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A series of tornadoes killed at least 605 persons in the districts of Jamalpur and Tangail in Bangladesh on the evening of 13 May 1996. The objective of this study is to understand the reason why so many fatalities occurred from the tornadoes. Bangladesh, one of the developing countries in Asia, has very different natural and human environments from developed countries like the United States. Those differences are considered key to understanding the current research question.

Effect of natural hazards in developing countries and developed countries

Natural hazards claim an average of 25,000 lives and cause damage in excess of $3 billion per year. Interestingly, about 95% of deaths caused by natural hazards occur in developing countries (UNEP, 1992), and natural hazards rarely cause a large number of deaths in industrialized countries. For example, recent hurricanes in the United States or typhoons in Japan have not caused more than 500 deaths (Berz, 1988). Even devastating Hurricane Hugo in 1989 and Andrew in 1992 caused less than 50 deaths each in the United States. On the other hand, cyclones in Bangladesh sometimes result in a large number of human lives being lost. 500,000 persons were killed by a 1970 cyclone and 140,000 persons were killed by a 1991 cyclone (Karim, 1995). These differences illustrate the important role of social and cultural characteristics in risk of death from natural hazards.

Study of the temporal and regional occurrence of natural hazards establishes the probability of occurrence of the hazard, but risk of death is also a function of the complex social and cultural patterns of the people exposed to the hazard. By understanding the relationships between social patterns and risk, we may take actions to reduce the risk of death from natural hazards. This study contributes to that understanding with respect to tornadoes in Bangladesh.

Natural hazards in Bangladesh

Previous study indicates that Bangladesh is affected by various kinds of natural hazards, including cyclones, flooding, tornadoes, drought, river-bank erosion and occasional earthquakes (Karim, 1994). In terms of proportion of population affected by natural hazards, Bangladesh had the highest death rate, 3,910 per million persons for the 1947-1981 period (Burton, Kates, and White, 1993). Cyclone and flood hazards in Bangladesh are well-known for their large amount of damage and death.

Cyclones, with their large number of deaths, have received most of the research attention directed at natural hazards in Bangladesh. Since the cyclone of 1970, which killed

500,000 persons, the government, with support from the World Bank, the Bangladesh Red Crescent Society (BRCS), a local nongovernmental organization, built a few hundred cyclone shelters. The warning system has undergone major improvements, and the Cyclone Preparedness Programme (CPP) of BRCS transmits the danger warnings to local people through its network (Chowdhury, Bhuyia, Choudhury, and Sen, 1993).

Other hazards have been overshadowed by the catastrophic effects of cyclones and have received less attention from researchers. Tornadoes have been a focus of hazards research in the United States but have received little attention in Bangladesh, in spite of high death counts. For example, on 26 May 1989, a tornado hit the Manikganj district, killing between 800 (Karim, 1994) and 1,300 (Grazulis, 1991) persons. This particular tornado might have been the world's deadliest tornado. Even so, no detailed studies on tornado hazards in Bangladesh have appeared in the literature. Thus, the reasons for the large number of deaths are still not clear.

This study examines a recent tornado(es) that killed at least 605 persons in the Jamalpur and Tangail districts on the evening of 13 May 1996. The general objective of this study is to understand the risk factors that account for such a large number of fatalities. An understanding of these risk factors may lead to actions that will reduce risk of death in tornadoes in Bangladesh and elsewhere.

Risk factors

In global terms the most frequent kinds of natural hazards are flooding, earthquakes, tropical cyclones, and drought. Volcanic eruptions, tornadoes and landslides are less frequent. There are great geographical variations in the risk to humans from these hazards. Factors affecting the risk may be classified as physical, such as how long the event lasts, how sudden and unexpected the event is, how often such events occur, and the number of incidents that preceded it; or social, such as population density and building structures (UNEP, 1992). Mitchell, Devine, and Jagger (1989) showed that a natural hazard is strongly modified by environmental, sociocultural, economic, and political contexts in which it occurs. Thus, the extent of damage caused by the natural hazard depends on human activities.

Chowdhury, Bhuyia, Choudhury, and Sen (1993) studied the Bangladesh cyclone of 1991 and concluded that at least 20 percent more deaths would have occurred in the absence of cyclone shelters. The reasons why so many people died were found to be poor housing, high population density, too few and inadequate shelters, problems with signals and warnings, perceptions (many people believe in widespread myth due to lack of knowledge), vulnerability of particular groups, availability of trees as life savers. Also, there was a significant difference in the death rates in both sex and age; namely, females, children and the elderly died disproportionately more than others.

In the case of tornado hazards in the United States, White and Haas (1975, p. 276) suggested that regional differences in the death rates could be caused by differences in tornado severity, urbanization, building construction, preparedness, hospital facilities, warning systems, and the distinctive behavioral characteristics of individuals. Sims and Baumann (1972) mentioned that cultural differences in the United States affect the tornado

death rates. Females might have higher death rate than males in some cases (Abbey and Fujita, 1981). According to Friedsam (1962), the young and elderly have higher death rates in general hazards than the other groups. It is well known that people living in mobile homes have higher death rates.

Schmidlin (1993a) completed the first large-scale summary of the personal attributes of tornado victims by studying the deaths in Ohio, USA, caused by tornadoes during 1950-1989. He found that the age groups at highest risk of tornado death were the very young (65 years), especially females. Location of the victims when tornadoes struck was analyzed, and some differences were observed. Analysis on primary cause of death from tornadoes indicates that head injury accounted for nearly half of the fatalities followed by trauma/multiple injuries (13%) and chest injury (12%). Those injuries were mostly caused by flying debris, which hit the victims during tornadic activity.

Schmidlin and King (1994) examined the risk factors for death in the 27 March 1994 Georgia and Alabama tornadoes, which killed 40 persons. They looked at cases of both deceased and surviving persons in the tornado path to determine whether there were differences in personal characteristics, behavior or location between the two groups. The results indicate that there were some differences in location, access to media, and awareness of the approaching tornado. However, there was no difference in gender, race, marital status, education, disability, or previous experience with tornadoes.

Finally, Schmidlin (1993b) proposed a conceptual model that includes multiple connections among the environmental (tornado frequency, intensity, and time of occurrence), societal (level of preparedness, quality of warning systems, experience with tornado disasters, and patterns of employment and housing), and cultural (individual response to hazards, trust in government/authority, fatalism in the threat of hazard, the daily and seasonal pace of society, and sex roles) factors in tornado mortality hazard. The model should be applicable for any society and was applied in this research.

Tornadoes in Bangladesh

Bangladesh has a long history of tornado incidents; however, detailed studies did not appear until the 1980s. Fujita (1973) showed a map of worldwide tornadoes, and it pinpointed some areas in Bangladesh. It also showed the relative intensity of the strongest tornadoes, and the tornadoes in Bangladesh were ranked as strong as F-4. According to Fujita's map, no other places were ranked as stronger than F-3 except the United States.

In fact, tornado statistics showed tremendous amounts of damage in Bangladesh in the past (Hasan, 1986). Hundreds of people were killed by individual tornadoes many times. Again, it is believed that the world's deadliest tornado occurred in Bangladesh on 29 April 1989. The tornado that occurred in Manikganj killed approximately 1,300 people, injured 12,000 people, and made 80,000 people homeless (Grazulis, 1991).

Three papers that discussed tornadoes in Bangladesh were published in 1981. According to Qayyum (1981), it had been considered that tornadoes in the Indian Subcontinent did not commonly occur before the incidents of the Demra Tornado in 1969, which killed 922 people, and the Manikganj Tornado in 1974, which killed 100 people. Qayyum stated that the annual occurrence of local severe storms of wind speed above 100

mph (which are considered tornadoes in Bangladesh) is approximately four times a year. Qayyum also mentioned that tornadoes are mostly accompanied by nor'westers (Kalbaishakhis in Bengali).

Another study investigated nor'westers and tornadoes using weather satellite pictures during 1975-79 (Afroze, Munim, Begum, and Choudhury, 1981). This indicated that 76% of nor'westers and tornadoes occurred during the pre-monsoon period and 38.3% of them occurred in April. The frequency of occurrences throughout the day was at a maximum during evening hours. In the synoptic chart, a discontinuity line was found along the actual locations of the clouds that spawned tornado(es).

The third study focused on tornado climatology in the Indian Subcontinent using 51 tornadic events since 1835 (Peterson and Mehta, 1981). A detailed distribution map was provided that showed several low-pressure troughs to explain that tornadoes occur near those frontal boundaries during the pre-monsoon period. However, there might exist a tendency to report only the relatively significant tornadoes that leave more damage and attract more attention. This implies that the actual number of tornadoes in Bangladesh is still not clear or accurate. Using limited data from tornadoes, Peterson and Mehta (1981) discussed some characteristics of tornadoes in Bangladesh - the first description to appear in the literature. They also highlighted the large number of deaths caused by tornadoes and anticipated that large loss of life will be reported in the future.

Some people may suspect the reason that Bangladesh has much more fatalities is simply due to its high population density (888 people per square kilometer in Bangladesh versus 27 in the USA). The theory might be partially true, but it cannot entirely explain the extreme death rates.

In Japan (327 people per square kilometer), a densely populated country like Bangladesh, nearly 20 tornadoes (Tatsumaki in Japanese) are reported every year (Shimada, 1977; Mitsuta, 1983; Ono, 1993), but the number of fatalities caused by tornadoes has been significantly smaller; only 0.5 person per year. Obviously the difference in number of tornado fatalities between Bangladesh and Japan cannot be explained only by the difference in population density. We need to understand the other social and cultural factors that may explain the disparity in risk of death from tornadoes.

In summary, there have been a large number of tornado fatalities in Bangladesh. In some tornadoes, the number of fatalities exceeded 500. Despite those large numbers of deaths, the reason why so many fatalities occur has not been studied and explained. In order to reduce loss of human life, studies on risk factors are essential. Risk factors can be categorized into three groups; environmental, societal, and cultural. Since no detailed data and information are available from past incidents, a detailed case study has been needed.

It can be hypothesized that the reason for such a large number of fatalities caused by the 13 May 1996 tornado(es) was the high environmental, societal, and cultural risk factors in Bangladesh. Environmental risk factors include frequency of tornado, time of year, time of day, local geography, characteristics of tornado, local meteorology. Societal risk factors include warning systems and preparedness programs. Cultural risk factors include population density, age and sex, structure of houses and house materials, social characteristics, and access to medical facilities.

Methodology

Field surveys and data collections were started three weeks after tornado(es) killed at least 605 persons in the Jamalpur and Tangail districts in Bangladesh, on 13 May 1996. The places I visited and contacted in Dhaka were Ministry of Disaster Relief, Disaster Management Bureau (DMB), Space and Atmospheric Research Center (SPARRSO), Disaster Preparedness and Management Cell, Bangladesh Red Crescent Society (BRCS), CARE (nongovernmental organization), Helen Keller International (nongovernmental organization), UNICEF-Dhaka Division, and the Bangladesh Observer (newspaper). The places I visited and contacted in the district of Tangail were Tangail district office, Tangail general hospital, Thana nirbari offices in six thanas (Gopalpur, Ghatail, Kalihati, Basail, Sakhipur, and Mirzapur), and field surveys in two villages in the Basail thana and one in the Sakhipur thana. In the district of Jamalpur, I only visited the district office.

Data associated with environmental risk factors

Tornado data do not exist in the Bangladesh Meteorological Department, except for several big events that caused a great deal of damage. Therefore, newspaper accounts (a local major English newspaper, Bangladesh Observer) were used to see tornado frequency from 1990-94 by carefully screening all the pages. Ideally, a long period of data should be acquired, but time and budget limited the present scope. Although the period is limited to the past five years, this represents a first attempt and probably the best way to gather data in Bangladesh.

Data associated with other environmental risk factors, such as time of year, time of day, local geography, characteristics of the tornado, and local meteorology were acquired from the field surveys and Bangladesh Meteorological Department.

Data associated with societal risk factors

Again, societal risk factors include warning systems and preparedness programs. I visited the Bangladesh Meteorological Department to acquire information on these.

Data associated with cultural risk factors

A report of "Basic Information of Tangail Tornado Affected Areas" surveyed and compiled by UNICEF-Dhaka Division and a report of "Preliminary Results of the Tangail Tornado Assessment" by Helen Keller International (NGO) provide good information on cultural risk factors, such as age and sex, structure of houses and materials, social characteristics.

Field survey

Field survey was made during the period 20-25 June 1996. I visited the tornado-affected areas accompanied by a translator. We visited three villages, Mirikpur and Burnikishoi, Basail thana and Chakadha, and Shakhipur thana. Mirikpur was the worst hit village with 210 fatalities. There were 15 deaths in Burnikishoi and 32 in Chokdah. A small number of very detailed questionnaires were given (more than 45 minutes to each person) in Mirikpur (N=6), Burnikishoi (N=1), and Chokdah (N=2). This information is useful for

understanding what exactly happened and how people reacted in the affected area when the tornado(es) hit.

In Mirikpur I drew a sketch of the direction trees fell during the strong wind to see if the phenomenon was tornadic or not. At the Tangail general hospital, the only hospital in the area, I administered additional questionnaires (N=7) to persons injured by the tornado. Also, I acquired nearly 300 patient records, including information such as age, sex, address, type of injury, arrival time to the hospital, and results of treatment. Other patient records were provided by BRCS, who sent two medical teams to the affected areas.

Results

Environmental risk factors

The storm was tornadic; several people witnessed it and described a tornado to me. The path showed zig-zag and skipping courses that are very common for a tornado path. The affected areas were limited to narrow damage paths with very sharp boundaries. My field survey in the village of Mirikpur showed that the storm was tornadic, judging from the direction trees fell (trees fell down towards the center of the slender devastated area, through which the center of the tornado was assumed to have passed). The fact that many people were blown away at a considerable distance (one person was blown over 1.5 km) also indicates that the storm was tornadic.

It is likely that a series of tornadoes occurred one after another. Probably, the first one occurred in the district of Jamalpur. Although there were three thanas affected by tornadoes there, it is not sure if the damage was caused by the same tornado family. The affected area in Dewanganj seemed to be damaged by another thunderstorm cell, because it is a little isolated from the others. I cannot conclude if the tornado that hit Madarganj proceeded continuously and hit Sarishabari later. Even if they were damaged by separate events, the events were likely to be caused by the same thunderstorm system because the sites are on the line of the storm.

In the district of Tangail, there are better data that allow me to define a more accurate track of tornadoes. The severe thunderstorm that produced a tornado in Madarganj around 4:00 p.m. entered Gopalpur, the northwestern part of the district of Tangail, around 4:30 p.m. It changed its direction in Ghatail thana from SSE to SE. The ending point of the tornado was Mirzapur at 6:00 p.m. There were four tornadoes produced by the cell, and the total path length in the district of Tangail was nearly 25 km. The maximum path width exceeded 1.5 km. The moving speed was estimated around 40-45 km/h. The Meteorological Department in Dhaka estimated the maximum wind speed of 320-450 km/h based on the fact that a pump machine (600 kg) was thrown a distance of 56 meters. This indicates a tornado on the F-scale of F3-F5. My field survey in Mirikpur ranked the tornado as F-4, based on the facts that healthy trees of 2-meter diameter and more than 20 meter height were uprooted, a concrete school building collapsed, and many trees were debarked.

According to a report of the Meteorological Department, the weather condition of the day was, "In the morning of 13 May 1996, NE and NW section of the sky were cloudy. Light southerly wind was blowing. After 12:00 p.m. wind suddenly became calm. Some people felt an unbearable heat half an hour before tornado hit". I checked the radar picture of

the day of 13 May 1996 at the Meteorological Department. There were no echoes in the tornado affected areas in the morning, but suddenly two strong echoes appeared over the northern affected area and over northeastern Bangladesh with almost same latitude around 3:00 p.m. Both of the storms strengthened and moved southward. There was no front in the synoptic weather charts in the area, so it can be said that those thunderstorms were convectional. However, atmospheric conditions must have been very unstable since softball-size hail was observed immediately before the tornadoes hit the affected area. This implies the existence of very cold air in the upper level, probably coming from Tibet over the Himalaya Range. The light southerly wind could carry moist air from the Bay of Bengal. The temperature is highest in the pre-monsoon season in Bangladesh, and the maximum temperatures were over 35o C in the inland. Very dry (dew point 40o C) air existed in India. These are favorable conditions for developing super-cell thunderstorms, which can spawn strong tornadoes. However, I could not determine if a meso-cyclone existed or not.

Tornado frequency is unknown for Bangladesh. This research on tornado occurrence per 10,000 square miles revealed that central Bangladesh has very high values - as much as the Great Plains states in the United States. During the period of 1990-1994, 44 tornadoes were reported (8.8/year), and 25 of them (57%) occurred in April and May.

Societal risk factors

There are no warning systems and preparedness programs for tornadoes in Bangladesh. Therefore, there are no shelters, and people do not know how they should react when facing a coming tornado. Warning and preparedness have been shown to be important in reducing tornado deaths in the United States, so their absence in Bangladesh must be considered a high societal risk factor.

Cultural risk factors

The household survey by the Helen Keller International revealed that 4% of the households affected by the tornadoes had suffered fatal casualties. In the district of Tangail, 585 persons died, of which 54 were outsiders, day laborers from outside of the area. Of total deaths, 74.5%, 19.7%, and 5.8% were from adults, 5-15 years age group, and under 5 children respectively (surveyed by UNICEF). Tornado fatalities information acquired from local governmental office (N=376) showed that more females died than males (196 vs. 179; 1 unknown).

According to medical doctors who worked in the field hospital in the affected area, 95% of patients received cut injuries and 50% of them incurred multiple cut injuries. Because most people could not go to the hospital immediately, those wounds got infected. For example, in Basail thana, the local hospital could not accept most patients, because of the small capacity and lack of equipment, so the injuries had to go to the Tangail General Hospital. There are no paved roads in the village, and most people were carried by others. Even on the paved roads, lack of transportation was a problem. Finally, there was no electricity available for several hours in the Tangail General Hospital, and no operations were done during that period. The facilities at the hospital were not great, and seriously

injured persons were sent to the capital city of Dhaka. In the end, most injured persons had to wait to see doctors until the next day. Such time loss is crucial for seriously injured people, children and the elderly.

Tin is the material that accounted for most of the death and injuries. During tornadic activity, flying tin became deadly missiles. Interestingly, the tornado-affected area was relatively wealthy, so more houses were built with tin than straw, mud, or bamboo. The statistics showed that 35.3% of houses were tin houses, and 49.9% were straw wall/tin roof houses in the area, while the average village in Bangladesh was 18.6% tin and 27.3% straw wall and tin roof.

Another reason for the large amount of damage was that people in the rural area built their houses on the elevated base of soil at the height of several meters above the fields preparing for rainy season. Those houses receive stronger winds and are easily destroyed and blown away. People who took shelter in their houses became victims, ironically.

The people in the locality are deeply religious and consider the tornado an act of God. Seven out of 15 persons surveyed thought the event was somehow related to God and received it as fate. Six of them did not know why the event happened, and only 2 said that it was a natural phenomenon. This fatalism could cause people to avoid taking an action to mitigate hazards.

Conclusion

In order to understand the reasons accounting for 605 deaths from tornadoes on 13 May 1996 in the districts of Jamalpur and Tangail in Bangladesh, environmental, societal and cultural risk factors were examined. Central Bangladesh was identified as the area with the highest frequency of tornadoes in Bangladesh. High frequency with no warning systems and preparedness programs expose people in high risk. High population density, deadly tin building materials, poor medical facilities, slow transportation, no emergency electrical service, fatalistic attitude toward nature, and a weak style of house building are considered very significant risk factors. Other factors will be analyzed with more detail and the analysis will be submitted to DISASTERS - The Journal of Disaster Studies and Management soon. This study is useful for comparisons and contrasts with tornado mortality patterns in other developed societies (Japan and USA) and contributes to the larger goal of a conceptual model of tornado mortality that can be applied to any society.

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