CYCLONE WIND HAZARD ASSESSMENT IN COASTAL REGIONS OF BANGLADESH

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Abstract

One of the most dangerous cyclone basins of the world is located in the Bay of Bengal and the population most affected lives in coastal areas in Bangladesh. Bangladesh often suffers from many climate induced disasters such as flood, drought, cyclone etc among which the cyclone is the most catastrophic one. The coastal morphology of Bangladesh influences the impact of cyclone hazards on the area. Especially in the south western area, cyclone hazards increase the vulnerability of the coastal dwellers and slow down the process of social and economic development. This includes districts like Chittagong, Noakhali, Patuakhali, Barisal, and Khulna where the cyclones strike most in Bangladesh. Cyclones continue to pose a dangerous threat to the coastal populations of Bangladesh, despite improvements in disaster control procedures. After 138,000 persons died in the April 1991 cyclone, a rapid epidemiological assessment was carried out to determine factors associated with cyclone-related mortality and to identify prevention strategies. Wind hazard assessment of the cyclones that make landfall in the coastal regions of Bangladesh is of great significance. To understand the land falling tropical cyclones of Bangladesh and the associated risk and vulnerability in coastal areas is also important and accurate results and probability of hazard assessment can be done through the application of GIS in the wind speed analysis of cyclones for the purpose. It is hoped that this study will contribute to taking proper disaster planning efforts in Bangladesh especially in the mitigation phase for the reduction of damage from the cyclone hazard. Future cyclone-associated mortality in Bangladesh could be prevented by more effective warnings leading to an earlier response, better access to designated cyclone shelters, and improved preparedness in high-risk communities.

Keywords: cyclones, assessment, wind, hazard, vulnerability

1. INTRODUCTION

Bangladesh often suffers from many climate induced disasters such as flood, drought, cyclone etc and among those natural hazards, cyclone occurs in Bangladesh almost every year. About one-tenth of the global total of tropical cyclones occurs in the Bay of Bengal and about one-sixth of tropical cyclones born in the Bay of Bengal had landfall on the Bangladesh coast (BUET-BIDS, 1993). The coastal morphology of Bangladesh influences the impact of natural hazards in these areas. In Bangladesh, even cyclones with low intensity can be very deadly at landfall because of the shallow bathymetry of the Bay of Bengal, funnelling shape of the coastline with low-lying flat terrain, and very high population density (Ali, 1979).

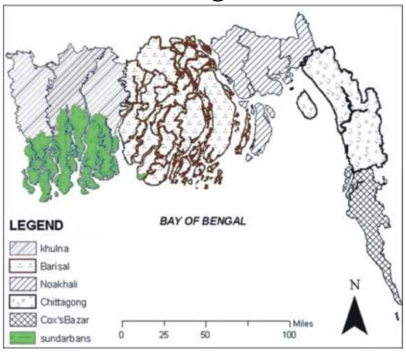
For this, the study aims to understand the land falling tropical cyclones of Bangladesh and the associated risk and vulnerability in coastal areas with the following objectives:

- To determine the probability of cyclone occurrence in different regions of Bangladesh coast.
- To compute the maximum wind speed for cyclone with of particular return period.
- To simulate maximum wind speed in different regions of Bangladesh coast.

This study would helps to understand the characteristics of potential cyclones that may make land fall in the coastal areas and thereby assessing hazards in these regions.

2. STUDY AREA

The coast of Bangladesh has been selected as the study site. For assigning land falling locations in this study, the coast of Bangladesh is divided into five zones. These are: Khulna, Barisal, Noakhali, Chittagong and Cox's Bazar. For the study 295 km has been considered as depth and 384 km in length.



Map 2.1: Coast of Bangladesh with subdivisions

3. ORGANIZATION OF DATA

Tropical cyclones in the Global Tropical Cyclone Climate Atlas (GTCCA) database are classified by the following criteria (Table 3.1).

Table 3.1: GTCCA Classification

Type	Category	Wind Speed (knots)
Tropical Depression	TD	<34
Tropical Storm	TS	34-63
Hurricane	H	>=64

In this study, the GTCCA classification is used to develop the historical storm dataset and climatology for Bangladesh. Occurred hurricanes are also categorized according to the Saffir-Simpson hurricane Scale which is described below.

Table 3.2: Saffir-Simpson Hurricane Scale

Category	Wind speed (Knot)
1	64-83
2	84-96
3	97-113
4	1144-135
5	>135

4. METHODOLOGY OF THE STUDY

There are three objectives in this study and for each objective separate methodology has been followed for the successful completion of task.

4.1 Data collection

This study is based on secondary data. For the wind field model, primary data are collected for maximum wind speed, track speed, and radius of maximum wind. The data are collected from different sources such as Bangladesh Meteorological Department (BMD), doctoral thesis of Maniruzzaman (1997), statistical year book (2000), doctoral thesis of Islam (2006). Angle of landfall of the cyclones has been evaluated from the cyclone tracks using the Arc GIS and Corel Draw software.

4.2 Data Analysis Procedure

For the systematic analysis of the collected data (collected from secondary sources), all the data are compiled to sought out and analyzed through the help of different software such as MS Excel, SPSS and GIS etc. The data analysis procedure is stated below-

- Determining probability of occurrence

- Probable wind speed for particular return period
- Grid preparation
- Developing the model
- Operational procedure of the model
- Simulation of cyclone parameters
- Result analysis

4.2.1 Determining probability of occurrence: The number of cyclone strikes in all five zones during the period 1877-2003 (127 years) is analyzed and frequency data were obtained by counting the numbers of tracks that carried cyclone-force winds across the coast in each segment. Then for each area recurrence or return period (years) is calculated. At last the probability of a cyclone striking in each zone in every year is calculated on the basis of it.

4.2.2 Probable Wind Speed for Particular Return Period: To fulfil the second objective, the equation $V_{max} = 6.3 (Pp - Po)^{1/2}$, Where V_{max} is the maximum wind speed and Pp and Po are the atmospheric pressures at the storm periphery and centre respectively (Simpson & Riehl, 1981) has been used to estimate central pressure from the maximum wind speed.

4.2.3 Grid Preparation: A digital map of coastal areas was overlaid with a grid of approximately 5 Km in size. As wind speed over the sea is not needed for the analysis and damage by the cyclones occur due to the wind speed above the land.

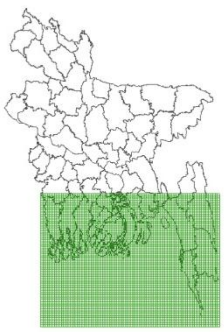


Figure 4.1: The wind speed grid laid over the coastal region map

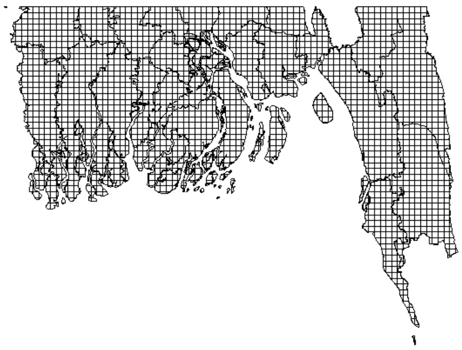
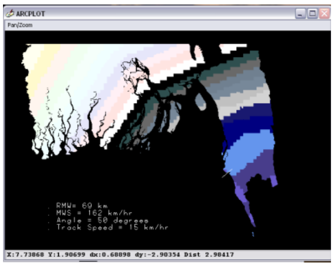


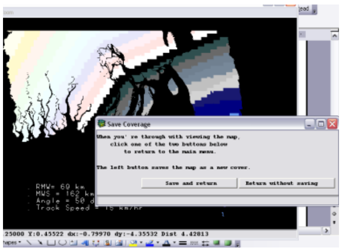
Figure 4.2: Coastal regions divided into cells

4.2.4 Developing the Model: In this study Gradient Wind Model has been used to determine the maximum wind speed for the simulated storm. The Arc Macro Language (AML) was used to implement the wind model in each cell to calculate the maximum wind speed in workstation version of the ARC INFO GIS software.

4.2.5 Operational procedure of the model: In order to run the module first main menu is called by using the Arc option of ARC INFO GIS software. All the inputs of the parameters are then entered. Then "Enter landfall point" button is clicked which shows the screens of the grids of coastal segment and gives a curser button to enter landfall point. After identifying the landfall point a track is drawn on the point from the given angle of cyclone track. Then the model is returned to the main menu. Then "Wind speed" button is clicked which commands the module to calculate maximum wind speed in each cell. After that output result (Photograph 4.5) is saved and the model is operates for another simulation (Photograph 4.6). In this way maximum wind speed are calculated for 100 simulated cyclones.



Photograph 4.5



Photograph 4.6

4.2.6 Simulation of Cyclone Parameters: To compute the maximum wind speed in each cell, 100 cyclones are simulated. Gradient wind field model required the data of pressure drop, radius of maximum winds, the track speed, the angle of track (measured clockwise in degrees from the north) and the maximum wind speed.

4.2.7 Result analysis: All the inputs required for the simulation procedure are given in the "arc" command of the Arc Info Workstation software and an output is obtained for each simulated cyclone which is stored in the computer. Then the estimated maximum wind speeds are analyzed in the Arc Map tool of Arc GIS software.

5. PROBABILISTIC ANALYSIS

5.1 FREQUENCY OF OCCURRENCE

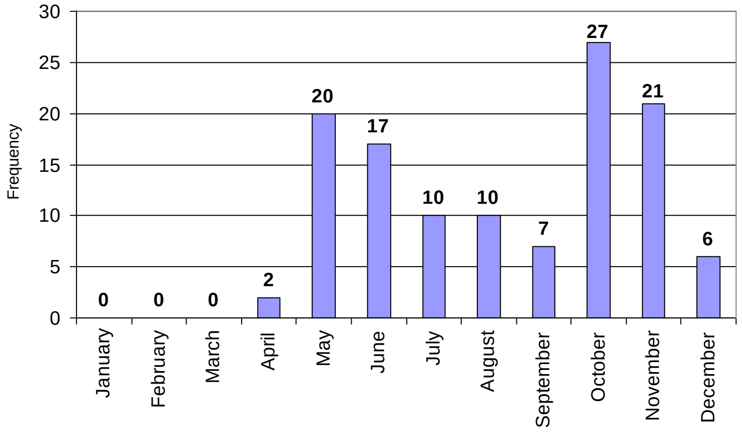


Figure 5.1: Monthly distribution of land falling cyclones from 1877 to 2007

5.2 NUMBER OF LAND FALLING STORMS

Table 5.1: Number of land falling storms in different coastal segments during the period from 1877 to 2003

Coastal Subdivision	**Tropical Depression (TD)**	**Tropical Storm (TS)**	**Hurricane (H)**
Barisal	15	9	7
Noakhali	4	4	1
Chittagong	2	12	7
Cox's Bazar	2	12	6
Khulna	16	15	5
Bangladesh coast (Total)	**39**	**52**	**26**

5.3 RETURN PERIOD

Table 5.3: Return periods of cyclones in different coastal segments

Coastal Subdivision	**Return period (in years)**	
	Wind speed < 33 mps	**Wind speed >= 34 mps**
Barisal	5.3	18.1
Noakhali	15.9	127.0
Chittagong	9.1	18.1
Cox's Bazar	9.1	21.2
Khulna	4.1	25.4
Bangladesh coast	1.4	4.9

5.4 PROBABILITY OF CYCLONE OCCURRENCE

Khulna is the most (28%) cyclone prone area and Noakhali is the least (7%) cyclone prone area and there is also 92% probability that cyclone will make landfall in this country in every year.

Table 5.4: Probabilities for a cyclone landfall in any one year for each of the coastal segment

Coastal Subdivision	Wind speed < 33 mps	Wind speed >= 34 mps	Total probability
Barisal	19	6	25
Noakhali	6	1	7
Chittagong	11	6	17
Cox's Bazar	11	5	16
Khulna	24	4	28
Bangladesh coast (Total)	72	20	92

5.5 PROBABLE WIND SPEED FOR PARTICULAR RETURN PERIOD

The probable extreme wind speed for cyclone with of particular return period which is the second objective of the study is the basis for developing and adopting cyclone-resistant building standards (Simpson & Riehl, 1981).

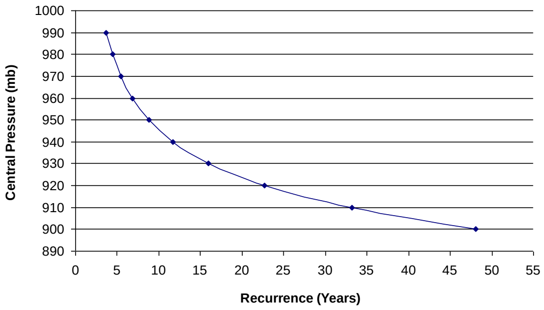


Figure 5.5: Recurrence interval (years) for cyclones when strength is measured by pressure

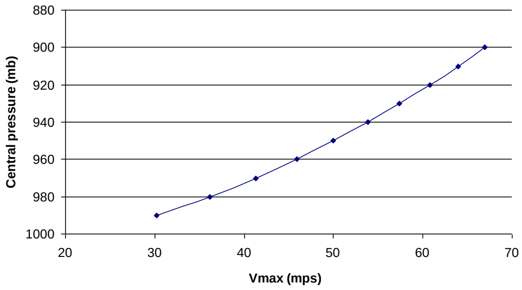


Figure 5.6: Maximum sustained wind speed *of the cyclones as a function of central pressure*

From the figure the central pressures for cyclones that will recur in different period such as 5, 10, 20, 30, 40 years etc are obtained. Then the corresponding maximum winds are obtained for the above mentioned return periods from the next figure.

Table 5.5: Maximum wind speed in respect to Recurrence year

Recurrence year or return period	Pressure	Max wind speed (mps)	Max wind speed (mph)
5	973	40	89
10	949	50	112
20	926	59	131
30	912	63	141
40	903	66	147

6. CYCLONE WIND ANALYSIS

6.1 SIMULATION OF WIND FIELD PARAMETERS

In order to achieve the third objective of the study, values of all the parameters have to be simulated. Data of cyclone track have been analyzed according to the coastal subdivisions and from this number of simulated cyclones in each of the five zones have been determined (Table 6.1). The different percentile range depending on their concentration pattern for all the parameters are given in Table 6.2 to 6.5.

Table 6.1: Number of simulated cyclones in each of the five zones

Coastal subdivision	Frequency in the study period	Simulated Cyclone
Barisal	31	26
Chittagong	21	18
Cox's Bazar	20	17
Khulna	36	31
Noakhali	9	8
Total	117	100

Table 6.2: Percentile value of angle of landfall (Units are in degrees)

Coastal subdivision	**Min Value**	**Percentile**					**Max Value**
		10	**25**	**50**	**75**	**90**	
Barisal	8	17.4	33	47	69	86	88
Chittagong	3	7.2	32	45	72.5	81.4	83
Cox's Bazar	3	29.1	34.75	45	75	80.6	85
Khulna	5	11.2	27.5	45	59.75	77.6	345
Noakhali	15	15	19	45	49.5	57	57

Table 6.3: Percentile value of track speed (Units are in km/hr)

Min Value		10
Percentiles	25	10
	75	15
	90	20
Max Value		20

Table 6.4: Percentile value of maximum wind speed (Units are in km / hr)

Minimum value		56
Percentiles	5	70
	25	85
	35	100
	50	150
	75	163
	80	193
	90	223
Maximum value		232

Table 6.5: Percentile value of maximum wind speed (Units are in km)

Minimum value		30
Percentiles	10	42
	30	55.2
	40	62.4
	70	65
	85	70
Maximum value		74

6.2 RESULT AND ANALYSIS

Using the distributions of historical data of storm parameters given in the above table values of all the parameters for 100 cyclones has been simulated and used in the model as input. Maximum wind speed for each of the cell for the each 100 simulated storm is then estimated with the model. The resulting maximum wind speed of the 100 simulated storms are then analyzed to determine the highest, lowest and average value of the maximum wind speed.

6.2.1 HIGHEST, LOWEST AND AVERAGE OF MAXIMUM WIND SPEED

Highest, lowest and average value among all the maximum wind speed in each cell estimated by the model for the 100 simulated cyclones are given below in figure 6.1,6.2 and 6.3 respectively.

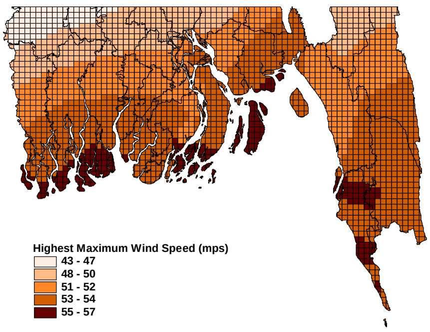


Figure 6.1:Simulated highest maximum wind speed

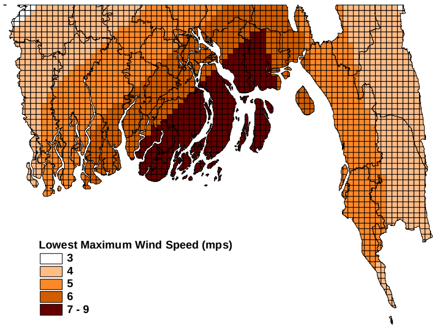


Figure 6.2: Simulated lowest wind speed

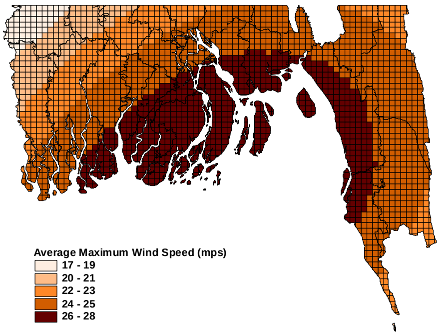


Figure 6.3: Simulated average maximum wind speed

The average maximum wind speeds of the 100 simulated cyclones at each zone are shown in the following Figure 6.4. Figure 6.5 to Figure 6.9 shows the frequency of cyclones in different average maximum wind speed categories for a total of 100 simulated storms at each of the five zones.

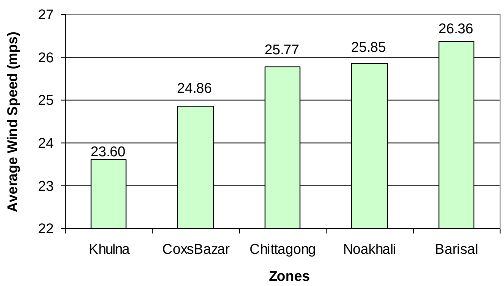


Figure 6.4: The average maximum wind speed

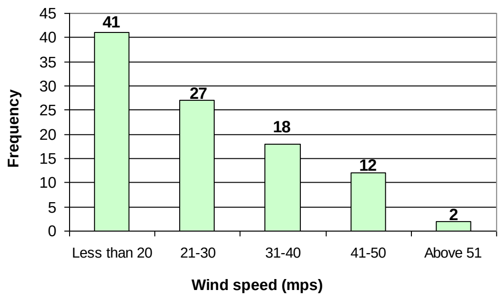


Figure 6.5: Noakhali

obtained from the simulation at each zone

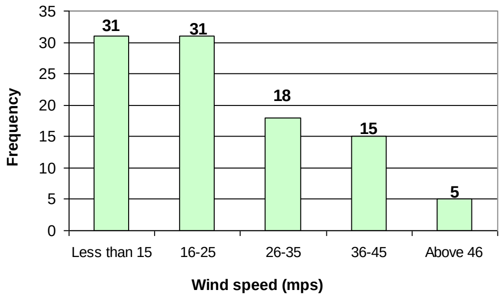


Figure 6.6: Khulna

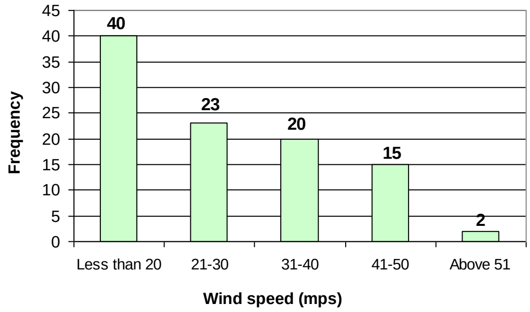


Figure 6.7: Barisal

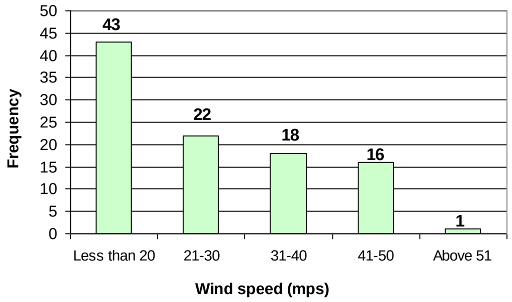


Figure 6.8: Chittagong

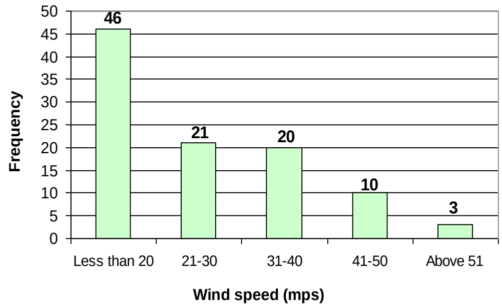


Figure 6.9: Cox's Bazar

CONCLUSION:

The trend of tropical cyclones hitting the Bangladesh coast is not steady. Among the coastal segments, Sundarban (southern part of Khulna), southern part of Bhola, Hatiya (Noakhali) and three other pocket region of Cox's Bazar district is the most vulnerable in terms of highest maximum wind speed of cyclone. The results of the analysis are directly applicable to planning, financing and developing a national programme for disaster prevention or mitigation. This will contribute to taking proper disaster planning efforts in Bangladesh especially in the mitigation phase for the reduction of damage from the cyclone hazard.

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