Impact of the cyclonic storm Komen along the coast of Bangladesh and recovery measures

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Abstract— Komen, a category 1 unusual tropical cyclone with wind speeds of over 85 km h^{-1}, struck south western coastal region of Bangladesh on 30 July 2015. Although it was not too intensified and dreadful, but it caused a considerable loss of life of the coastal people of Bangladesh both socially and economically. Many people lost their lives and several injured due to this disaster. It brought heavy rainfall of several days and many areas of the southern Bangladesh were inundated by the associated flood. In this paper, it is analyzed how the coastal people of Bangladesh and the environment in which they live were affected by the cyclone. A brief account is presented of loss of life and of the damage suffered in various sectors including agriculture, industry, and physical infrastructure. Using information obtained from different sources, this study shows how the coastal people of this country suffer resulting from storm surges and how much protection against natural disaster is there. The casualties may be attributed to a number of physical characteristics of the cyclone such as duration of the storm and associated surges, landfall time and location and other factors. This study also shows what the challenges are needed to be taken care into account to socio-economic development for Bangladesh mitigating disaster and its related losses.

Index Terms— Komen, Cyclone, Storm surge, Economic damage, Casualties, Cyclone shelter

1 INTRODUCTION

The world most storm surge affected country, Bangladesh, is situated at the northern tip of the Bay of Bengal (see Fig. 1) between longitudes 85^{o}E to 95^{o}E and latitudes 15^{o}N to 23^{o}N. It is bordered on the west, north and east by India, on the south-east by Myanmar, on the south by the Bay of Bengal (BOB). The geographical location of the country makes it vulnerable to the tropical cyclones and associated surges and other natural hazards [1]. The long continental shelf with shallow bathymetry, gently sloping and funneling coastline, complex land-sea interface, etc. increase the volume of losses. A number of tropical cyclones associated with surges in each year cause a considerable loss of many lives and properties, which is considered as a real threat for the coastal population of Bangladesh. About 5% of the global cyclones form over the BOB and on an average 5-6 cyclones form every year, but the resulting loss is about 80% of the global casualties [2], where the coast of Bangladesh is found to be most vulnerable [3]. It is to be mentioned here that the coast is visited by several devastating cyclones, but November 1970, 1985, April 1991, 1997, SIDR 2007, and AILA 2009 are of worth mentioning [3]. Khalil [4], Debsarma [2], Paul [5] have shown how much devastating were they. In those studies, one can figure out the losses in life and socioeconomic sectors in details.

However, very recent cyclonic storm Komen hit the coast of Bangladesh on 30 July 2015. The cyclone and associated surge devastated the south and south-eastern areas of the country. Cox's Bazar, Chittagong, Bandarban, Noakhali, Feni and Bhola districts were significantly affected (see Fig.2). At least 7 people (2 of them were children) were reported dead, 38 were missing, and a number of people were injured due to this tropical cyclone. Based on the rapid impact assessment conducted by the Humanitarian Coordination Task Team (HCTT), a total of 2.6 million people were affected, more than 218,000 households were in need of emergency assistance. Meanwhile, Government district level 'D-form' data immediately after the disaster indicated many houses were flattened or went under water, trees uprooted, power supplies were disrupted, and communication systems ceased to operate in some places. Crops were damaged and shrimp projects were flooded. Due to the impact of the cyclonic storm Komen, heavy to very heavy rainfall was active all over the country and many areas of the southern Bangladesh were inundated. Consequently, the lives and livelihoods of the people of those areas further became worse. A Need Assessment Working Group (NAWG) was formed to identify the damage and needs of all these areas affected by the cyclone and subsequent flooding. The cumulative effect of the floods followed by Komen increased the number of affected population to 2.6 million and it was estimated that 218,665 people and 57,774 households were affected badly. The present paper in this regard gives a descriptive account of the impact of the CS Komen along the coast of Bangladesh and suggests the main measure to mitigate the resulting losses.

The rest of the paper is organized as follows. Section 2 deals with the time history of the storm Komen. Section 3 presents losses and damages resulting from the CS Komen. Cyclone preparedness process, cyclone warning system of Bangladesh, shelter system, relief distribution process is detailed in Section 4. Numerical simulation of the CS Komen and discussion of the results are presented in section 5. Section 6 deals with the challenge to socio-economic development. Finally, conclusion is given in Section 7.

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Fig. 1 A picture of the northern part of the BOB covering the area $15^{\circ}-23^{\circ}$ N Latitudes and $85^{\circ}-85^{\circ}$ E Longitudes (After Murshed [22]).

2 Time History of Komen

According to the Indian Metrological Department (IMD), on 25th July evening, the CS Komen developed from a low-pressure area over the BOB, which lay over northeast BOB and adjoining Bangladesh & Gangetic West Bengal and concentrated into a depression over the same area in the morning of 26th July. At 0300 UTC (universal time coordinated) 26 July, IMD classified the system as a depression. The depression moved slowly westwards and lay centered at 1200 UTC 26 July near lat. 22° N and long. 90.5° E. It remained stationary there till 0300 UTC 28 July and then moved slowly southwestwards and lay centered at 1200 UTC of the same day near lat. 22° N and long. 90.2° E . It then moved southeastwards, intensified into a deep depression (DD) and lay centered at 0600 UTC 29 July near lat. 21° N and long. 90.8° E . The DD moved east-northeastwards initially and then north-northeastwards till 1200 UTC 29 July. It then moved nearly northward, intensified into a CS Komen and lay centered at 1500 UTC 29 July near lat. 21.7° N and long. 91° E . It continued to move nearly northwards and crossed Bangladesh coast between Hatia and Sandwip (near lat. 22.5° N and long. 91.4° E) during 1400-1500 UTC 30 July. After the landfall, it moved north-northwestwards and gradually weakened into a DD at 2100 UTC 30 July over Bangladesh near lat. 23° N and long. 91° E . It then moved west-northwestwards and further weakened into a depression at 1200 UTC 31 July and lay centered over Bangladesh and adjoining Gangetic West Bengal near lat. 23.1° N and long. 89.5° E . The time series for the positions and the nature of the cyclone Komen is shown in Table 1 and the track of the cyclone is shown in Fig. 3 for better perspective.

3 Losses and Damages

Although cyclone Komen was not very much dreadful, but it caused a lot of harm to the coastal people of Bangladesh in several ways. During crossing the Bangladesh coast, the cyclone associated with a surge of about 2 m (Source: IMD) affected Chittagong, while heavy rainfall caused flooding and landslides. About 800 mm (31 in) of rainfall was recorded over three days in Chittagong and 1,000 mm (39 in) in Cox's Bazar over ten days in southeastern Bangladesh [6]. According to the flood forecasting and warning centre (FFWC), about 15 to 24 rivers were flowing over danger level since the rain started. Some lower and riverside parts of Northern and central Bangladesh had experienced flood as a result of the CS Komen. The excessive deluge of river waters caused river erosion and embankment breaching in many places. Rough seas killed two people in Cox's Bazar when a boat capsized. Rain-induced landslides killed five people in Cox's Bazar, and two others died in the town due to flooding. In total, Komen killed 45 people in Bangladesh, among them 21 in Cox's Bazar and 7 in Bandarban, some of whom due to illnesses spread by the storm. The damage of hectares of crops, fish farms put the affected people in danger of long-term food security and income generation. Affected communities were having insufficient food, as they could not afford to buy food and basic commodities due to loss of income. They were eating fewer meals per day, borrowing money at high-interest rate and purchasing food on credit. The storm damaged 88,900 houses across including hundreds of fishermen huts. Trees knocked onto houses killed at least three people in separate instances. Flooding submerged at least 360,000 acres of crops for at least a week after Komen struck the country. Many water routes in Barisal district had been suspended. Access to safe drinking water was serious concern because of damaging water sources. Many waterborne diseases broke out due to this reason. Most of the affected community faced the problem of sanitation facilities as well.

4 Cyclones and Storm Surges Preotection Activities

4.1 Cyclone Preparedness Programme

Although cyclones and storm surges may not be preventable but it can be reduced the extent of damages through prudent works. In order to do that, many organizations carried out some important roles. However, the most dedicated agency for cyclone disaster information dissemination and mobilization at the coastal level is the Cyclone Preparedness Programme (CPP). The CPP is an organization of large contingent of volunteers at the field who carry out the important function of mobilizing people at the community level to handle cyclones. The main objective of the CPP is to protect and diminish the loss of lives and properties from the assault of cyclones and storm surges in the coastal areas and offshore islands of Bangladesh. On the activities of the CPP, it can be divided into two major parts, namely the pre and post-cyclone actions.

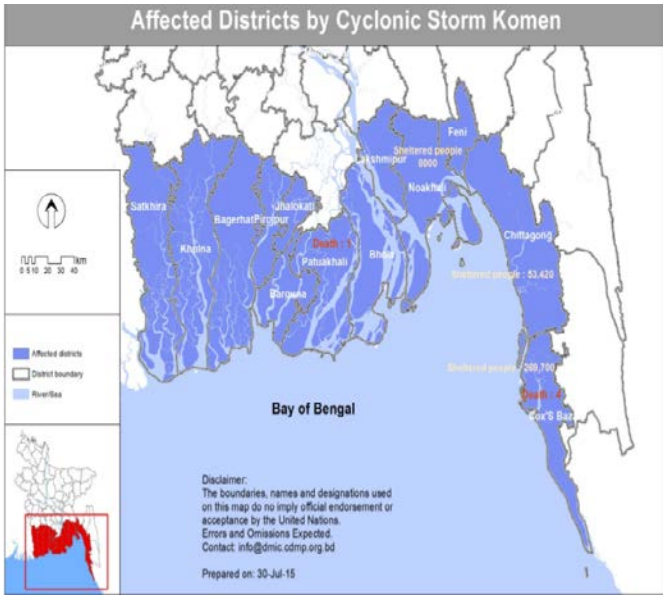

Fig. 2 Affected districts by the cyclonic storm Komen (Source: DMIC, www.dmic.org.bd)

As pre-cyclone action, the CPP is concerned with forecasting, warning and evacuating residents and as post-cyclone action, it is concerned with relief and rehabilitation in the event of a cyclone. After the devastating cyclone of November 1970, CPP has been founded as 'basic to human survival and development of the coastal region'. The CPP acts under Bangladesh Red Crescent and Red Cross Society (BDRCS) in collaboration with the Government of Bangladesh. All staffs including volunteers work day-night to provide safety to the affected community. The volunteers disseminate the warning signals, alert the people, evacuate them to safe places, rescue marooned people after the cyclone, provide the injured with first aid etc. Each CPP team is provided with warning equipment like transistor radio, megaphone, siren, signal light, first aid kit, etc. Teams are also provided with cycles for communication and signal flags for hoisting in poles in cyclone shelters and other points to communicate warning signals to people in the coastal area.

During cyclone Komen, the CPP started disseminating cyclone warning message in 13 coastal districts. Seven community radio stations in Bangladesh work to address cyclone Komen 24/7 in the coastal region of Bangladesh with standing orders on disaster (SOD) of Government of the People's Republic of Bangladesh. They were also keeping contact with the Red Crescent members, scouts, and volunteers at local levels. Considering the importance of the situation many radio stations situated in coastal zone as well and they were broadcasting weather forecasting special bulletin, PSA, docudrama, magazine program repeatedly and draw the attention of all to prepare for facing Komen so that the community remains alert to take initiative in advance and thus the damage can be reduced. A Need Assessment Working Group (NAWG) was formed to identify the damage and needs of all those areas affected by the CS Komen and subsequent flooding. This assessment was appointed by HCTT and was covered in ten districts. The Government responded with rice and cash in many of the affected areas while a number of humanitarian organizations and United Nation (UN) agencies have responded with food assistance, health and WASH relief. World Health Organization (WHO) and other health cluster partners are providing emergency drugs and medical.

4.2 Cyclone Warning System in Bangladesh

Cyclone warning in Bangladesh comes from the Bangladesh Meteorological Department (BMD). The storm warning centre (SWC) of the BMD issues special weather bulletins when a depression forms in the BOB to alert especially the coastal and island populations of the country so that a significant reduction in the loss of lives and properties can be made [7]. The SWC issues warnings in different stages of the formation of the cyclones depending on the wind speed [8]. The first stage is the cyclone alert stage (Signal No. I, II and III) and at this stage, an alert message is sent to CPP, radio, and television when wind in a TC reseches 50 km h^{-1}. The second stage is the cyclone warning stage (Signal No. IV). This stage is initiated at least 24 h before a predicted landfall when the speed of wind rotating in a TC reaches between 51–61 km h^{-1} and a message in this regard is sent to the respective authorities and media with information about the current and forecasted positions of the TC and suggested safety measures for fishing boats [9]. The third stage is a cyclone disaster stage (Signal No. V, VI, VII, and VIII, IX, X) starts when the maximum wind speed of a TC exceeds 61 km h^{-1}. At this stage, an updated danger warning message is disseminated every 30 minutes. The final stage is started at least 10 h before the predicted landfall [9] when the maximum sustained wind speed of a TC exceeds 89 km h^{-1}. A warning message is then disseminated every 15 minutes and the residents are urged to evacuate at this point. The National Disaster Management Council (NDMC) then reviews disaster management policies and provides directives to all concerns for preparedness, disaster risk reduction, evacuation, response, and recovery. The CPP with its volunteers plays a leading and vital role in disseminating the cyclone warnings among villagers via megaphones, sirens, signal lights, and cyclone warning flags [5]. Before landfall of any cyclonic storm, a proper warning system is the most crucial part to reduce the extent of damages. It is being improved day by day. In recent years some improvements of warning system are presented below (source: BMD):

1. Improvement of Observational Network
    - Surface and upper air observation
    - Satellite receiving system
    - Radar system and communication link

2. Introduction of numericl weather prediction (NWP) technique
3. Enhancement of human capacity
4. Installation of the media center for live and quick dissemination of forecast and warning
5. Dissemination of forecast and warning through voice record
6. Dissemination of forecast and warning through mobile phone SMS
7. Dissemination of forecast and warning through the interactive and dynamic web site (www.bmd.gov.bd)

4.3 Cyclone Shelter

Cyclone shelter is actually a structured building constructed on RCC pillar of which the ground floor is kept open for free flow of tidal surges. The structural design has been prepared in such a way that it can withstand the heavy gusty and squally wind. The majority of the coastal population live their life by agriculture and fishing and live in bamboo and timber-framed huts, walled with matt, straw or palm leaves. A large proportion of their dwellings are flattened by even a moderate cyclone and washed away by storm surges. But the land and the adjacent sea are their main sources of livelihood, relocation from the areas of risk is out of the question for most of them. Moreover, the population of coastal areas increases in a natural way every year. While land and alternative sources of livelihood remain scarce in Bangladesh. Out of 35 million people in 700 km long stretched coastal areas of Bangladesh, 7 million lives in high disaster risk. So protection against strong cyclones is very crucial for coastal inhabitants by evacuating to a place of greater safety and construction of cyclone shelters that are properly designed, sufficient to accommodate the villagers, are essential prerequisites to save lives during a cyclone. Sufficient stocks of food, medicine and other essential objects are needed for the people there as well. During cyclone Komen, 331120 people took shelter for saving their life (Source: DMIC). After the devastating cyclone of 1970, many government and non-government organizations of Bangladesh have constructed around 2500 cyclone shelters and multi-purpose cyclone shelters in 16 coastal districts [10]. This number is not sufficient and so more construction is needed. Besides this, due to poor maintenance, a number of those shelters have already become unfit for use. Because of those reasons, cyclone shelters construction, maintenance and management policy 2011 has been made by the Government of the People's Republic of Bangladesh which is working in this regard.

4.4 Relief to the Survivors

After cyclone Komen, it was very difficult to pass the daily life of cyclone affected people. About 2.6 million people were affected and more than 218,000 households were in such situation that they need for emergency assistance. According to HCTT, the majority of the communities were facing problems in relation to food. There were an acute scarcity of food and pure drinking water as well. Access to safe drinking water was quite impossible from the onset of disaster because of water sources damaged, destroyed or contaminated and large populations displaced. Heavy to very heavy rainfall was active all over the country and many areas of southern Bangladesh were inundated which includes most of the areas affected by flooding. So sanitation was also a big issue because collapsible latrines and water borne diseases were broken out in affected areas. To meet the needs, the Government responded with rice and cash in many of the affected areas while a number of humanitarian organizations and UN agencies have responded with food assistance, health and WASH relief. BDRCS provided from its disaster preparedness stocks 3,000 tarpaulins for emergency shelter, 30,000 packets of ORS (Oral Rehydration Solution) and installed two mobile water treatment plants to address the emergency needs of the affected population. WHO and other health cluster partners provided emergency drugs and medical supplies in the affected district. Emergency appeal under IFRC provided support through safe drinking water, sanitation and hygiene kits.

TABLE 1
POSITIONS AND NATURE OF THE CS KOMEN (DATA SOURCE: BMD)

Date (2015)	Hour (UTC)	Latitude (°N)	Longitude (°E)	Nature of the storm
26 July	0600	22.0	90.8	Monsoon Depression
26 July	1200	22.0	90.5	Monsoon Depression
27 July	0000	22.0	90.2	Monsoon Depression
28 July	0000	22.0	90.2	Monsoon Depression
28 July	1200	22.0	90.2	Monsoon Depression
29 July	0600	21.0	90.8	Deep Depression
29 July	1200	21.5	90.8	Deep Depression
29 July	1500	21.7	91.0	Cyclonic Storm
29 July	2100	21.8	91.2	Cyclonic Storm
30 July	0000	21.8	91.3	Cyclonic Storm
30 July	0300	21.9	91.4	Cyclonic Storm
30 July	0900	22.0	91.4	Cyclonic Storm
30 July	1200	22.2	91.4	Cyclonic Storm
30 July	1500	22.6	91.3	Deep Depression
30 July	1800	22.8	91.1	Deep Depression

5 NUMERICAL SIMULATION OF CYCLONE KOMEN

Here in this part we have recapitulated the numerical simulation of the cyclonic storm surge Komen and made up a numerical simulation of this. It is pertinent to pin point out here that numerical prediction of storm surge is the main economic basis of the warning systems. If it can be made accurately, the suffering of the coastal people can be reduced considerably. In this regard, a large volume of works has been conducted for

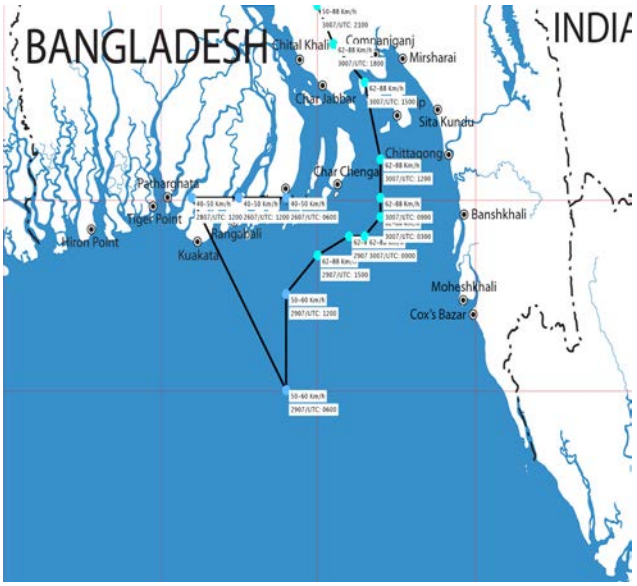

Fig. 3. The track and intensity of the CS Komen. according to the Saffir–Simpson scale (Data source: BMD and IMD).

Fig. 4 Few pictures related to the impact of the cyclone Komen (Source: BMD)

the numerical simulation of storm surge along the coast of Bangladesh. Rahman [3], Paul and Ismail [11, 12], Paul [8, 13, 14] in this regard may be mentionable. Among these studies, Rahman [3] and Paul and Ismail [11] were conducted only to show the impact of surge on water level in the absence of astronomical tide. Paul [13] developed the model of Paul and Ismail [12] for attaining a prediction accuracy including surge affecting factors for the region of interest. However, in all the studies it is concluded that for having a better prediction of water levels all the factors affecting surge levels for the region having coastal complexities should properly be taken into account. However, the CS Komen has paid no attention as per the best of our knowledge. Its numerical simulation may be a help in justifying the conduction of the study and taking necessary steps in mitigating damages resulting from future storm surges with proper prediction. In our numerical estimation, we have employed the codes used in the study of Paul and Ismail [15]. The only difference here is in meteorological inputs (e.g., storm track, maximum sustained wind radius and wind speed) as are discussed in the above sections. Firstly, tide model is run from the cold start (zero start) and from this start a stable tidal condition is generated by forcing the sea level to be oscillatory with M_2 tidal constituent along the southern open boundary of the parent scheme in the absence of meteorological forcing [15]. After attaining a stable tidal condition, the surge model is run for having water level due to the non-linear interaction of tide and surge at the model time $t = 0$. Our calculated results including their discussion, comparison and validation are presented in the next section.

5.1 Simulated Results

For the CS Komen 2015, the results were computed for 108 hours from 0600 UTC 26 July to 1800 UTC 30 July (see Table). However, they are presented for the last 48 hours from 1800 UTC 28 July to 1800 UTC 30 July at some representative coastal and island locations of Bangladesh and the obtained results of our computations are shown in Fig. 5. Figure 5 depicts the computed total water levels due to the nonlinear interaction of tide and surge at eight coastal locations depicted in Fig. 1. Our computed total water levels are found to vary between 1.17-2.59 m along the coast of Bangladesh. IMD reported that tidal wave (storm surge + astronomical tide) was of about 2 m along Bangladesh coast around the time of landfall. They also reported that the storm corssed the Bangladesh coast between Hatiya and Sandwip during 1400 to 1500 UTC on 30th July. Our model simulated peak total water results at Chittagong and Sandwip were found to be 2.11 m and 2.07 m, respectively. Thus our results that came out through model simulation agree well with the reported results by the IMD. Also based on a report from the BMD, cyclone Komen started crossing Chittagong coast near Sandwip at 1500 UTC 30 July and storm surge of about 1-2 m was realized at the time of landfall. Thus our computed total water levels (see Figs. 5) are found to be consistent with the sequence of events, data and landfall time mentioned above.

6 A Challenge to Socio-Economic Development

Bangladesh is a disaster prone country. Almost every year Bangladesh is frequently visited by devastating natural disasters like cyclones, storm surges, floods, drought, river bank erosion and landslides which cause harm many lives, affect thousands of people, and damage property millions of dollars every year. So, it has a great impact on social life and national economy. Although Bangladesh is now middle income country, but this country has many socio-economic problems like over population, critical land-person ratio and high poverty so

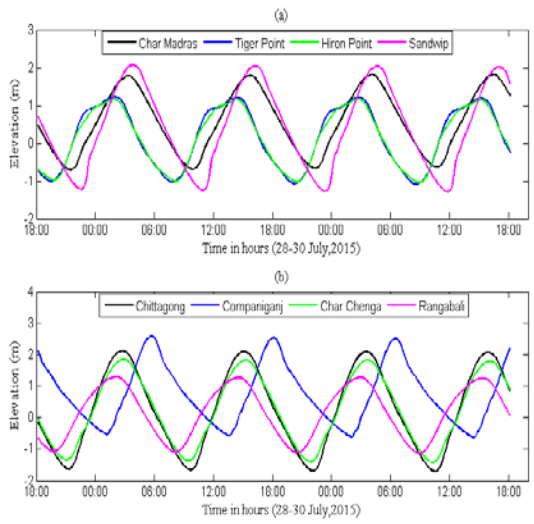

Fig. 5 Computed time variation of water levels with respect to the MSL due to the non-linear interaction of tide and surge associated with the CS Komen along the coast of Bangladesh.

that each natural disaster has an extremely large impact. More than 165 million people live in an area of only 147570 km². More than 45 million people, almost one-third of the population, live below the poverty line (source: HCTT). Of these, 26 million people, 18% of the population, live in extreme poverty (source: HCTT). About 65% of households in the southern region are functionally landless. Population density of the coastal areas is 1000 per km². Agriculture is the main source of income and land is the main productive asset of the people of rural areas. And for Bangladesh, it is the largest sector of the economy occupying three-fifths of the employed labor force and producing nearly half of the economy's output. So, it signifies both economic and social status. Although about 80% of the cultivated land is used for food grains. But this is not enough for its own requirements. Moreover, poverty leads to inadequate food intake, disease prevalence, and short life expectancy. So, this background of socio-economic scenario shows us that the ability of individuals and socio-political institutions to cope with catastrophic natural calamities are very limited.

After cyclone Komen losses in every section have been estimated. A total of 2.6 million people were affected. Dwelling houses, cattle, poultry, fisheries, standing crops, manufacturing industries, embankments, roads, culverts, trees were destructed. The damage of hectares of crops and fish farms put the affected people in danger of longer term food security and income generation. The storm damaged 88,900 houses across Bangladesh, including hundreds of fishermen huts. Besides this, at least 360,000 acres of crops were submerged by flood. As a result of widespread damage to standing crops, government and private food stocks were faced scarcity of food because of importing additional food for affected coastal people. The potential damage on housing, infrastructure and industrial plants means the need for significantly increased imports of capital goods and other manufactures which affect the economy of the country. The damage of the shrimp firms implies a major loss of export revenue of the country. There was also a heavy damage in many textile plants which impacted on the production of the ready-made garment and the largest export income. All these things showed that social life and economy of the country hampered directly and indirectly by the CS Komen. However, the Bangladesh government with the help of many donors as well as debtors (national & international) overcomes the situation taking a long period of time. Considering all these facts, it can be noted here that still it is a great challenge of socio-economic development for Bangladesh mitigating disaster and its related losses. The challenges of meaningful disaster mitigation, preparedness and prevention cannot be met by the efforts of Bangladesh alone, the international community should boost up their adequate support in this regard.

7 Conclusion

In Bangladesh natural disaster occurs almost every year during monsoon period, so it is a big issue for the country. In this study, our main target was to focus on how the cyclone Komen affected coastal people of Bangladesh and how the country managed the situation to handle its relevant activities like preparedness, warning system, cyclone shelters, relief management, etc. It is apparent that the cyclone adversely affected all socio-economic sectors of the country. Socially, Komen hampered badly of normal life of the victims mentally and physically as well as damaging infrastructure and production it had a negative impact on the country's economy. So, managing situation during cyclone and recovering from the direct and indirect losses caused by the cyclone is a great socio-economic challenge for the country. Taking several proper steps and improving warning system through a proper numerical model, losses can be mitigated. Besides this, national and international support can play a vital role to make a recovery. However, the numerical outputs as emanated from our numerical simulation are found to be satisfactory and hence the model though which the numerical simulation is made can be utilized in practical forecasting.

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Conflict of interests The authors declare that they have no conflict of interest.

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