Spatial Vulnerability Assessment of Extreme Lightning Events in Bangladesh Using GIS

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Abstract

This study explores human death, injury and overall casualties as a result of ongoing extreme lightning events in Bangladesh. Especially the month of May starting from 2010 to mid-2017 were taken under consideration for this study where, a total of 1811 lightning casualties composed of 339 fatalities and 273 injuries are identified. Spatial and geographic aspects of division wise lightning events are evaluated with the help of ArcGIS. The annual average number of fatality is 227 for the whole country whereas, 43 fatalities and 35 injuries over the entire study period was found in May only. The rate of lightning fatality is high in Pirganj of Thakurgaon, Nikli of Kishoreganj, Shibganj of Chapainawabganj, Nawabganj of Dinajpur, Ullapara of Sirajganj, Bagmara of Rajshahi, Bhuapur of Tangail, and Tarail of Kishoreganj. The majority of lightning-related fatalities occurred to males. Maximum people affected by lightning strike during working outside like in field, hoar, road side etc. Farming is the major activity during lightning fatalities. One seventh of death people are affected during stay in indoor like-house, mosque etc. The rural people affected by lightning fatalities accounted 93%. The analysis shows that the highest lightning vulnerable zone is Sunamganj, Sylhet.

Key words: Casualty, Extreme lightning, Lightning frequency, Spatial vulnerability,

Introduction

Nowadays lightning events considered as a major disaster in Bangladesh. In the past few years due to the devastating situation of lightning, the Ministry of Relief and Disaster Management declared lightning hazard as a disaster in 17th May 2016. Lightning death is a worldwide problem representing the important cause of weather-related death after tornadoes, flash floods, and hurricanes. Low and middle-income countries in the tropical and subtropical regions of the world are most affected by lightning (Ali, 1999). On earth, the lightning frequency is approximately 40ï 50 times a second or nearly 1.4 billion flashes per year (Oliver and John, 2005) and the average duration is 0.2 seconds made up from a number of much shorter flashes of around 30 microseconds.

Bangladesh is one of the countries at particular risk, with a high number of devastating lightning injuries in the past years, causing high mortality and morbidity. Worldwide, mortality from lightning is estimated at between 0.2 and 1.7 deaths $1{,}000{,}000^{-1}$ people, affecting mainly the young and people who work outdoors (Folger, 2013). A previous study reports that in Bangladesh, the incidence of lightning 0.9 deaths $1{,}000{,}000^{-1}$ people $year^{-1}$, which is higher than in high-income countries (Karim, 1995). Gomes *et al.* (2006) reported 133 deaths plus 137 injuries from 73 incidents in 2005. Ono and Schmidlin (2011) estimated an annual death toll of 500 to 1000 for Bangladesh. Another study reported that lightning constitutes more than 25% of the total number of electricity-related casualties in Bangladesh (Mashreky *et al*., 2012). A mixture of personal interviews over parts of the country in 2003 and a media review during a 3-day period in 2016 is reported for mainly injuries by Biswas *et al.* (2016). Lightning injuries are the highest during the summer months (April, May, and June). However, in some countries such as India and Vietnam, lightning mostly occurs during the rainy season (Sumangala, 2015). Worldwide, men are five times more likely than women to be struck by lightning (Holle and Islam, 2017). The most vulnerable age for lightning injury is estimated to be between 10 and 29 years (Gomes *et al.,* 2006). Scientists say warmer conditions associated with climate change are causing more water evaporation from the land and ocean, increasing clouds and rainfall and the potential for lightning storms. The months of April, May and June are the warmest in Bangladesh and the moist air quickly rises upward to meet with dry north-westerly winds to cool and form large storm clouds (Bandara *et al*., 2004). The 'SAARC Storm Program' says that lightning deaths in Bangladesh are more than other SAARC countries. According to the USNLSI (2016), one-fourth of world-wide lightning deaths occur in Bangladesh every year. In 2016, the country had vigorous lightning events in May with strikes causing 96 deaths and in 2017, the death toll was 59 in May only. Most lightning deaths and injuries occur when people caught outdoors in the summer months during the afternoon and evening (Dewan *et al.*, 2017).

In Bangladesh severe lightning starts from March and remain active up to October-November. But in May the lightning frequency, lightning injury and lightning death is the highest. Lightning occurs mainly in wet days of summer. There are some other factors like mixing of temperature, plenty of humidity, and friction of cold and warm air has great impact to generate thunderstorm. But there are huge lacking of lightning data, lightning detecting devices (OTD and LIS) and lightning identifiable technologies. There are huge opportunities to research on lightning in Bangladesh if the proper technical support ensured. This study explores lightning history and lightning casualties using data from related NGOôs, research and newspaper reports on lightning deaths on May from 2010 to 2017. The specific objectives of this study were to reveal lightning frequency and death in last one decade, and to identify the most vulnerable region of lightning events in Bangladesh based on division wise scenarios.

Materials and Methods

Selection of the study year

From 2010 to 2017, a lot of lightning strike hits Bangladesh including alarming year 2017, especially in May. The month May is chosen because there had died a lot of people by lightning strike in May.

Data Sources

Lightning strike data

In Bangladesh the lightning data was rare to collect, as there had no modern technology to identify and store lightning data. All lightning strikes data were collected from Bangladesh Disaster Forum (BDF), Bangladesh Meteorological Department (BMD) and the daily newspapers named ñThe Daily Prothom Aloò and ñThe Daily Kaler Kanthaò published in Bengali language.

GIS data

To conduct this study, mainly GIS raw data was collected through various institutions working with lightning issue and from different reports, research articles, newspaper articles, journal papers and many more. The major GIS data and information like- base map, river map and other shape files were collected from Center for Environmental and Geographic Information Services (CEGIS), Disaster Forum and internet as well.

Spatial analysis

The exact locations of the lightning strike data were collected from the sources said above and were plotted using GIS software named Google earth. The data were analyzed by ArcGIS software to estimate the lightning casualty rate throughout the whole Bangladesh. Casualties in the present study were defined as the sum of deaths and injuries. In addition, lightning events, deaths, injuries and casualty rates (number of events/deaths/injuries/casualties with the rank per district) have been calculated to make the obtained results comparable with regional, national and global scale. The rate of a particular disaster could be calculated using the following formulae (Aldana *et al.*, 2015) ï

The scale maintained to formulate the grid maps are:

Country map; per square box = 25 kilometer^2

Division map; per square box = 1 kilometer^2

LFR = × F/Y é é é é é é é é é é .(*i*)
where, LFR = Lightning frequency rank

× F = sum of lightning frequency in May

Y = number of years (2011 to 2017)

LD = × D é é é é é é é é é é .(*ii*)
where,

LD = data of lightning death

× D = sum of lightning death

SDP = (× SD×100)TD é é é é é é .(*iii*)
where,

SDP = percentage of shelter death

× SD = sum of shelter lightning death

TD = total lightning death (2011- 2017)

OSP = (× OSD×100)TD é é é é .(*iv*)
where,

OSP = percentage of open space death

× OSD = sum of open space death

R = [(N/P) × 1000000] / n é é é ...(*v*)
where,

R = rate (million^{-1} population year^{-1}),

N = no. lightning events, deaths, injuries,

P = annual total population affected

n = number of years (2011 to 2017)

C = (I+D)/2 é é é é é é é é é .(v*i*)

where,

C = casualty by lightning of the area

I = injury by lightning strikes

D = death by lightning strikes

These rates were calculated for the districts of each division and then ranked in descending order. These ranks were then mapped in class incrementing by steps of ranks. These computed rates have been mapped separately to determine the distribution of high or low number of events, deaths, injuries and casualties resulting from lightning.

Results

Lightning events in Bangladesh

From figure 1, it is observed that the highest lightning frequency was 324 with 120 thunderstorm days in Srimangal station, while the second highest was also 324 with 114 thunderstorm days in Sylhet. The third highest was Mymensingh with 206 lightning in 94 thunderstorm days. In the capital city Dhaka lightning frequency was found 124 in 58 thunderstorm days in 2014. Figure 1 also indicates that the lowest lightning frequency was 48 with 29 thunderstorm days in Comilla station. Lightning frequency and lightning day was comparatively less in coastal zone stations like in Khulna (57), Teknaf (72), Bhola (86), Sandip (87), Kutubdia (93), Hatiya (112), Satkhira (123) and Patuakhali (141).

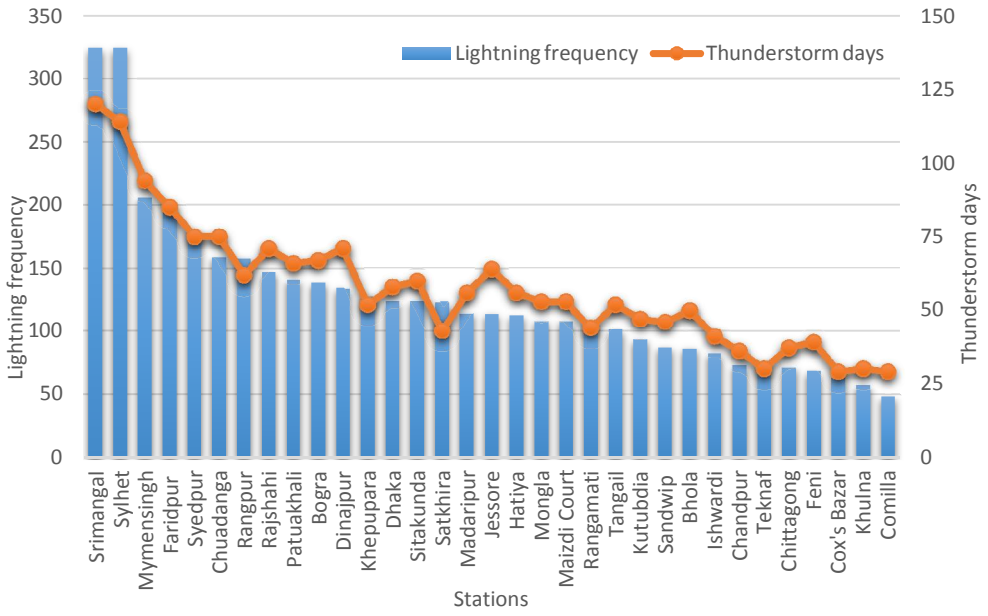


Fig. 1. Lightning statistics in 2014 for 33 stations in Bangladesh.

From 1978 to 2000, it is found that lightning frequency was 234 in 100 days each year. The annual time series of deaths shows an increase trend since the late 2000s, which is a result of greatly improved communications leading to better media reporting of lightning casualties. Bangladesh has also become much more populated in recent years. As a result, the most recent 6 years have 251 fatalities year^{-1} (Dewan *et al*., 2017).

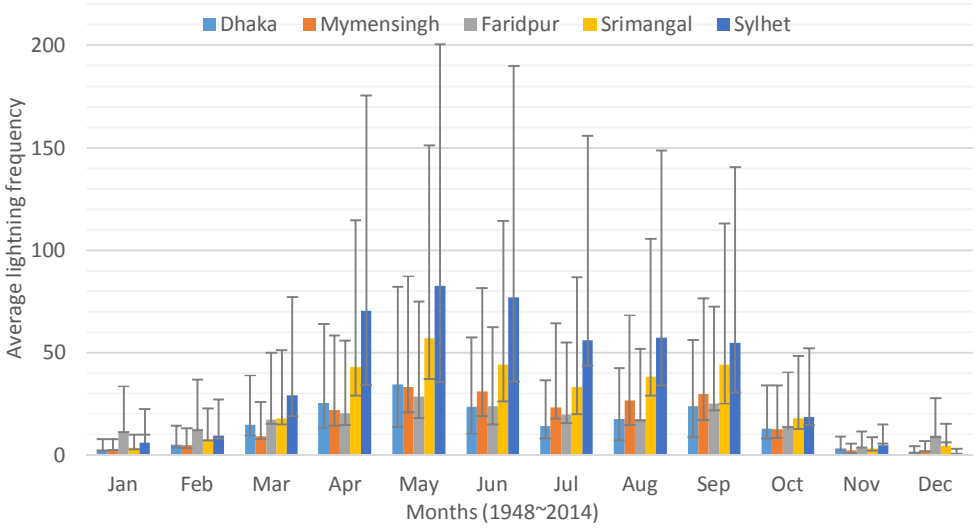


Fig. 2. Monthly average lightning frequency for 5 major affected districts 1948-2014.

Figure 2 shows the monthly average lightning frequency for 5 major lightning affected districts. Lightning occurred mainly in wet days of three months (April, May and June) of summer season with the highest average lightning frequency in May (83).

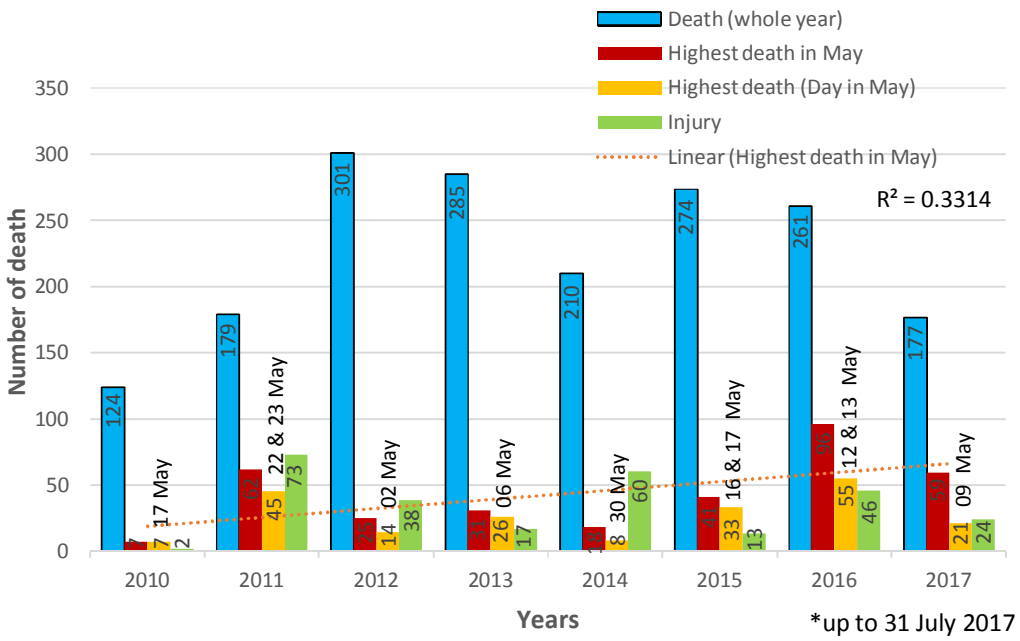


Fig. 3. Lightning injury and death in May 2010-2017

Lightning casualties in May

Figure 3 shows the temporal variations of lightning casualty over last 8 years. It has been found that the average frequency of lightning death increased significantly from 2010 to 2017 and was the maximum in May. In May 2016, highest (96) people died due to lighting in Bangladesh, although in total 261 people died in whole year. In addition, lot of people injured, the supply of electricity was stopped due to damage of transformers, the supply of water was delayed due to disruption of water pumps, water logging condition due to heavy rainfall, many houses were destroyed due to thunderstorm, crop loss and many domestic animals were died.

Lightning Vulnerability in Bangladesh

Spatial distribution of lightning frequency and lightning death

Figure 4 shows the lightning frequency in May (2010-17). There were several lightning frequency (01-05) zone in more than 90% area of Bangladesh in May, but severe lightning (26-40) occurred in only 3% area of total land area. Medium lightning frequency (11-20) recorded in coastal regions (Teknaf, Coxôs bazar, Kutubdiya, Chittagong, Sandip, Hatiya, and Khulna). Figure 5 shows the lightning death in May from 2010 to 2017. In last eight years, the maximum (14) people died by lightning was in Pirganj, Thakurgaon. The death rate was higher in Nikli (13) of Kishoreganj, Shibganj (13) of Chapainawabganj, Nawabganj (11) of Dinajpur, Ullapara (11) of Sirajganj, Bagmara (10) of Rajshahi, Bhuapur (9) of Tangail and Tarail (9) of Kishoreganj.

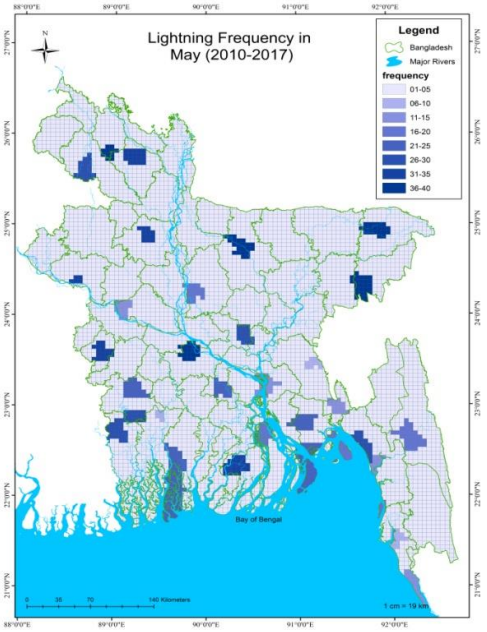


Fig. 4. Lightning frequency in May (2010-2017).

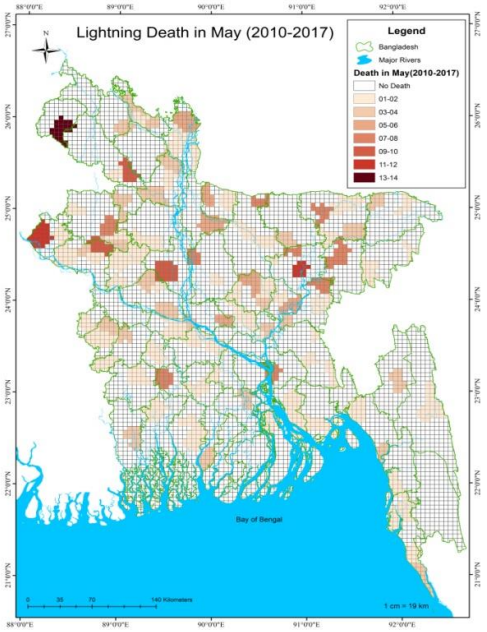
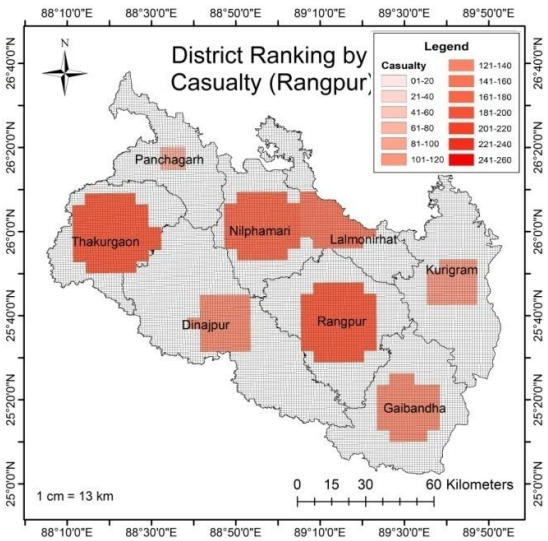
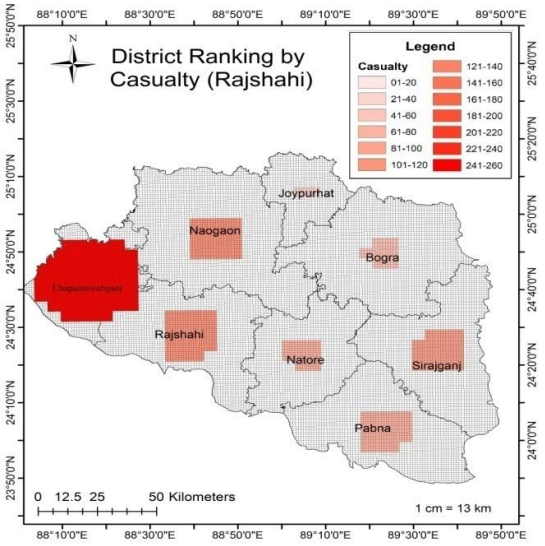


Fig. 5. Lightning death in May (2010-2017).

Vulnerability assessment





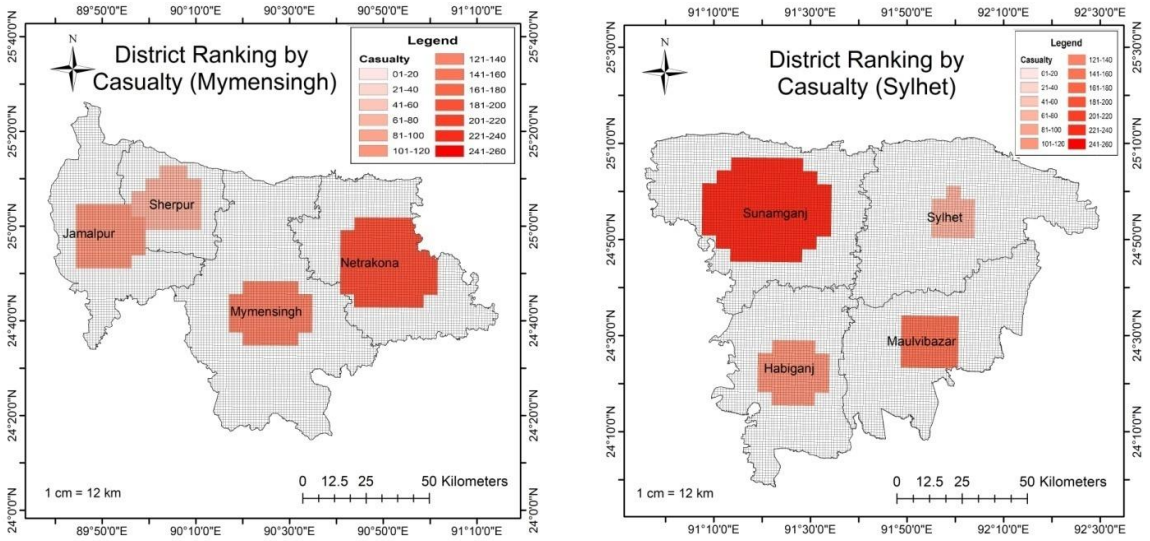
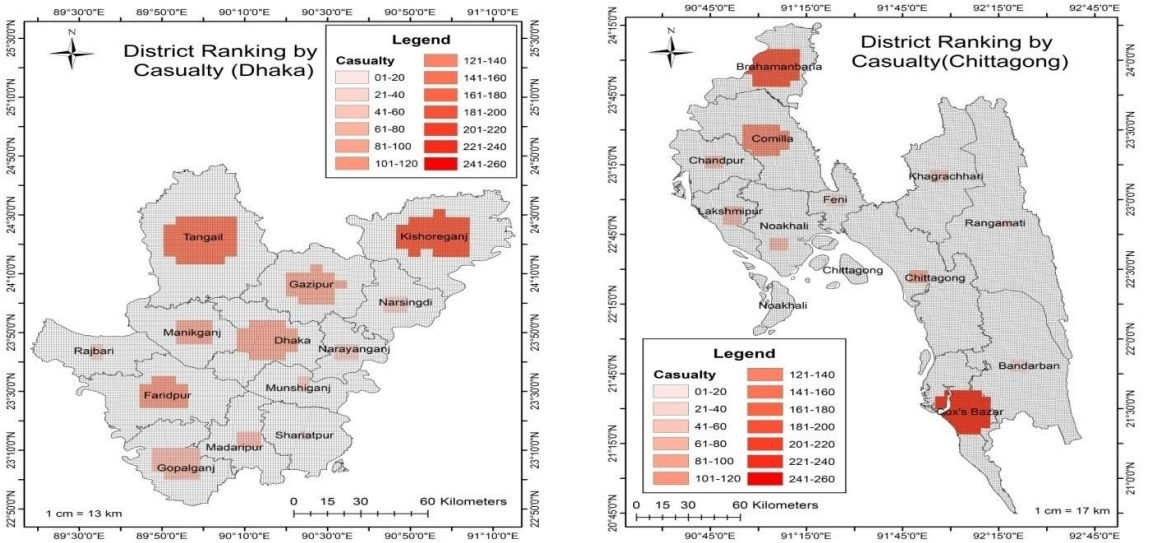


Fig. 6. District ranking by injury, death and casualty.

In figure 6, Rangpur, Rajshahi, Mymensingh, and Sylhet division was ranked by casualty (injury and death) of lightning occurrences. Rangpur and Nilphamari districts were 2nd and 3rd in terms of lightning vulnerability. Kurigram and Panchagarh districtôs people were less injured while the death was higher in Lalmonirhat district. The most vulnerable zone was western part of Rangpur. Chapainawabganj was the most affected area in Rajshahi. Naogaon and Rajshahi districts were 2nd and 3rd in terms of lightning vulnerability. Netrakona was the most affected area in Mymensingh. Mymensingh and Jamalpur districts were 2nd and 3rd in terms of lightning vulnerability. The lowest casualty (63) was recorded in Sherpur district and the most vulnerable zone was eastern part of Mymensingh division. Sunamganj district was the most affected area in Sylhet division. Maulvibazar and Habiganj districts were 2nd and 3rd in terms of lightning vulnerability. The most vulnerable zone was western part of Sylhet division.



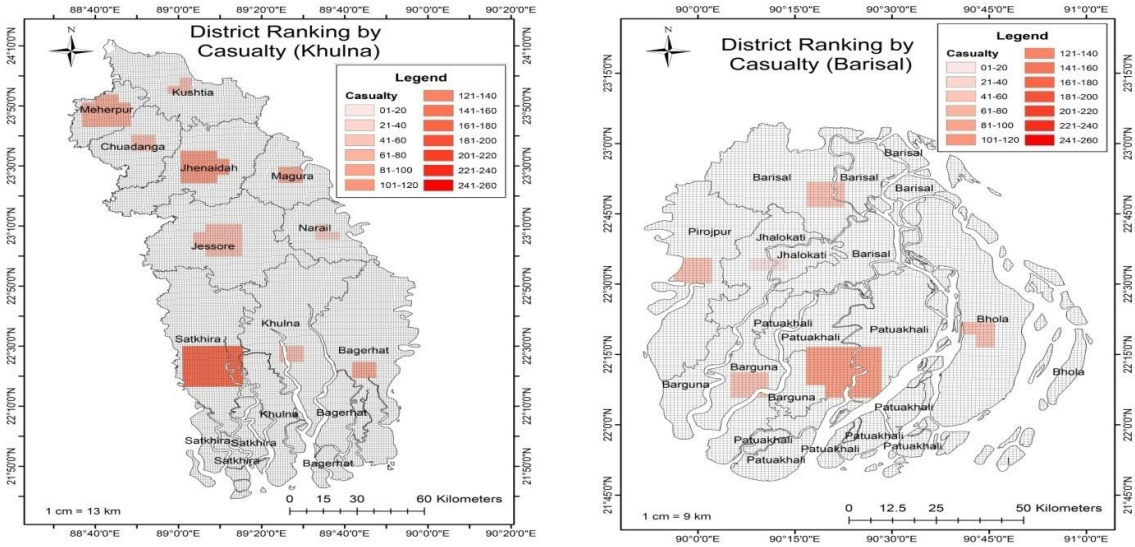


Fig.7. District ranking by injury, death and casualty.

Figure 7 shows the vulnerable zones based on casualty (injury and death) in Dhaka, Chittagong, Khulna, and Barisal division. Tangail was the most affected area in Dhaka while the most vulnerable zone was the northern part of Dhaka division. Brahamanbaria was most affected and the most vulnerable zone was the north-western part of Chittagong division. The most vulnerable zone was the western part of Khulna division, and Barisal division was less vulnerable zone of Bangladesh. It was found from the study that males were most affected by lighting injuries. The majorities of victims were from rural communities and were hit in the summer time, in the afternoon. The rural portion of lightning deaths was 93%. People of rural communities in Bangladesh had a number of misconceptions including religious myths and superstitions, as well as social humiliation attached to lightning injuries.

Conclusions

The effect of climate change on countries including Bangladesh is increasing frequently. As a result climatic extreme events like lightning strikes are also increasing rapidly. Lightning casualty has been identified as one the main causes of weather-related death in Bangladesh. In response to the lightning event in 2017, when 21 lives were lost in just a day due to lightning and in 2016, 55 lives were lost in just two days. The magnitude of the problem has become worse over recent years. The majority of victims were males from rural communities, and most injuries were incurred in the afternoon. Maximum people were affected by lightning strikes during outside working like in field, hoar, road side etc. Farming is the major activity at the time of lightning deaths. One seventh of total lightning death was occurred during stay in indoor like in house, mosque, shop etc.

The maximum lightning death however was recorded in Pirganj of Thakurgaon. Higher death was also noticed in Nikli of Kishoreganj, Shibganj of Chapainawabganj, Nawabganj of Dinajpur, Ullapara of Sirajganj, Bagmara of Rajshahi, Bhuapur of Tangail, and Tarail of Kishoreganj. Data from 1990 to 2016 revealed that the highest lightning death recorded in Sunamganj district of Sylhet division. Then Chapainawabganj of Rajshahi, Cox's Bazar of Chittagong, Netrokona of Mymensingh, Kishoreganj of Dhaka, Thakurgaon of Rangpur, Satkhira of Khulna and the lowest in Patuakhali of Barisal. Lightning strikes almost everywhere in Bangladesh, but the less vulnerable divisions were Barisal and Khulna. The number of tall trees (coconut tree, betel nut tree, fan palm and palm tree) is very important cause for fewer casualties in southern part of Bangladesh. Labor-intensive agricultural economy, poor infrastructure, illiteracy, peopleôs awareness, and a tropical climate plays a role in higher rates of lightning-related deaths and injuries in countries such as South Africa, Malaysia, India, and Bangladesh. The information of this study can be beneficial to agencies accountable for the management of this severe meteorological hazard. Furthermore, the results of this study have the potential to develop specific public policies and lightning safety education in Bangladesh. However, lightning deaths are not currently reported in the health system or in the police recording system, which is reliable for public researchers.

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