Chapter 10
Climate Change and Lightning Risk in Bangladesh

Fahmida Kabir and Md. Jakariya

Abstract In developing countries, lightning hazard is an underrated natural hazard despite having the potential to cause major loss and damages to human life and property and Bangladesh is not an exception. The existing national database of Bangladesh lacks information on lightning casualties. Hence, five years of database on lightning-related deaths and injuries from 2011 to 2016 was constructed through an innovative data mining process. An average of 913 casualties was identified, with an average of 182 people being affected by lightning occurrences each year in Bangladesh. The largest death toll was found among the male population (74%) compared to the females (26%), as males are more involved with labor-intensive agricultural practices in a developing country like Bangladesh. Most casualties occurred during the pre-monsoon (March–May) and monsoon (June–September) seasons with lightning incidents occurring mostly between morning (0600 LST) and afternoon (1800 LST). The most vulnerable age groups were found to be from 16 to 30 and 31 to 45 followed by <16, 46–60 and >60. Outdoor activities accounted for the highest number of lightening causalities; activities mostly involved agricultural practices followed by open area activities. Indoor dwellings also had significant amount of casualty especially in the veranda/balcony and while sleeping. The spatial distributions of lightning casualties were determined by GIS mapping; districts with no, low, moderate and high casualties were determined. Northwestern (Chapainawabganj) and northeastern districts (Kishoreganj and Moulavibazar) of Bangladesh accounted for the highest number of casualties. This study will therefore provide useful information in developing lightning safety measures in Bangladesh.

Keywords Lightning · Lightning casualties · Spatial distribution

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Md. Jakariya and Md. N. Islam (eds.), *Climate Change in Bangladesh*, Springer Climate, https://doi.org/10.1007/978-3-030-75825-7_10

Introduction

Lightning is one of the most powerful atmospheric phenomena that have fascinated mankind throughout the history. It has the potential to cause serious life-threatening injuries (Raga et al. 2014) and economic damages (Illiyas et al. 2014) in the society; therefore, it is important for people and administration to recognize lightning as a serious threat to the well-being of the human life and property. Globally, estimated 24,000 fatalities and 240,000 injuries occur due to lightning (Raga et al. 2014; Holle 2017). In Bangladesh, there has not been any natural disaster that goes unnoticed. However, major calamities can make some natural hazard go unnoticed (Sabur 2012), hence making us vulnerable to natural hazard such as lightning. According to Raga et al. (2014), minor- or moderate-scale disasters are not recognized as disaster due to their slow impact but this can build up overtime and turn out to have significant impact. The challenge with lightning is that it originates within the clouds, thus making it impossible for human to prevent it (Allaby 2003).

Lightning causes social and economic damages in the society with increased loss due to misleading information and lack of consciousness regarding lightning safety measures (Kithil 1995). Besides death, the most common injuries due to lightning strike involve an individual to suffer from burns, hearing problems, headaches, etc. (Gomes et al. 2006). Economic damage is another aspect of lightning. According to Uman (2008), in the USA 30% of its electric collapses because of lightning and it further costs billions of dollars of claims from the insurance companies due to property damage. In India, damages from the agricultural, housing and industrial sectors cost billions of rupees (Illiyas et al. 2014). The economic loss that occurs due to lightning has not been measured in Bangladesh, but as the country is developing it should soon start counting the economic loss (Gomes and Kithil n.d.).

Several factors contribute when it comes to an individual's exposure to lighting depending on their living conditions (houses that are not properly grounded and lack safety measures), working environment, occupational activities, awareness level, specific time of the year, knowledge of safety, etc. Literacy rate has been considered as a factor that can influence the amount of lightning accidents in a country. Countries with low literacy rate (e.g., India 66%, Pakistan 54% and Bangladesh 54%) had shown the trend of lack of compliance for the lightning protection regulations (Gomes and Kadir 2011). Low literacy rate contributes to lack of consciousness to follow the lighting safety directions, lack of willingness to follow the rules even if known and misinterpretation of lightning event. In Sri Lanka despite 80% of literacy rate in most of the districts, the deaths and injuries due to lightning are caused because of the reluctant nature of the people; the issue has not been as much as serious for them to consider it and take safety measures (Gomes et al. 2006).

Most common circumstances of lightning fatalities are recorded indoors as houses those were accounted for deaths and injuries due to lightning were not lightning-protected structures (Cardoso et al. 2014). According to Dlamini (2009) and Navarrete-Aldana et al. (2014), inappropriate construction, poorly earthed structures and lack of safe shelters and houses are responsible for casualties indoors. Lack of conscientiousness of professionals to follow the building code and to install safety measures is also another reason that causes indoor lightning incidents (Gomes and Kithil n.d.). Casualty from lighting greatly depends on the kind of activity an individual is involved with; countries whose socioeconomic activities greatly depend on the outdoor agricultural fields increase its people exposure to lightning hazard (especially during the early rainy season which requires a lot of activity in the growing lands) (Raga et al. 2014), because of which the population itself is being exposed to natural threat. In Brazil, most of the lighting casualties are related to agricultural activities comparing to that of the USA where most of the casualties are related to leisure or sports purposes such as golfing, fishing and camping. Activities differ by region to region in a given country, and one region may not have the same kind of lighting-related fatalities comparing to the other; e.g., in Brazil, fatalities related to telephone usage are more in the central region of the country than the northern region that has reported greater number of deaths related to playing football (Cardoso et al. 2014).

It is inevitable to assume lightning-caused casualties are highest among the populous regions; i.e., areas with high density of population will have the highest amount of people likely to be stricken by lightning, which has been true for many cases such as Turkey, Colombia and San Paulo (Brazil). As per Tilev-Tanriover et al. (2015), the number of lightning incidents was high for regions with highest density of population (Western Turkey) and lowest for the lowest population density (Central Turkey). In Colombia even though death ratio is larger for rural areas dispersedly located, it is said that the largest amount of death in Colombia due to lightning occurs in the urban regions as the population is concentrated toward those regions (Navarrete-Aldana et al. 2014); Sao Paulo of Brazil accounted for the highest number of deaths by lightning which the author directly linked to the largest amount of population of the state (Cardoso et al. 2014); but according to Raga et al. (2014), the author clearly suggests increased fatalities are not related to population density of an area, it is rather related to the exposure of an individual to thunderstorms, lack of education and working condition that makes an individual vulnerable to be stricken by lightning.

Lighting activity increases depending on different times of the year, and it is different for countries falling under different time zones; but in most of the cases lighting incidents occurred during summer. In the USA, lightening incidents reaches to its peak during summer having maximum during the month of July and decline just after the end of same month (Curran et al. 2000); **% of the fatalities in Swaziland occur during the summer season starting from October through February with a peak in November. However, there was no fatalities were recorded in Swaziland during the period of 2000–2009 (Dlamini 2009). In Mexico, causality incidents occur mostly in the first half of the rainy season (July and August) (Raga et al. 2014). Lightning incidents peak during the late spring (April–September) for Turkey having the highest incidents occurring during the months May and June (Tilev-Tanriover et al. 2015). In India, monsoon season

(June–September) accounts for 57% of fatalities with the incidents going down during winter (December–February) (Singh and Singh 2015).

In developed nations, lightning-related casualties have gone down due to the shifting of the population from rural to urban areas which does not require them to work on the labor-intensive agricultural activities (Holle 2016b). Developed nations are also economically advanced which allows them to be able to construct buildings/structures equipped with lightning safety systems, well-grounded houses and transports that are metal topped and fully enclosed (Dewan et al. 2017). Moreover, developed countries have been involved in numerous studies (e.g., the USA) and are quantifying lightning casualties that is enabling them to come up with better explanation on specific case studies, and providing better medical care to the injured and allowing them to put forward improved information on the phenomenon (Walsh et al. 2000).

In developing countries, lightning hazard is an underrated natural hazard despite having the potential to cause major loss and damages to human life and property (Dlamini 2009). As per Holle (2016a), a large number of people from the developing nations are involved with labor-intensive agricultural practices; they also reside in houses that are not well grounded or equipped with lightning safety devices that cause greater number of casualties in these nations (Dewan et al. 2017).

Review of the existing literature suggests that Asian developing countries have not received enough attention in addressing lightning-related phenomenon (Table 10.1). There has not been much studies in Bangladesh regarding lightning-related casualties except for few newspaper articles, and therefore, there is a lack of researches concerning lighting risk in Bangladesh, yet to be explored by its scientific community.

This research is an in-depth study of lighting in Bangladesh. The objective of the study is to find out variety of feature related to lightning-related deaths and injuries in Bangladesh bringing early and unwanted deaths to individuals considering factors such as gender, age groups, months, seasons, time, professions, activities and regions during the occurrence of the casualties.

Approach of the Study

The study is based on secondary qualitative information collected from reports published by the two most widely read online newspapers. Since the research topic was one of its kind and not many researches had been done, so very limited source of national reports was available. The only means to collect information was media-based literature from which data could be analyzed. The ultimate aim was to present the trend of increased casualties due to lightning and its physical attributes in Bangladesh in the last five years (2011–2016).

Secondary data source is an integral part of this study. Information was also collected from other published secondary sources for this study. Researcher who also conducted similar studies mostly depended on newspaper archives, online

Table 10.1 List of estimated lightning deaths and injuries identified and published by some of the authors carrying out similar study around the world

Location	Time frame	Casualties (deaths and injuries)	References
Australia	1824–1992	650 deaths identified	Coates et al. (1993)
Brazil	2000–2009	1321 deaths identified	Cardoso et al. (2014)
Canada		999 deaths (1921–2003) 47 fire-ignited deaths by lightning (1986–2001) Injuries (1986–2005)	Mills et al. (2008)
Colombia	2000–2009	757 deaths identified	Navarrete-Aldana et al. (2014)
India	2001–2014	31281 deaths identified	Selvi and Rajapandian (2016)
India	1979–2011	5259 deaths identified	Singh and Singh (2015)
Malawi (Nkhata Bay District)	2007–2010	11 deaths 44 injuries identified	Salerno et al. (2012)
Mexico	1979–2011	7300 deaths identified	Raga et al. (2014)
Singapore	1956–1979	80 deaths identified	Chao et al. (1981)
Swaziland	2000–2007	123 deaths identified	Dlamini (2009)
Turkey	1930–2014	895 deaths 149 serious injuries 535 injuries identified	Tilev-Tanriover et al. (2015)
UK	1993–1999	22 deaths 341 injuries	Elsom (2001)
USA	1959–1994	3239 deaths 9818 injuries	Curran et al. (2000)

newspaper data and death certificates from the government health database. Many on the other hand relied on the database available by the Ministry of Health (Cardoso et al. 2014; Chao et al. 1981) and Ministry of Home Affairs by accessing the information technology division (Selvi and Rajapandian 2016), weather databases and meteorological services (Tilev-Tanriover et al. 2015; Singh and Singh 2015; Chao et al. 1981). Information has also been accessed from organization such as Tornado and Storm Research Organisation (TORRO) by UK (Elsom 2001) and Storm Data by the USA (Curran et al. 2000).

Five years of study period was fixed from the year 2011 to 2016 from source_A and source_B. These two news sources were selected because of more data availability of the last five consecutive years compared to other online newspapers. Five years of study period was fixed due to limited research study period.

In-depth search of newspaper reports was studied, surveyed and noted in Excel sheets separately for source_A and source_B. This included the listing of number of months, deaths, injuries, gender casualties, age group, activity involved, weather events, duration, months, years, locations and analysis of regions having the most number of casualties related to lightning.

The data in Excel sheets were quantified through tally, and their values were determined. Those values were then used to make graphical charts, and the required results were found and attached. For mapping, Arc Geographical Information Software (GIS) was used to export region-wise casualty map for Bangladesh.

Results and Discussion

Lightning Casualties

Figure 10.1a, b shows five years of casualties (deaths and injuries) reported in source_A and source_B. From the figures, we can see that the casualties in the year 2011 were higher compared to the following years and then an increased casualty rate for the year 2016. The number of lightning deaths and injuries varies from year to year as seen in the figures. These numbers are estimated values since not all the casualties are reported due to limited geographical coverage; through Fig. 10.1a, b, it can be seen that deaths from lightning per year are above 25 to as much as 170 reported in a year for the last five years (2011–2016).

Gender Casualties

Figure 10.2a, b shows a visible difference in the gender variation in lightning casualties. It can be seen that comparatively more males are killed or affected by lightning than the females. Both the newspaper data analyses during the study period have found that the males accounted for 74% of lightning-related casualties (deaths and injuries) compared to females (that accounted for 26% of the casualties related to lightning) in Bangladesh.

A review on casualty due to lightning across the globe has been summarized in Table 10.2. Studies show that among the fatalities and injuries relating to lightning, the casualty percentages of males are greater than that of females. Most of the outdoor works are done by males for which males are more likely to be struck by

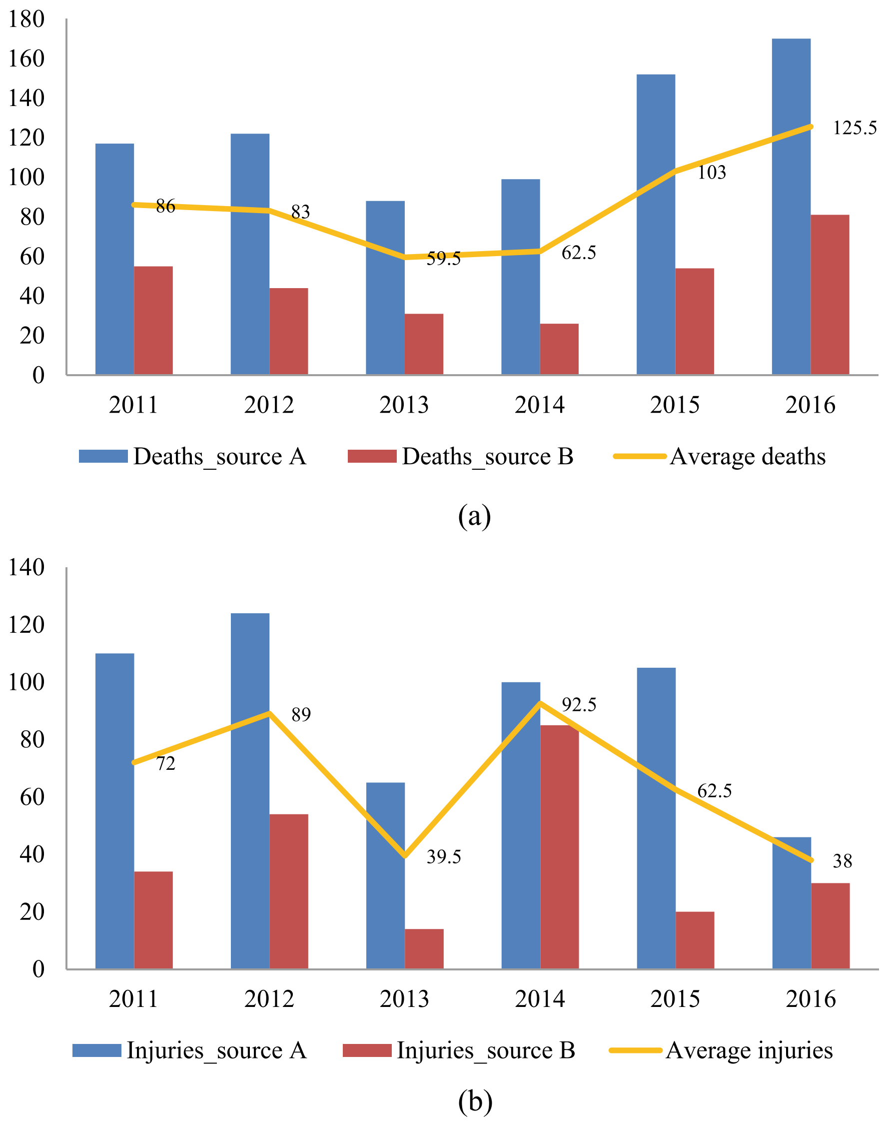


Fig. 10.1 **a** Deaths and **b** injuries reported from 2011 to 2016 through media analysis

lightning (Dlamini 2009; Tilev-Tanriover et al. 2015). Whereas in Turkey, probability of the females members to be striken by lightining is higher compare to other countries; as Turkey has 37% of females that contribute to the agricultural activities whereas for USA (2010) the percentage is 1%, Canada (2008): 1%, UK (2012) 1% and Mexico (2012): 4% (Tilev-Tanriover et al. 2015).

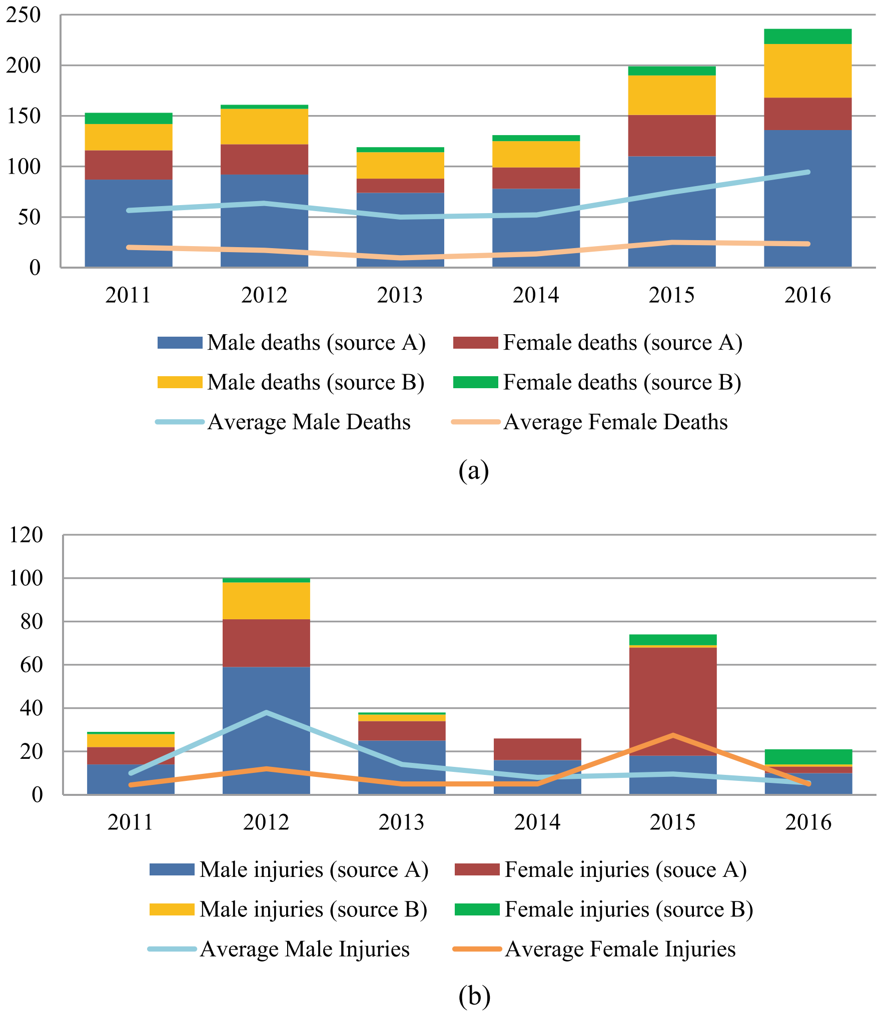


Fig. 10.2 **a** and **b** Gender casualties

Vulnerable Age Groups Involved in Lightning Incidents

People of different age groups that have been affected by lightning are represented in Fig. 10.3. Newspaper reports often lack on mentioning the age of people; hence, age groups have been set into five different categories with a difference of fifteen years of gap in between, starting with <16, 16–30, 31–45, 46–60 and >60. It is visible from the figures that the age group that is mostly affected by lightning is from 16 to 30 and 31 to 45 followed by <16, and 46–60 and the least affected are of >60 of age.

Table 10.2 Casualty percentage for male and female identified by different authors around the world

Location	Male (casualty %)	Female (casualty %)	Time frame	Authors
India	89	–	1979–2011	Singh and Singh (2015)
Colombia	80.3	19.7	2000–2009	Navarrete-Aldana et al. (2014)
Canada	84	16	1921–2003 (excluding the years from 1950 to 1964)	Mills et al. (2008)
UK	65	35	1993–1999	Elsom (2001)
Brazil	81	19	2000–2009	Cardoso et al. (2014)
Swaziland	68.3	–	2000–2007	Dlamini (2009)
USA	83	–	1950–1994	Curran et al. (2000)
Turkey	67	33	1930–2014	Tilev-Tanriover et al. (2015)

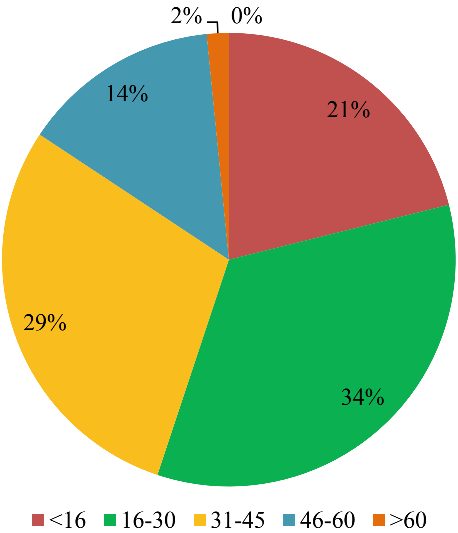


Fig. 10.3 Affected age groups due to lightning

Diurnal, Local Standard Time and Monthly Variation of Lightning Incidents

Most of the lightning incidents reported occurred during the morning and afternoon period followed by noon, evening and night and few percentage of incidents occurring during midnight and early hours of the day as shown in Fig. 10.4.

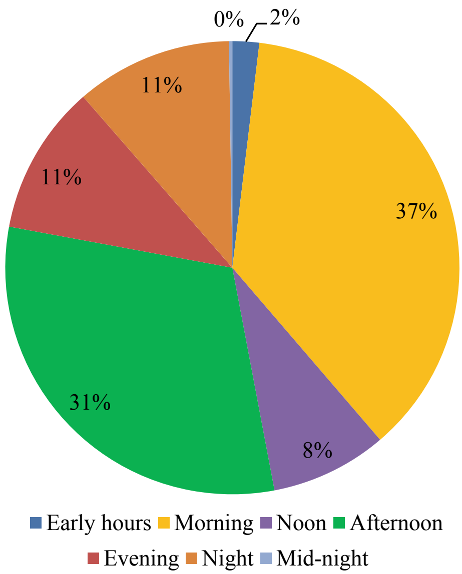
The local standard time for Bangladesh is +6GMT. The time has been recorded to show which hour has the most amounts of lightning incidents occurring. It can be seen from Fig. 10.5 that lightning-related casualties occurred mostly during early morning (6:00 a.m., 7:00 a.m., 8:00 a.m.) and late morning (10:00 a.m.) reporting peaked during the noon (12:00 p.m.) followed by afternoon and late hours of the day.

Monthly distributions of lightning incidents have been analyzed from the data sources. Incidents occurred mostly during pre-monsoon season (March–May) and monsoon (June–September) as shown in Fig. 10.6, reporting peaked during the month of April, May and June for each given year.

People from Different Occupations Involved in Lightning Casualties

Figure 10.7 represents a major portion of people from the farming profession who are likely to be affected by lightning followed by people from other professions, students, housewives and laborers. Fishermen on the other hand represent a very small percentage among the affected group of people.

Fig. 10.4 Diurnal distribution of lightning incidents



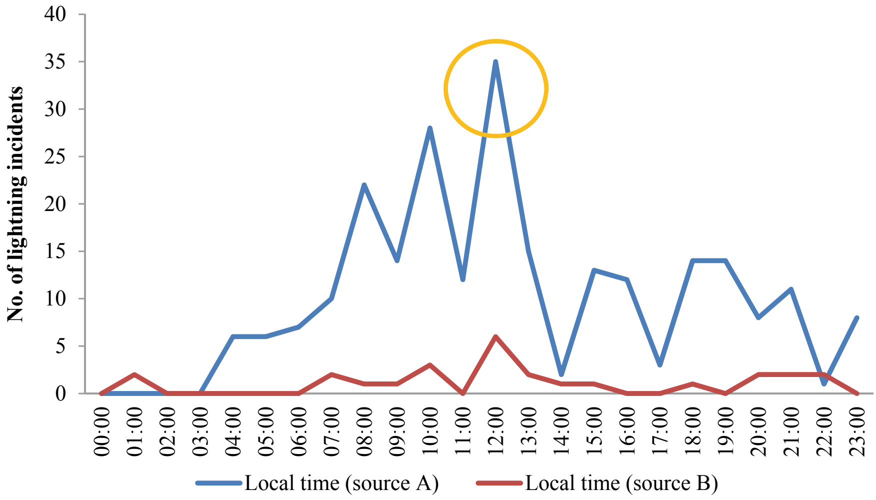


Fig. 10.5 Local standard time (LST) of lightning incidents

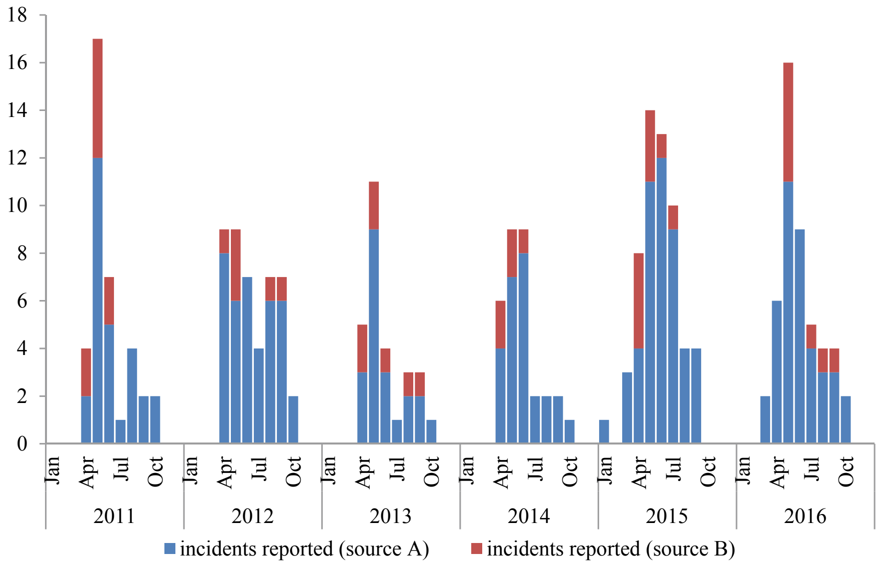


Fig. 10.6 Monthly variation of lightning incidents

Activities and Weather Events During Lightning Incidents

Majority of the lightning incidents occurred outdoor compared to indoors. Outdoor lightning activities have been divided into three categories: agricultural activities,

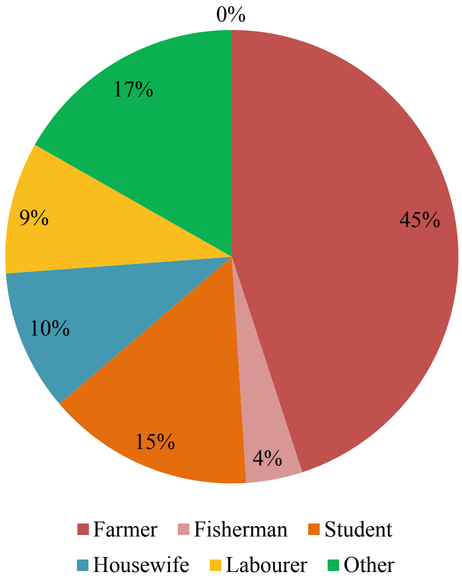


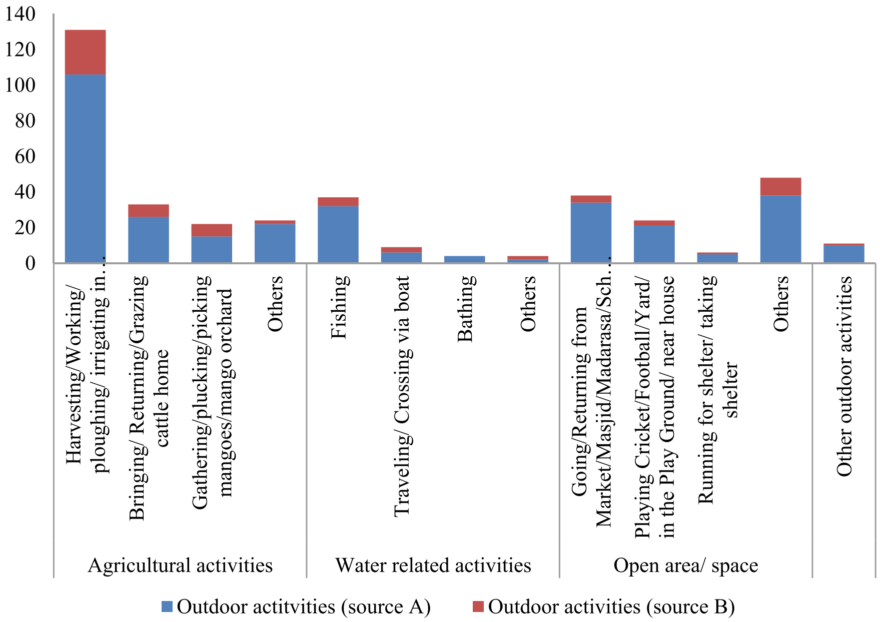
Fig. 10.7 Different professions involved in lightning casualties

water-related activities and activities occurring in open area/space as shown in Fig. 10.8a. It can be seen that majority of the lightning incidents are related to the outdoor agricultural activities, e.g., harvesting/working/plowing and irrigating paddy/farmlands/fields, followed by activities involving cattle herding or grazing and mango collecting/plucking. Water-related activities mostly involved fishing and traveling by the mean of boat. Open area activities involved going/returning from market/school/bazaar followed by reactional activity such as playing cricket/football in the open areas. Indoor activities are represented in Fig. 10.8b; even though indoor activities account for less amount of lightning-related casualties it still plays an important consideration. Figure 10.8b shows that majority of the indoor lightning incidents occurred in the veranda/balcony, while sleeping inside the house and when lightning struck on thatched and tin-roofed houses followed by kitchen-related activities.

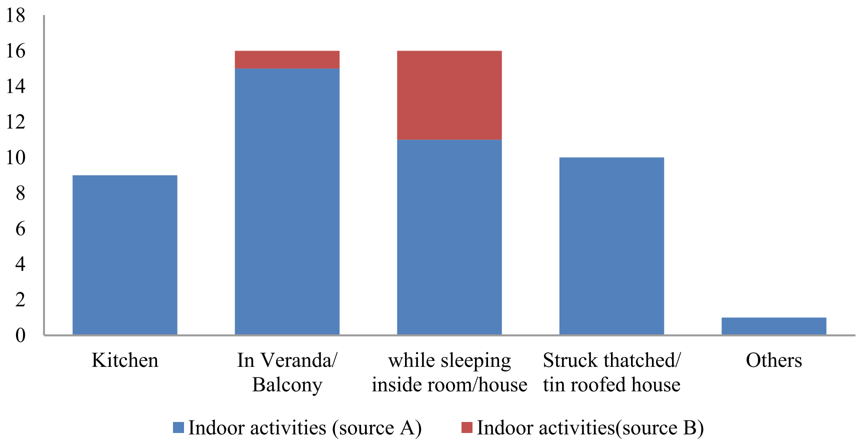
Most incidents reported lacked proper mention of weather events; among the mentioned weather event, lightning incidents occurred mostly during the nor'-wester/thunderstorm followed by heavy rainfall as shown in Fig. 10.9; we can also see that the weather events had a certain percentage of drizzle and stormy winds during the occurrence of lightning incidents.

Spatial Location of Lightning Casualties

The spatial locations of lightning casualty have been extracted through GIS mapping. The casualty rate has been fixed through no. of reporting from the particular



(a)



(b)

Fig. 10.8 Outdoor (**a**) and indoor (**b**) activities related to lighting casualties

area where lightning incidents occurred. The casualty rates have been divided into four categories: no casualties having zero casualty (green), low casualties (1–11) (light green), moderate casualties (12–21) (orange) and high casualties (22–40)

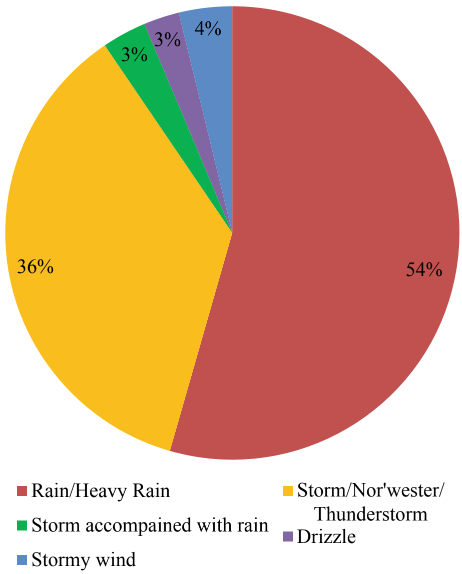


Fig. 10.9 Weather events reported during lightning incidents

(red). District with the highest number of casualities are Chapai Nawabaganj, Kishoreganj and Sunjamganj, which means lightning reported from these areas are as high as 22–40 reports, moderate casualties in Thakurgaon, Dinajpur, Rangpur, Lalmonirhat, Gaibandha, Naogaon, Mymensingh, Habiganj, Maulavibazar, Brahmanbaria, Jhenaidah, Satkhira, Chandpur and Chittagong accounting 12–21 reports followed by rest other districts having low casualty reports except for districts like Feni, Rangamati, Shariatpur, Jhalokati, Patuakhali and Barguna had no casualties reported for lightning incidents, during the years of the study period (Fig. 10.10).

Annual Lightning Incidents Reported

Figure 10.11 shows the amount of lightning incident reported in the years 2011 and 2012 was high but the years 2013 and 2014 had comparatively lower lightning incidents reported compared to the previous two years. Lightning incident reporting drastically increased for the years 2015 and 2016 as per the study.

The deaths and injuries occurred due to lighting as shown in Fig. 10.1a, b show that the number of deaths due to lightning is higher than the injuries. But it is said that the numbers of injuries are as high as deaths but compared to fatalities the injuries are reported less (Mills et al. 2008). According to Singh and Singh (2015), there are more people injured by lightning strike than fatalities per year.

Figure 10.2a, b shows that the deaths and injuries among males are greater than that of females; this is most likely because larger proportions of males are involved

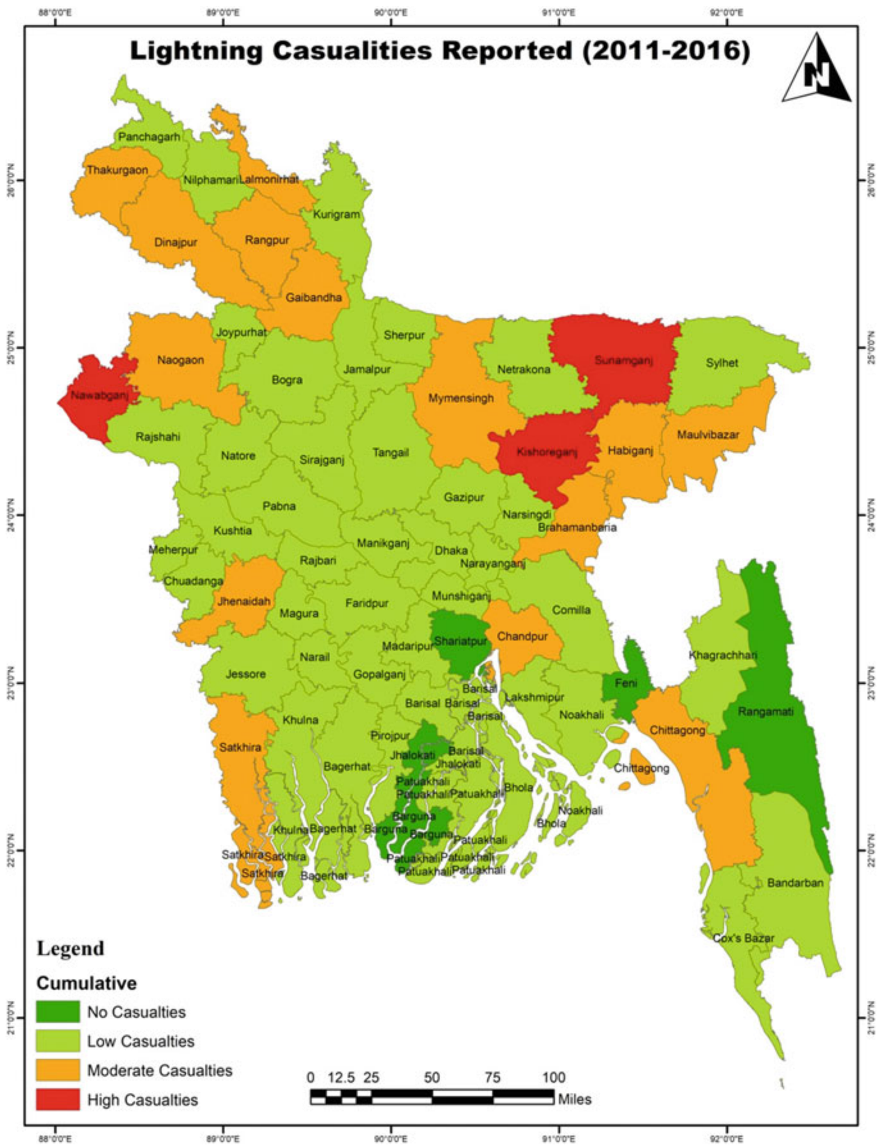


Fig. 10.10 Spatial distribution of lightining

with outdoor and traditional activities compared to females. The results are similar to the findings of other regions where males accounted for larger amount of casualties than female, e.g., in India (Singh and Singh 2015), Colombia (Navarrete-Aldana et al. 2014), Canada (Mills et al. 2008), Swaziland (Dlamini 2009), UK (Elsom 2001), USA (Curran et al. 2000), etc.

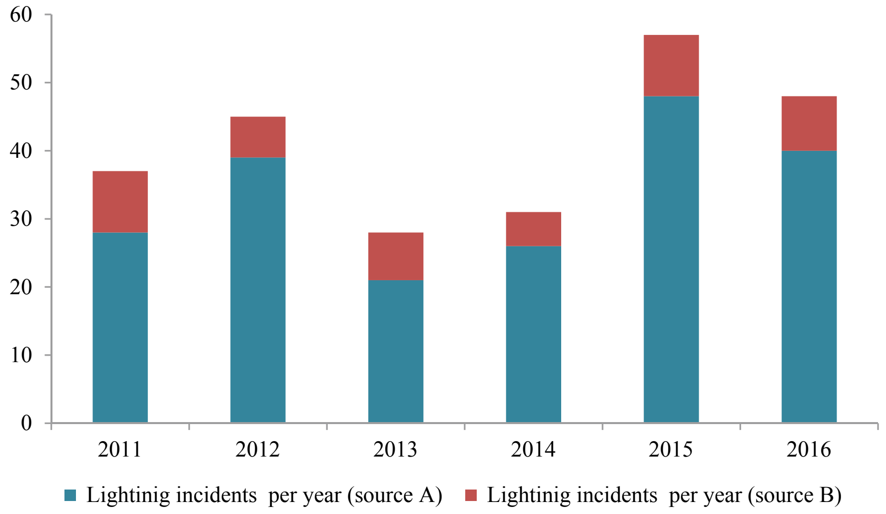


Fig. 10.11 Lightning incidents reported per year

During the data analysis, a large portion of people of the age groups 16–30 and 31–45 accounted for most amounts of lightning casualties (shown in Fig. 10.3); this particular feature has a co-relation with the different professions of the people (Fig. 10.7). From the profession analysis, a major group of people were from the farming profession, and during the data collection process majority number of farmers were aged from 20, 25, 30 and 35. Hence, it can be said that the lightning causality rate of people from the age groups of 16–30 and 31–45 is high as they fall under the working class of the society. Age group below <16 accounts for a good percentage of lightning casualties as people from this age category are mostly school-going students walking from home to school or vice versa or playing outdoors.

From Figs. 10.4 and 10.5, lightning incidents have been seen to occur most during the morning and afternoon. According to Yamane et al. (2010), in all other prior studies around the world, lightning casualties have been seen to occur during the daytime maximum due to vertical instability resulting from heating of the land surfaces and leading to lightning producing convection. The monthly variation of lightning casualties peaked in the pre-monsoon (March–May) and monsoon (June–September) season as shown in Fig. 10.6. This peak in the pre-monsoon season is due to the occurrence of severe local convective storms during this season (or known as nor'wester) accompanied with hail, gusts, rainfall and lightning (Yamane et al. 2010). According to Mannan and De (1995), the violent thunderstorms occur during March through May as since it is a transition phase. During this time, temperature and evaporation increase as sun becomes more overhead during March to May and as Bangladesh is full of water bodies moisture support increases during these months, thus helping in convective developments, forming giant cumulonimbus clouds and resulting in severe thunderstorm (Mannan and De 1995). Another reason for this peak could be because of the cropping season during mid-March to mid-July (Kharif-1) (Hasanuzzaman n.d.), thus resulting in increased human activities outdoors and hence increased casualties occurring during these months.

Lighting casualties mostly occurred outdoors as per the findings of this study compared to indoor; the activities involved are similar to those in the developing countries. According to Gomes and Kadir (2011), substantial amount of time is spent by people outdoors, who depend on labor-intensive agricultural practices. Figure 10.8a shows activities involving outdoor activities, showing the most amount of lightning casualty is related to harvesting/farming/plowing, etc., followed by cattle herding, grazing and walking them to shelters. A good amount of people was affected by mango plucking or gathering. This particular activity is something that is done out of recreation and can actively avoid during the thunderstorm period. Water-related activities account for lesser lightning casualty compared to agricultural activities but should be acknowledged since many people are involved with fishing be it professionally or for recreational purpose; but traveling by boat is an important means of transportation for most of the rural people, and hence to avoid the lightning-related casualty it is important to ensure safe traveling through boat. Figure 10.8b depicts the indoor lightning casualties, and it is visible from the figure that people who are affected by lightning are not residing in lightning-protected houses. It is not possible to directly quantify the lightning-protected houses provided by Bangladesh housing, but it can be concluded by saying that not many housings are lightning safe and that an unspecified section of the rural Bangladeshi dwelling is unprotected to lightning (Dewan et al. 2017).

Since the lightning-related deaths and injuries occur mostly during the pre-monsoon season due to the occurrence of severe thunderstorms during these periods of the season, the weather conditions recorded in Fig. 10.9 even though scattered stand true for the higher percentage of storms/thunderstorms and rainfall during lightning incidents.

According to Chowdry and Karmakaras (1986), as mentioned by Yamane et al. (2010) nor'wester storms occur during the pre-monsoon season of Bangladesh, most routinely in the north central region of Bangladesh. The southern region of Bangladesh experiences SW/S wind during the pre-monsoon season which with the help of sea moisture and other water bodies in that region gets enough moisture to build up thunderstorm activities. In the western side of Bangladesh, there lies Gangetic Plain of West Bengal, due to the presence of hilly tracts in Bihar and Orissa; thunderstorm develops due to the downdrafts of hilly region as it mixes with the sea moisture laden in the southeast surface winds. Nor'wester downdrafts are also experienced in the middle region of Bangladesh with the help of moisture form the Padma and Meghna rivers causing thunderstorm activities. The thunderstorm activities are also in the northern part of the Bangladesh due to the wind system present in the foothill region of Himalayas (Mannan and De 1995). These thunderstorm activities show how geographically Bangladesh falls under severe thunderstorm activities during the pre-monsoon season, so casualty form lighting is eminent; but this rate of casualty due to lightning can be reduced if awareness is built and structural solutions are given so that people can seek for shelter during these thunderstorm activities.

It cannot be said if lightning incidents have increased from the past years due to lack of data availability, and further analysis of other weather events for those years can actually determine if the weather events had any co-relation between the incidents reported for those years (specifically 2015 and 2016); but from Fig. 10.11, it can be said that the reporting has increased from previous years but there is still scope of underreporting due to limited geographical coverage as it is visible from the graphical data presented in my study.

Policy, Plan and Action

Bangladesh regulative framework provides relevant legislative, policy and best practice framework for disaster management under which the activity of Disaster Risk Reduction and Emergency Management in Bangladesh is managed and implemented. The regulative framework requires more articulation in addressing the risk associated with lightning. The National Disaster Management Policy (National Disaster Management Policy 2015) mentions about nor'wester and Lighting Hazard Management, but incorporating lightning with other natural hazard hinders the attention it should get as one of the main natural hazards in Bangladesh. The National Plan for Disaster Management ('National Plan for Disaster Management (2016–2020) Draft' n.d.) very recently added lightning as one of the main hazards of Bangladesh. Setting up specific research center to understand the 'lightning' phenomenon and integrating 'lightning forecasting and early warning system' will help achieve the priorities enlisted in the plan of the NDMP 2016–2020 (Draft), and it will also help in better understanding of the risk associated with lightning and also achieve government aims to protect the vulnerable people from the adverse effect of natural calamity and in building resilience of the poor and reduce their exposure and vulnerability to environmental shocks, geo-hydro-meteorological hazards, emerging hazards, man-made disasters and climate-related extreme events. The Disaster Management Act (National Disaster Management Act 2012) does not have lightning mentioned under its definition of disaster, and the act needs to be revised and updated with specific addition of 'lighting' mentioned under its definition of disaster so that lightning is acknowledged as a single disaster event and gets the adequate amount of attention and awareness it requires throughout the nation. In the Standing Orders on Disaster (SOD) (Standing Orders on Disaster 2010), roles and responsibilities of the ministries, committees and organizations are described. As per the report of Palma (2016), the Government of Bangladesh had declared lightning as one of the natural disasters; the report also mentions government compensation of 20,000 TK according to the standing orders to be provided to the families who lost a family member due to lightning. But compensating 20,000 TK would not be enough if the wage earner of the family is lost due to lightning. Hence, the SOD should have specification and categorization on compensating families depending on their socioeconomic status and specify the duty to the assigned ministry responsible for the allocation of such funds. If the lightning-affected families are not adequately compensated or provided with monetary resources, it will result in increased poverty. This will hinder the government vision of eradicating poverty which is fundamental to the vision of the Government of Bangladesh.

Conclusion

Lightning casualties in Bangladesh are related to accidental circumstances due to lack of awareness, but they are mainly influenced by the geographical location and activity of the people. A better perception and understanding of lightning-related casualties will help in generation of public policies, regulations, safety measures, construction of lightning-protected infrastructures, early warning systems and significant public awareness. Early warning system will help alert public on the availability of the cumulonimbus clouds (CB clouds/thunder clouds) in the sky forecasted for the day, which people can avoid by limiting their outdoor activities. In Bangladesh, the socioeconomic status puts its people under the threat of lightning. Bangladesh is a developing country, and its people are still involved with labor-intensive agricultural practices, which force them to go out for work even in the severe weather conditions. In this case, the government can put up lightning safe shelters so that the people can take shelter during such severe weather events and provide lightning-protected boats that will allow and ensure safe means of transportation when traveling through waterways. Lightning-related deaths and injuries have become an extensive disaster in Bangladesh. So, it is required to study the threat that lightning brings to the society and to recognize how it may become an important determinant of social and economic welfare which may result in even higher damages in the absence of adequate action time ahead.

References

Allaby M (2003) Floods (Facts on file dangerous weather series). Facts on File Science and Library, New York

Cardoso I et al (2014) Lightning casualty demographics in Brazil and their implications for safety rules. Atmos Res 135–136:374–379 (Elsevier B.V). https://doi.org/10.1016/j.atmosres.2012.12.006

Chao TC, Pakiam JE, Chia J (1981) A study of lightning deaths in Singapore. Singapore Med J 22 (3):150–157

Coates L, Blong R, Siciliano F (1993) Lightning fatalities in Australia, 1824-1991. Nat Hazards 8 (3):217–233. https://doi.org/10.1007/BF00690909

Curran EB, Holle RL, Lopez RE (2000) Lightning casualties and damages in the United States from 1959 to 1994. J Clim 13(19):3448–3464. https://doi.org/10.1175/1520-0442(2000)013%3c3448:LCADIT%3e2.0.CO;2

Dewan A et al (2017) Recent lightning-related fatalities and injuries in Bangladesh. Weather Clim Soc 9(3):575–589. https://doi.org/10.1175/WCAS-D-16-0128.1

Dlamini WM (2009) Lightning fatalities in Swaziland: 2000-2007. Nat Hazards 50(1):179–191. https://doi.org/10.1007/s11069-008-9331-6

Elsom DM (2001) Deaths and injuries caused by lightning in the United Kingdom: analyses of two databases. Atmos Res 56(1–4):325–334. https://doi.org/10.1016/S0169-8095(00)00083-1

Gomes C, Kadir MZAA (2011) ‘A theoretical approach to estimate the annual lightning hazards on human beings. Atmos Res 101(3):719–725 (Elsevier B.V.). https://doi.org/10.1016/j.atmosres.2011.04.020

Gomes C, Hussain MAF, Abeysinghe KR (2006) Lightning accidents and awareness in South Asia: Experience in Sri Lanka and Bangladesh. In: Proc 28th intl conf on lightning protection (September 2006), pp 1240–1243. https://doi.org/10.1016/j.atmosres.2011.04.020

Holle RL (2016a) Lightning-caused deaths and injuries related to agriculture. In: 24th international lightning detection conference and sixth international lightning meteorology conference, Vaisala, San Diego, pp 1–5

Holle RL (2016b) The number of documented global lightning fatalities. In: 24th international lightning detection conference and sixth international lightning meteorology conference. Vaisala, San Diego, pp 1–4

Holle RL (2017) Lightning fatalities in Bangladesh in may 2016. In: 2017 American meteorological society annual meeting, 8th conference on the meteorological applications of lightning data, Seattle, Washington, pp 10–13

Illiyas FT et al (2014) Lightning risk in India—challenges in disaster compensation. Econ Polit Wkly 23–27

Kithil R (1995) Lightning’s social and economic costs—National Lightning Safety Institute. In: International aerospace and ground conference on lightning and static electricity, 26–28 Sept 1995. National Lightning Safety Institute. Available at: http://lightningsafety.com/nlsi_lls/sec.html

Mannan MAC, De UK (1995) Pre-monsoon thunderstorm activity over Bangladesh.pdf, vol 6, pp 591–606

Mills B et al (2008) Assessment of lightning-related fatality and injury risk in Canada. Nat Hazards 47(2):157–183. https://doi.org/10.1007/s11069-007-9204-4

National Disaster Management Policy (2015)

National Disaster Mangement Act (2012)

National Plan for Disaster Management (2016–2020) Draft (no date)

Navarrete-Aldana N, Cooper MA, Holle RL (2014) Lightning fatalities in Colombia from 2000 to 2009. In: 2014 international conference on lightning protection, ICLP 2014, pp 40–46. https://doi.org/10.1109/iclp.2014.6971992

Palma P (2016) Lethal lightning. The Daily Star, 30 Sept. Available at: http://www.thedailystar.net/frontpage/lethal-lightning-1291849

Raga GB, de la Parra MG, Kucienska B (2014) Deaths by lightning in Mexico (1979–2011): threat or vulnerability? Weather Clim Soc 6(4):434–444. https://doi.org/10.1175/WCAS-D-13-00049.1

Sabur AKMA (2012) Disaster management system in Bangladesh: an overview. India Q 68(1):29–47. https://doi.org/10.1177/097492841106800103

Salerno J et al (2012) Risk of injury and death from lightning in Northern Malawi. Nat Hazards 62(3):853–862. https://doi.org/10.1007/s11069-012-0113-9

Selvi S, Rajapandian S (2016) Analysis of lightning hazards in India. Int J Disaster Risk Reduction 19:22–24. https://doi.org/10.1016/j.ijdrr.2016.08.021

Singh O, Singh J (2015) Lightning fatalities over India: 1979-2011. Meteorol Appl 22(4):770–778. https://doi.org/10.1002/met.1520

Standing Orders on Disaster (2010) Ministry of Food and Disaster Management Disaster Management & Relief Division Disaster Management Bureau. https://doi.org/10.1097/00006199-195908020-00056

Tilev-Tanriover et al (2015) Lightning fatalities and injuries in Turkey. Nat Hazards Earth Syst Sci 15(8):1881–1888. https://doi.org/10.5194/nhess-15-1881-2015

Uman MA (2008) The art and science of lightning protection. Cambridge University Press

Walsh KM et al (2000) National Athletic Trainers' Association position statement: lightning safety for athletics and recreation. J Athletic Trainning 471–477

Gomes C, Kithil R (no date) Developing a lightning awareness program model third world based on American- South Asian experience

Hasanuzzaman M (no date) Cropping seasons

Yamane Y et al (2010) Severe local convective storms in Bangladesh: part I. Climatology. Atmos Res 95(4):400–406 (Elsevier B.V.). https://doi.org/10.1016/j.atmosres.2009.11.004