the embankment. People live close to the river are more vulnerable than those live away from the river. Fishermen live close to the river and they are more vulnerable people. We have seen several mass graveyards of the cyclone victims at Rayenda village.

This team found a breach in the cross embankment. Local people reported that it was destroyed after two hours of the cyclone pass the village. This destruction of the embankment was mainly caused by the pressure of trapped water from the storm surge.

3.6.1 Conclusions

1. About 132 people died in Rayenda village due to storm surge about 8 feet height above embankment.

2. Most of the crops and livestock were destroyed due to excessive wind. Many houses are destroyed by the cyclone.

3. Local fisherman was reluctant to take precautions against cyclone warning. They are continuing fishing in the river until evening. Some people did not go to shelter due to fear of stealing of their daily household goods.

4. The capacity of the nearby shelter is inadequate.

5. The cross dam was failed due to excessive pressure of retained water.

6. Trees on the country side of the embankment were heavily damaged. Plantation on the embankment normally increases velocity of the storm surge by reducing the flow area and make flow more supercritical.

Photo 3.13. Local people shows height of the water level of the storm surge

Photo 3.14. Embankment was severely damaged and this picture was taken after some initial repair of the embankment

Photo 3.15. Homeless people start living near the embankment after the cyclone passed

Photo 3.16. Boats near the river banks also damaged

Photo 3.17. Many burial ground of cyclone victims were found in every village

Photo 3.18. BUET team share and condole the survivals (a little boy) of the SIDR

Photo 3.19. Damaged local road

Photo 3.20. Failure of the local embankment due to excessive water storage gathered from storm surge

Photo 3.21. Damaged embankment due to SIDR

Photo 3.22. SIDR completely destroyed houses near coastal embankment

Photo 3.23. Local people reports their survival story to the BUET team during their field visit

Photo 3.24. Measuring salinity of the water in the Baleswar river

3.7. Caste study-4: Assessment of vegetation damage in the study area.

Vegetation damage was studied using satellite MODIS images. This image was downloaded from the MODIS web site (MODIS, 2008). MODIS/TERRA images include average of 8 days reflectance (Surface Reflectance 8-Day L3 Global 250m). Two images of one before the cyclone on November 9, 2008 and one after the cyclone on November 25, 2008 was compared. Normalized Difference Vegetation Index (NDVI) is an excellent measure of vegetation health. The formula for computing NDVI is as follows:

$$NDVI = \frac{NIR - \mathrm{Re}\, d}{NIR + \mathrm{Re}\, d}$$

NDVI value of zero means no green vegetation and close to unity indicates the highest possible density of green leaves. Healthy plants have a high NDVI value because of their high reflectance of infrared light, and relatively low reflectance of red light. Areas of consistently healthy and vigorous crop would appear uniformly bright. Stressed vegetation would appear dark amongst the brighter, healthier crop areas.

NDVIs of the later images are deducted from earlier images. Figure 4.2 shows the difference of NDVI of the two above mentioned images over Bangladesh. This image clearly shows damage of the vegetation due to the cyclone SIDR. Red area indicates serious damage and, yellowish shows moderately damaged area.

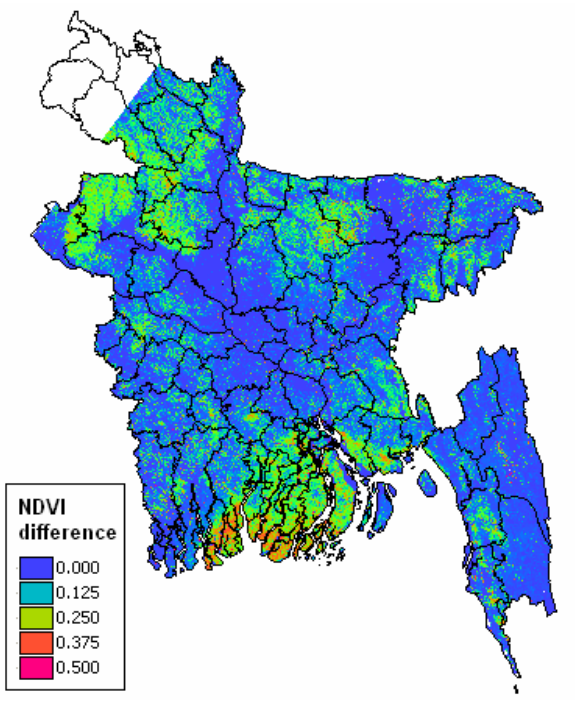


Figure 3.2. Shows difference of NDVI before and after the cyclone.

3.8. Caste study-4: Assessment of vegetation damage in the study area.

The damage of the world heritage site the Sundarbans was studied using same MODIS images. Figure 4.3 shows the NDVI map of the Sundarbans areas before and after the cyclone. It was clearly found that some part of the Sundarbans where cyclone hits are damaged and others are not affected. Figure 4.4 shows the difference of NDVI between the two cases. The red color shows severe damages and green shows moderate or little damage of the vegetation.

Histogram of the NDVI differences of the Sundarbans area is shown in Figure 4.5. Based on this histogram, a classification of the intensity of damage was developed. The following table summaries the intensity of vegetation damage with the image NDVI values. The affected area (high and severe) of the Sundarbans is around (16+7) = 23% of the total area. The moderate and low change of vegetation areas are not considered in this estimation. During the field visit, this classification of the severity of vegetation damage was validated by the study team. More research should be conducted in future to validate the damage of vegetation and ecosystem of the Sundarbans and natural restoration of the ecosystem.

Changes of NDVI	Severity of vegetation damage	% Area of the Sundarbans
0.0	No change	19
0.1	Low	40
0.2	Moderate	18
0.3	High	16
0.4	Sever	7

The histogram of the classification is shown in the Figure 4.6. It has found that majority of the Sundarbans observed low damage or no change of vegetations. A few area about one fifth of the total area of the Sundarbans are damaged severely by the cyclone. The classified damage of vegetation map is shown in Figure 4.7

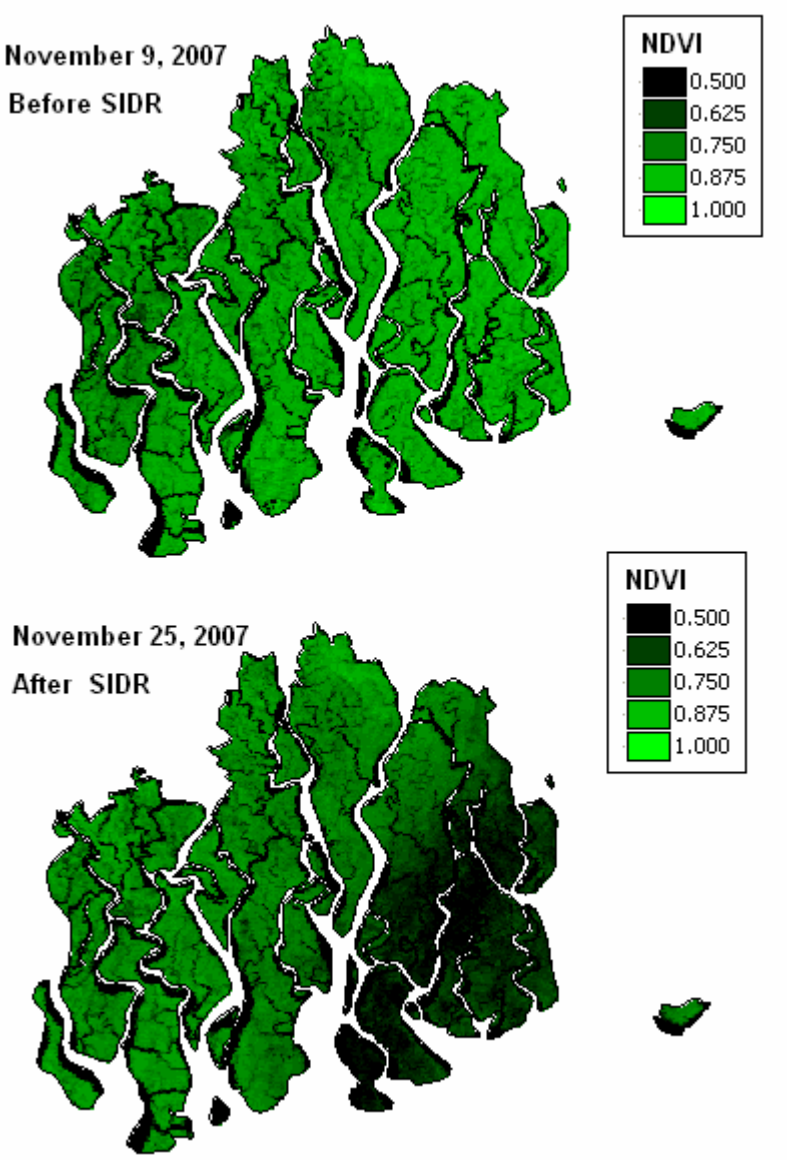


Figure 3.3. (a) NDVI of the Sundarbans area before the cyclone and (b) NDVI values of the same area after the cyclone.

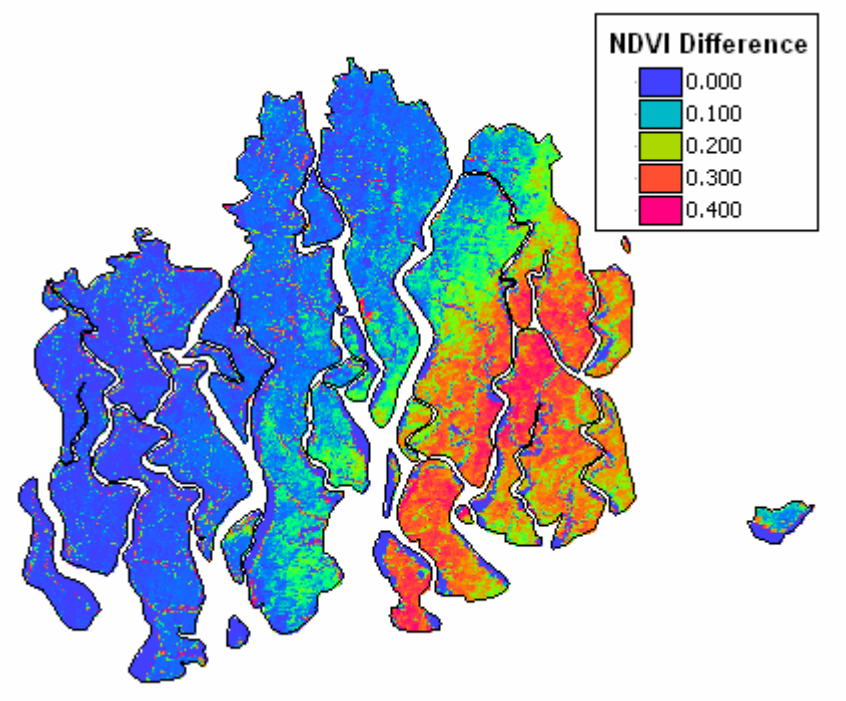


Figure 3.4. NDVI difference of before and after the cyclone in the Sundarbans area.

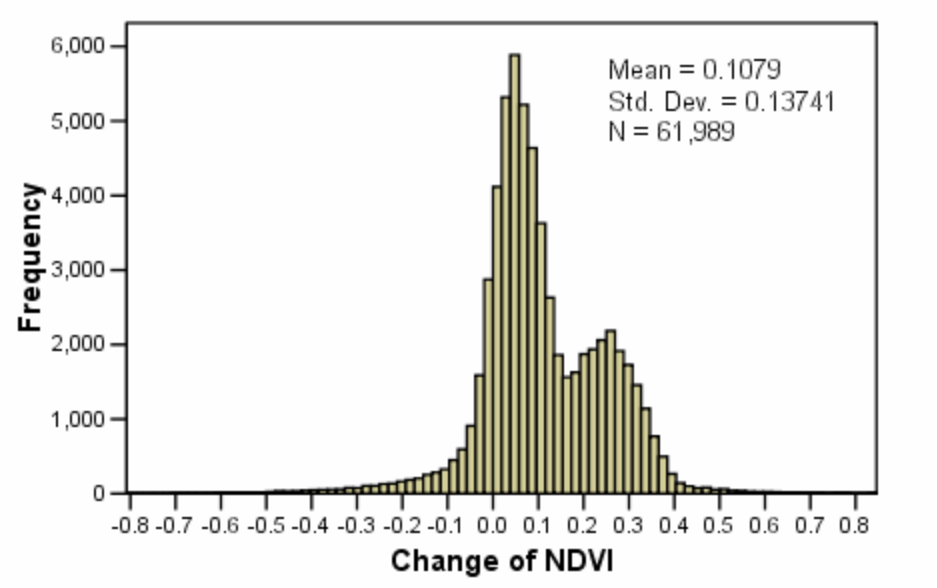


Figure 3.5. Histogram of the change of NDVI in the Sundarbans area

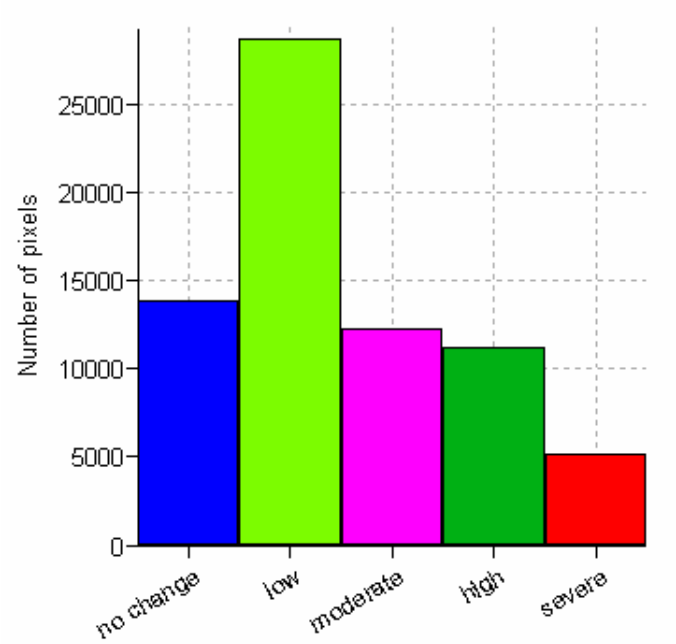


Figure 3.6. Classification of changes of NDVI based on severity of the damages of vegetation in the Sundarbans area

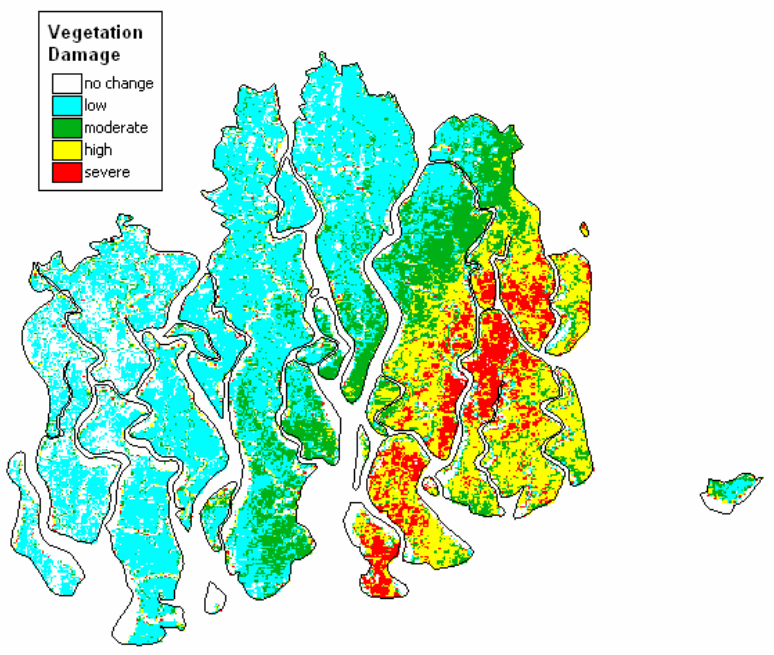


Figure 3.7. Classified map of the changes of NDVI shows degree of damages of the vegetation ion in the Sundarbans area

3.8.2 Salinity condition

Salinity samples are taken randomly during our field visit. Electric Conductivity (EC) of water are collected from four locations namely "Pashur River", "Cyclone Shelter Mongla", "Morelganj River", "Tapashbari"and "Boleshwar River". The data was plotted in Figure 4.8. The distribution of salinity was plotted as filled contour using inverse distance weighted average method (IDW). The contour plot shows increasing of salinity of water towards the coastal area and its tributaries (Baleswar river).

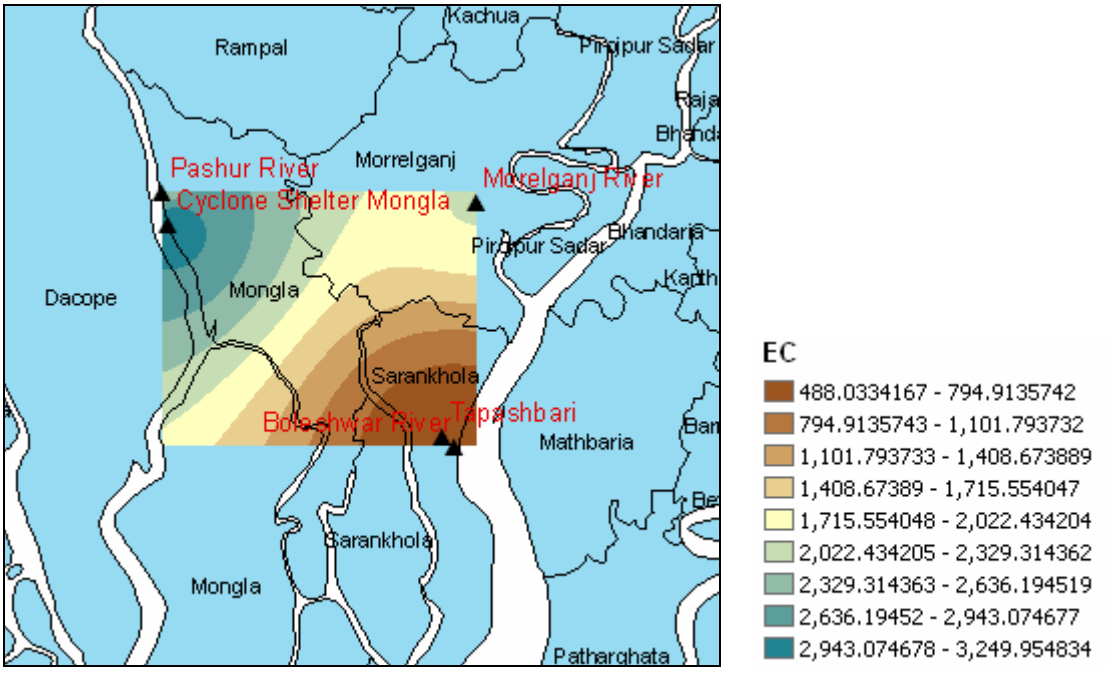


Figure 3.8. Shows filled contour surface based on EC of water samples collected from four points (shown as triangle).

Photo 3.25. Trees fallen in the pond cause pollution and disruption to the aquatic system.

Photo 3.26. Vegetations are damaged mostly by strong wind of the cyclone

Photo 3.27. Shallow rooted trees are more vulnerable than deeply rooted trees

Photo 3.28. Farmers lost their crops due to intrusion of storm surge water

Photo 3.29. Rural electricity supply lines are heavily disrupted and fallen from cyclone

Photo 3.30. Heritage site "Sat Gombuj Mosque" is narrowly escaped from a fallen tree.

Chapter 4: Conclusions and Recommendations

4.1. Conclusions

1. No fatality was reported around the shelter where storm surge was not occurred. But most of the crops and a few livestock are destroyed due to excessive wind. Some houses and electric poles are destroyed by the cyclone.

2. Many people died in shelters due to storm surge about 10 to 12 ft. height above embankment. Most of the crops and a few livestock are destroyed due storm surge.

3. The capacity of the shelters is inadequate.

4. The reasons behind neglecting the cyclone warning are found as follows.

    a. There was a warning of Tsunami a few days ago but no Tsunami occurred. During that warning many people went to the cyclone shelter. This false warning was stayed a longer time than it should be and it misleads people.

    b. Last devastating cyclone was occurred in 1991, which was about 16 years from now. That may make people a bit lavish and neglect to take precautions.

    c. Some people are afraid of steeling of their daily household goods such as bedding, cooking pots and cloths. They remain home to avoid chances of steeling.

    d. There was no shelter for livestock and that makes people also resultant to leave their home.

    e. The cyclone shelter was over crowded during that night and some people were not able to enter the shelter.

5. NGO and government officials and army reached immediate if the area is close to city center. In some remote areas it takes about two days due to blockage of road from fallen trees. Post relief activities were found continuing for the cyclone victims.

6. Local fisherman was reluctant to take precautions against cyclone warning. They are continuing fishing in the river until evening. Some people did not go to shelter due to fear of stealing of their daily household goods.

7. Embankments are damaged in many places. A cross dam was found failed due to excessive pressure of retained water. The trees on the downstream side of the embankment increase velocity of the surge water and cause destruction of the embankment.

8. Field sample of salinity of water shows that it increases towards the coast. Water quality of some ponds is found not suitable for drinking.

4.2. Recommendations

1. More shelters at dense spatial frequency are proposed.

2. Considering the budget constraint, more shelters of smaller size will be better than less number of larger sized ones.

3. Provision for livestock in the shelter premises.

4. Better water supply and sanitation system.

5. Management of the shelter should be institutionalized during non disaster period.

6. Better system for dissemination of disaster information. Warning system should be more understandable to the people. Present system (based on signal) is designed primarily for navigation.

7. No plantation should be allowed on the embankment.

8. Water in the cyclone affected ponds should be purified using lime, chlorine or other water purified agents.

9. Post rehabilitation should focus on creating job opportunities and provide micro credit for housing, agriculture, livestock and fisheries.

References

Banglapedia (2008) at http://banglapedia.search.com.bd/HT/C_0397.htm

GOB, UNDP, World Bank (1993) Multipurpose cyclone Shelter Programme. Executive Summary of Final Report.

MODIS (2008) MODIS Data products at
http://lpdaac.usgs.gov/modis/dataproducts.asp#mod09

NASA (2008) Hurricane Season 2007: SIDR (Indian) at
http://www.nasa.gov/lb/mission_pages/hurricanes/archives/2007/h2007_sidr.html

NOAA (2008) NOAA Researcher's Warning Helps Save Lives in Bangladesh at
http://www.oar.noaa.gov/spotlite/2007/spot_cyclone.html

SMRC (998), The impact of tropical cyclones on the coastal regions of SAARC countries and their influence in the region, SAARC Meteorological Research Center (SMRC), 1998.

TRMM (2008) TRMM real time monitoring of tropical cyclones. at
http://www.eorc.jaxa.jp/TRMM/NRTtyphoon/asia_e.htm

Wikipedia (2008) Cyclone SIDR at http://en.wikipedia.org/wiki/Cyclone_SIDR

Zafanoor (2008), BREAKING: Deadly SIDR on the Way at
http://keepmehonest.wordpress.com/2007/11/13/breaking-deadly-sidr-on-the-way/

Appendix

Historical records of tropical cyclones made landfall at the Bangladesh Coast (SMRC, 1991)

SL. No.	Date/Year	Type of Disturbance	Relevant Information	Reference/Source of Information
1.	1582 A.D. (Date and month N/A)	Severe Cyclonic Storm with a core of hurricane winds	Coast: The cyclone crossed the coast of Backerganj (Sarkar Bala). Loss and damage: People killed = 200,000. The destruction was reported to have been caused by a storm wave. According to Banglapedia, a five-hour hurricane and thunderstorm destroyed houses and boats in the coast near Bakerganj (presently in Barisal and Patuakhali). Only Hindu temples with a strong foundation were spared.	• Ain-i-Akbari • Riyaz-Us-Salatin • Bengal District Gazetteer, 24 Parganas-by L.S.S. O'Malley, ICS, 1914, published- by the Bengal SOC Dept.
2.	1585 A.D. (Date and month N/A)	N/A	A tropical storm hit the eastern side of Bakerganj (now Barisal) near the mouth of the Meghna River estuary, causing devastation of crops. Casualty: unknown.	• Banglapedia
3.	1699 A.D. (Date and month N/A)	Severe Cyclonic Storm	Coast: The cyclone crossed the Sundarbans coast Loss and damage: People killed = 50,000. Other information is not	• Daily Ittefaq, May 5, 1991.

			available.	
4.	1760 A.D. (Date and month N/A)	Severe Cyclonic Storm	Coast: The cyclone crossed the Sundarbans coast Loss and damage: N/A. The whole area was almost damaged. Other information is not available.	• Daily Ittefaq, May 5, 1991.
5.	1765 A.D. (Date and month N/A)	Severe Cyclonic Storm	Coast: The cyclone crossed Chittagong coast Loss and damage: N/A. The whole area was destroyed. Other information is not available.	• Daily Ittefaq, May 5, 1991.
6.	1767 A.D. (Date and month N/A)	Severe Cyclonic Storm	Coast: The cyclone crossed Backerganj (Barisal) coast. Surge height: 13.03 m (43 ft) Loss and damage: People killed: 30,000. Other information is not available.	• Daily Ittefaq, May 5, 1991.
7.	May-June, 1797 (Actual date N/A)	Severe Cyclonic Storm with a core of hurricane winds	Coast: The cyclone crossed Chittagong coast Loss and damage: Every house in the area was destroyed. Two ships were sunk in Chittagong Port. Other information is not available.	• Bangladesh Meteorological Department • Banglapedia
8.	June, 1822 (Actual date N/A)	Severe Cyclonic Storm with a	Coast: The cyclone crossed the coast of Backerganj (Barisal),	• Journal of Asiatic SOC. of Bengal, Vol. 46, Part II, pp 332- by

		core of hurricane winds	Sarkar Bala. Loss and damage: People killed = 50,000. Cattle killed = 100,000. Storm wave swept away the collectorate records. Other information is not available.	H.F. Blandford • Buist's 1st catalogue Trans. Bombay Geo. Soc. Vol. XII. Appendix A. • Sailors Horn Book for the law of storms. Appendix A. - by H. Piddington.
9.	June 2, 1823	Cyclonic Storm	Coast: The cyclone crossed Chittagong coast Other information is not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
10.	June 8, 1824	Heavy Storm (Severe Cyclonic Storm)	Coast: The cyclone crossed Chittagong coast Other information is not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
11.	October 31, 1831	Severe Cyclonic Storm	Coast: The cyclone crossed Barisal coast (Grazed the Balasore-Orissa coast)	• Bangladesh Meteorological Department. • Bengal District

			Surge height: 2.12-4.55 m (7-15 ft) Loss and damage: People killed = 22,000 (along the coast of India and Bengal) Cattle killed > 50,000 Other information is not available.	Gazetteer (Balasore)- by L.S.S. O'Malley, ICS
12.	June 3-5, 1839	Cyclonic Storm	Coast: Crossed Head Bay (Bengal coast) Other information is not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
13.	September 19-21, 1839	Cyclonic Storm	Coast: The storm passed north across Sundarbans coast between Calcutta and Barisal. Other information is not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
14.	May 11, 1844	Cyclonic Storm (Gale)	Coast: Crossed Noakhali and	• Disastrous storms in the Bay of Bengal, A

			Chittagong coast. Other information is not available.	Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
15.	May 12-13, 1849	Cyclonic Storm (Gale)	Coast: The cyclone crossed Chittagong coast Other information is not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
16.	April 23-28, 1850	Cyclonic Storm	Formation: Formed over West Nicobars. Coast: It moved north to Bengal from West Nicobars. Other information is not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
17.	May 12-15, 1852	Cyclonic Storm	Formation: Formed near 15°N.	• Disastrous storms in the Bay of Bengal, A

			Coast: It moved northward and crossed the Sundarbans coast; the center passed 39 miles (63 km) east of Calcutta Other information is not available.	Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
18.	May 13-17, 1869	Cyclonic Storm	The storm moved northwestward from Cape Negrais to Bengal and crossed the Bengal coast Other information are not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
19.	June 5-10, 1869	Cyclonic Storm	Coast: From the North Bay the cyclone passed over Bengal. Other information is not available.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson.
20.	October 1872 (Date	Cyclonic Storm	Coast: The cyclone hit the coast of Cox's Bazar	• Disastrous storms in the Bay of Bengal, A

	was not available)		Other information is not available.	Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson. • Banglapedia
21.	October 29-November 1, 1876 (The Great Backerganj Cyclone of 1876)	Severe Cyclonic Storm with a core of hurricane winds.	Coast: The cyclone crossed the coast of Backerganj (present Barisal) near Meghna estuary. Maximum wind: 220 km/h (119 knots) Surge height: 3-13.6 m (10-45 ft) According to Banglapedia, a cyclone with a storm-surge of 12.2 metres (40 ft) hit Meghna River estuary near Chittagong, Barisal, and Noakhali. Casualty: about 200,000. The storm also caused epidemic and famine, and vast property damage.	• Disastrous storms in the Bay of Bengal, A Listing of Cyclonic Storms by Month Through 1979, Prepared for the Office of U.S. Foreign Disaster Assistance Agency for International Development, Washington D.C. 20523 - by F. Henderson. • BMD • Hurricane Storms and tornadoes- by D.V. Nalivkin, 1982, pp. 68. • Journal of Asiatic Soc. Vol. XL VI- by H.F. Blanford pp. 338. • Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea, 1877-1970, IMD, 1979. • Banglapedia