Disaster Risk Index (DRI) for Tropical Cyclone of Bangladesh

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Abstract

The risk and magnitude of damages to people and property due to natural disasters are very severe in Bangladesh. Cyclone is one of the major natural disasters in context of Bangladesh. Since it is a natural phenomenon, occurrence of cyclone cannot be prohibited. But the occurrence time of a cyclone can be predicted from statistics. So, reduction of losses and possible mitigation measures can be taken easily if desired. Cyclone not only affects life of people but also has huge impact on social and economic losses. Geographical location of Bangladesh is primarily responsible for cyclone disasters. Although it is a physical phenomenon it affects society, community, people, institutions, environment and the overall development of the country. Due to cyclone hazard it is difficult to meet the targets of the MDG'S. There is a very good relationship between development process and cyclone risk. The DRI developed here provides the national decision makers access the information to identify risk and propose adequate disaster risk management policies. This paper presented different perspective of cyclone risk assessment and established cyclone Disaster Risk Index (DRI) for the local level for Bangladesh. This will help to prepare and plan habitable human settlements at coastal areas.

1. Introduction

According to Norwegian Institute for Urban and Regional Research (NIBR), Asia is the most disaster-prone continent, with China, Bangladesh, India and Iran on top of the list when measured by absolute number of affected people (Sørensen et al, 2006). Impact of Natural Disasters on GDP of Bangladesh, 1990-2000 is 5.21% (DFID Report, 2005). Among 84 high cyclone prone countries around the world with highly populated coastal areas and deltas, Bangladesh, China, India, the Philippines, and Japan are at risk (UNDP, 2004). Cyclone is a characteristic feature of Bangladesh's physical environment and accepted as a normal hazard of social and economic life of Bangladesh. Historically, cyclone is mentioned as a disaster in this belt in the book Ain-e-Akbari of 16th century. During the last three decades almost all of the coastal areas and offshore islands of Bangladesh faced cyclones.

A DFID scoping study found that poverty alleviation, development and disaster risk reduction (DRR) are highly correlated (DFID report 2005). Inadequate attention to DRR can hinder progress in poverty alleviation and sustainable development. Most recently to improve understanding the relationship between development and disaster risk at the global level, UNDP has started development of a Disaster Risk Index (DRI) for individual country. In this paper, it is argued that less attention has been given to conducting in depth research on disasters, especially from risk perspective. This paper is an attempt to assess the cyclone risk in different perspective from UNDP and attempted to calculate cyclone Disaster Risk Index (DRI) for local level coastal areas for Bangladesh, rather for whole country.

2. Scope of the Study

District level DRI for tropical cyclone is developed in this project. This provides the disaster factors through a district-by-district comparison of human vulnerability and exposure to cyclone and the identification of development factors that contribute to the risk. The method used here can also be used for developing DRI for other natural disaster such as flood, earthquake, drought etc. The results obtained here can be used to propose the most suitable location for cyclone shelter.

3. Tropical Cyclone

A tropical cyclone is a storm system characterized by a low pressure centre and numerous thunderstorms that produce strong winds and flooding rain. The term "tropical" refers to both the geographic origin of these systems, which form almost exclusively in tropical regions of the globe, and their formation in Maritime Tropical air masses. The term "cyclone" refers to such storms' cyclonic nature, with counter clockwise rotation in the Northern Hemisphere and clockwise rotation in the Southern Hemisphere. Depending on their location and strength, tropical cyclones are referred to by other names, such as hurricane, typhoon, tropical storm, cyclonic storm, tropical depression and simply cyclone.

4. Trends in Tropical Cyclones

The Bay of Bengal is potentially energetic for cyclonic storms due to its favourable atmospheric and oceanic condition. Therefore, the highest incidence of TCs, almost 7% of total number of annual storms,

located here. Amongst two storms generate winds of 55 mph or greater (as cited in Bowditch, 1977). Mainly, two cyclonic seasons are in the north Indian Ocean, viz. pre-monsoon (especially May) and post-monsoon (especially October and November). A few cyclones form in transitional monsoon months June and September also. Singh et al (2001) have shown an increased TC frequency during November and May over the north Indian Ocean from 1877 to 1998.

5. Vulnerability Patterns of Tropical Cyclones

There are many dimensions of vulnerability. Among these social vulnerability refers to the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors and shocks like natural disasters to which they are exposed.

Mainly people of Bangladesh are vulnerable to disasters for three reasons. Firstly, the important type of vulnerability- poverty. It is an indicator of lack of access to resources, income opportunities and inequitable distribution of power. People of Bangladesh are poor and marginalized; it is difficult for them to access resources such as development loans or land. People here are simply unable to recover their losses due to their miserable poverty. In addition to the economic dimension, there are also other aspects of social positioning such as class, religion, community structure, community decision making processes and political issues that determine poor people's vulnerability. Therefore, poor are economically as well as vulnerable to social, cultural and political capacities to cope with disasters.

Second is vulnerable livelihood of the people. According to DFID (2005), this has three components - livelihood assets (human, social, physical, natural and financial capital), livelihood strategies and livelihood outcomes. This sort of vulnerability arises due to shortage of jobs, low income, declining natural resources, and decreasing profitability of rice farming. Frequently cyclones adversely affect the livelihoods of people by damaging their means of earning (destruction of the factory, loss of land due to erosion in flooding, destruction of the shop) and/or tools (loss of draught animals, ploughing tools, etc) in case of Bangladesh.

Third, patterns of natural resource use are changing, as urban development and commercial quarrying and environmental degradation. Localized and systemic environmental degradation is becoming highly influential as well, lowering the natural resilience to cyclones. Phenomena like El Niño/La Niña, climate change and the potential for rising sea levels, are affecting the patterns and intensity of cyclones.

6. Disaster Risk Approaches

The DRI enables the calculation of the average risk of death per country in large- and medium-scale disasters associated with earthquakes, tropical cyclones and floods, based on data from 1980 to 2000. It also enables the identification of a number of socio-economic and environmental variables that are correlated with risk to death and which may point to causal processes of disaster risk.

Since 1970s, engineers, architects, social scientists, social activists all have been highlighted on the impact of natural hazards. They find that the impacts not only depend on the physical resistance of a structure, but on the capacity of people to absorb the impact and recover from loss or damage. Now it is clear that development processes were not only generating different patterns of vulnerability, but were also changing and increasing patterns of hazard due to events such as impact of global climate change. Finally, disasters are no more viewed as extreme events created entirely by natural forces but as unresolved problems of development (Yodmani, 2000). Thus the focus of interest moved to social and economic vulnerability, with increasing evidence that natural hazards had widely varying impacts on different social groups and on different countries. According to Munich Re during the last four decades economic losses have increased more than ten times per decade. The causal factors of disaster thus shifted from the natural event towards the development processes that generated different levels of vulnerability. Disaster Risk has been presented by Ward, 1999 as follows

$$\text{Disaster risk} = \frac{\text{Hazard} * \text{Vulnerability}}{\text{Manageability}}$$

Manageability here stands for the degree to which a community can intervene and mange a hazard in order to reduce its potential impact. Manageability is synonymous to Capacity, so this can be substituted to have the following disaster risk formula:

$$\text{Disaster risk} = \frac{\text{Hazard} * \text{Vulnerability}}{\text{Capacity}}$$

7 Development of Disaster Index

Disaster Risk can be expressed in different ways for example by the number of people killed, percentage killed or percentage killed as compared to the exposed population. As per the UNDP report the first two are used for DRI for cyclone calculation, and the percentage killed as compared to the exposed population for calculating relative vulnerability. Though exposed populations to cyclone should not be compared without standardization.

UNDP Bureau for Crisis Prevention and Recovery made a global report "Reducing Disaster Risk - A Challenge For Development (2004)" that provides the Disaster Risk Index (DRI), as the first global assessment of disaster risk factors through country-by-country. "It enables the calculation of the average risk of death per country with comparison of human vulnerability and exposure to three critical natural hazards: earthquake, tropical cyclones and flooding. It also identified of development factors that contribute to disaster risk. In the DRI, this relationship is expressed through the concept of physical exposure, referring to the number of people located in areas where hazardous events occur combined with the frequency of hazard events. Physical exposure is not an indicator of vulnerability, but is a condition sine qua non for disaster risk to exist. It also enables the identification of a number of socio-economic and environmental variables that are correlated with risk to death and which may point to causal processes of disaster risk." In the DRI, countries are indexed for each hazard type according to their degree of physical exposure, their degree of relative vulnerability and their degree of risk which is calculated using following formula

$$R = PhExp * Vul \quad (1)$$

Number Where, PhExp is the physical exposure, i.e. the frequency and severity multiplied by exposed population; Vulnerability is the concept that explains why, with a given level of physical exposure, people are more or less at risk. In theory, vulnerability is modified by coping capacity and adaptive capacity.

Two methods are available for calculating physical exposure. First, by multiplying hazard frequency by the population living in each exposed area. The frequencies of hazards were calculated for different strengths of event, and physical exposure was computed as follows,

$$PhExp = \sum F_i * Pop_i \quad (2)$$

Where, PhExp is the physical exposure at national level, Fi is the annual frequency of a specific magnitude event in one spatial unit; Popi is the total population living in the spatial unit.

A second method was used when data on the annual frequency of return of a specific magnitude event was not available. In this case (Cyclone), physical exposure was computed by dividing the exposed population by the numbers of years when a particular event had taken place as shown below

$$PhExp = \sum \frac{Pop_i}{Y_n} \quad (3)$$

Where, Popi is the total population living in a particular buffer, the radius of which from the eye varies according to the strength, Yn is the length of time in years PhExp is the total physical exposure of a country (here used for second level administrative area, namely district), in other words the sum of all physical exposure in this country (here district).Frequency of cyclone is calculated based on the following formula,

$$E(x) = \lambda = -\ln(1 - P(x \leq 1) \quad (4)$$

Where, E(x) is the statistical expectation, i.e. the average number of events per year, P(x) is the probability of occurrence. Here, to obtain physical exposure, a frequency per year was derived. Then population was extracted for the selected district and multiplied by frequency in order to obtain the average yearly physical exposure (BBS, 2006). Here, equation (2) is used to ascertain physical exposure of population of a particular locality. Due to unavailability of data no. of killed in a district is taken as the arithmetic average of the total killed for simplicity for a given storm that affects the different district. Affected districts for a given storm are taken form "EM-DAT: The OFDA/CRED International Disaster Database.

8. Cyclone DRI and Bangladesh

DRI help to assess cyclone disaster risk for the individual areas of Bangladesh to find a holistic picture of the country. It calibrated according to the risk of death between 1980 and 2007. Here, data from 23 coastal districts of Bangladesh were selected for DRI calculation from 1980 to 2007. This is because of the data before this period is not reliable. 191 cyclones in the period of 28 years have been considered. Total population of these coastal areas is 43.7 million. The key steps followed in producing the DRI, according to UNDP report, were:

8.1 Calculation of Physical Exposure

The DRI calculated for the areas exposed to cyclones and the population living in these areas to arrive at a calculation of physical exposure for each district. This is the average number of people exposed to a hazard event in a given year. Physical exposure varies both according to the number of people as well as to the frequency of cyclone. In the DRI, physical exposure is expressed both in absolute terms (the number of people exposed in a country) and in relative terms (the number exposed per million people). When more people are killed with respect to the number exposed, the relative vulnerability to the hazard in question is higher. BBS (2006), population data have been used to calculate physical exposure.

8.2 Calculation of Relative Vulnerability

Vulnerability of locality depends on the physical exposure of a spatial unit and no of the death for a

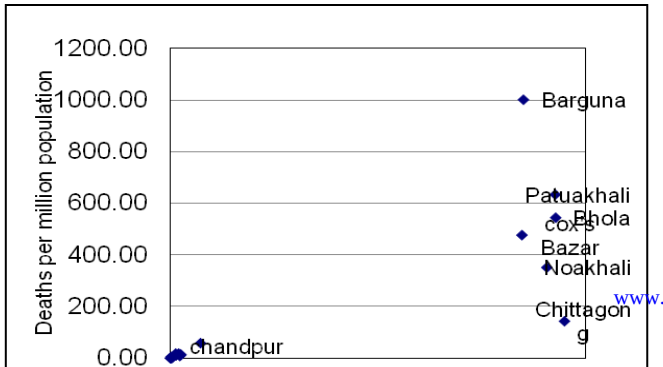
particular disaster. Here, for a set of cyclones and for a district, relative vulnerability is the total number death in million to the exposed population to those cyclones. Total number of death for each cyclone was taken from EM-DAT database.

8.3 Results and Discussion

Figure1: reveals that loss of human life from cyclone is tied to development status of a region. No developed region has recorded more than 200 deaths per million population from 1980-2007.

Table 1
Disaster Risk for tropical Cyclone, 1980-2007

District Name	Avg. No. of Storm per Year	No. of people killed per year	No. of people killed per million	Avg. physical exposure	physical exposure in% of population	Relative Vulnerability	Risk
Bagerhat	0.0649	23.5	15.19	100512.9	6.488762	234.16	23.5357
Jessore	0.0105	4.5	1.82	26016.6	1.052641	172.97	4.5000
Khulna	0.0649	22.7	9.55	154365.8	6.488762	147.15	22.7143
Satkhira	0.0593	25.5	13.66	110607.9	5.931658	230.22	25.4643
Shariatpur	0.0105	16.1	14.88	11392.74	1.052641	1413.81	16.1071
Munshigonj	0.0052	0.6	0.47	6792.52	0.524936	89.38	0.6071
Madaripur	0.0105	13.2	11.53	12066.94	1.052641	1095.08	13.2143
Gopalgomj	0.0105	13.3	11.43	12266.14	1.052641	1086.03	13.3214
Faridpur	0.0052	0.4	0.20	9220.336	0.524936	38.73	0.3571
Noakhali	0.0818	906.2	351.61	210791.3	8.178943	4298.94	906.1786
Lakshipur	0.0265	1.1	0.74	39522.24	2.652675	28.01	1.1071
Cox's Bazar	0.1106	846.3	477.11	196189.7	11.06099	4313.43	846.2500
Chittagong	0.1224	948.7	143.48	809158.7	12.23747	1172.43	948.6786
Feni	0.0265	72.5	58.42	32903.36	2.652675	2202.34	72.4643
Comilla	0.0158	1.6	0.35	72754.4	1.583147	22.09	1.6071
Bandarban	0.0052	1.5	5.15	1564.938	0.524936	981.33	1.5357
Patuakhali	0.1106	926.4	634.20	161576.8	11.06099	5733.67	926.4286
Pirojpur	0.0649	19.9	17.87	72094.56	6.488762	275.43	19.8571
Jhalakhati	0.0105	12.6	18.21	7307.762	1.052641	1730.06	12.6429
Bhola	0.0818	927.6	544.65	139297	8.178943	6659.21	927.6071
Barisal	0.0538	23.0	9.75	126695.4	5.37764	181.26	22.9643
Barguna	0.0761	849.9	1001.62	64595.07	7.61237	13157.79	849.9286
Chandpur	0.0105	0.2	0.09	23907.89	1.052641	8.96	0.2143
Total Bagladesh	3.43	7467.62	64.02	1.5E+08	343	49.77	



This observation reinforces intuitive views about the disaster development relationship. This heightens the inequality especially in rural char areas. Livelihoods there at risk due a range of factors: poverty and asset depletion, environmental degradation, market pressures, isolation and remoteness, the weakness or lack of social services and climate change. Therefore, contemporary patterns of urbanization and rural livelihoods needs to be viewed alongside other critical development pressures.

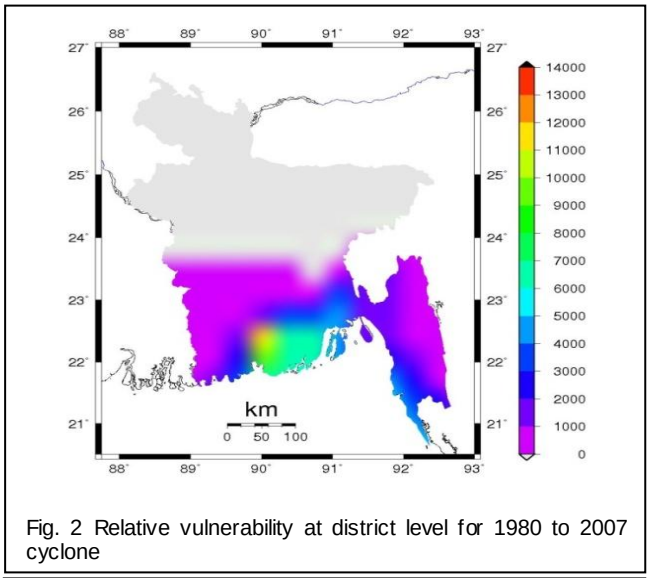


Fig. 2 Relative vulnerability at district level for 1980 to 2007 cyclone

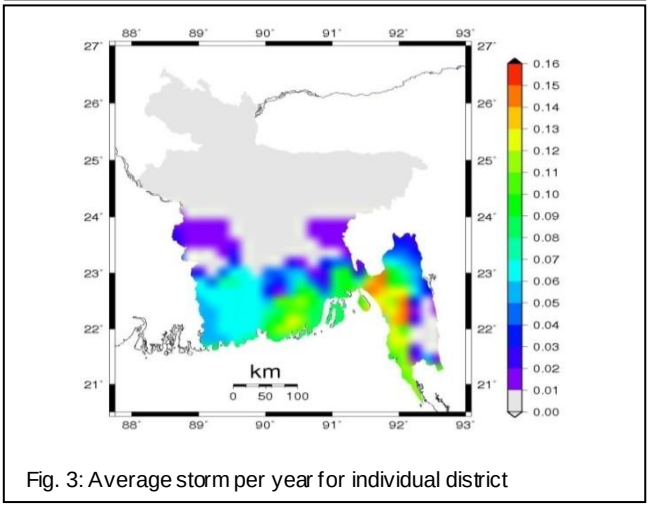


Fig. 3: Average storm per year for individual district

average cyclones per year this area is less vulnerable than other coastal region. Mainly, physical exposure in million populations is very large, and the area is more developed than other areas. The analysis carried out for tropical cyclone risk showed a strong correlation between physical exposure and human development. An area with large, predominantly rural populations and with a low development is most closely associated with cyclone risk. There are a number of reasons for this. Rural housing in many areas are tend to be more vulnerable to high winds, flooding and landslides than urban housing and are generally be associated with higher mortality. Conversely, the weakness or nonexistence of emergency and rescue services in rural areas and lack of access to disaster preparedness and early warning are all other factors that would help to explain mortality rates. The cyclone preparedness programme in Bangladesh is one of the few success stories. By coupling cyclone shelters and community-based preparedness measures, the programme has managed to dramatically reduce vulnerability from the 1970s to the (still high) levels observed in the 1980-2007 reporting period (Table 2)

9. Conclusion

One of the major findings of our study is the local level Disaster Risk Index (DRI) for cyclone. The value of DRI indicates the vulnerable areas for cyclone; where cyclone is likely to affect the local community severely. Therefore, from our study it can be concluded that DRI can be a useful tool for selecting the suitable location for Cyclone shelters in coastal areas of Bangladesh.

Table: 2
Impacts of Cyclone

Year	Scale	Deaths	Affected / Displaced	Total Damages (US$ ‘ 000s)
1970	Similar to 1991 and 1997 3,648,000	300,000	3,648,000	86,400
1991	235 kmph	138,000	15,438,849	1,780,000
1997	250 kmph	111	3,052,738	Not available
1998	150 kmph	19	108,944	Not available
2007	220 kmph	>4,000		

Source: DFID (2005)

Again, it is observed that there is a good relation between cyclone risk and development level of the coastal areas of Bangladesh. DRI demonstrate the ways to assess the significance and role of cyclone hazard in the national development. The DRI developed here, with a national level of observation and a local level of resolution that would enable the identification and explanation of relative risk and vulnerability, have enormous potential to support national development planning. But without the responsibility of the Government and participation of the local people, sound development cannot be achieved. One of the major goals of MDG’s is sustainable development. To meet the targets of MDG disaster risk due to cyclone could be reduced significantly.

10 Recommendation

There are limitations of the data source used for evaluating cyclone DRI. The data used here is based on some drastic assumption which may severely affect the result. The value of DRI would be more reliable if proper investigation is carried out to accumulate the number of people killed in an area. Future work can be taken to develop disaster risk for flood, drought and earthquake following the procedure described in this study. Work can be taken to build on individual indices for cyclone, earthquake and flood to form a multi-hazard DRI. This multi-hazard DRI can be a sharp tool for policy advocacy.

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