

Original Research Paper

Physical Reasons and Mitigation Strategies for Increased Lightnings in Bangladesh

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Abstract: Bangladesh lightning victims' data spanning from 2007 to 2020 were analyzed to relate victims' activities to lightning strikes under the current upstream water piracy-set heating whence to suggest some mitigation measures. The victims' data from the online Bangladesh news media bd news 24.com were categorized in columns of places, times of occurrences, engagements of the victims, the numbers of the dead and the injured ones including animals and property losses and the online references. After the initial survey, the data were arranged cumulatively victims' broad activity-, district-, month- and year-wise. The highlights are - people's outdoor activities paid a heavier toll than the indoor ones; the riskiest district was Sunamganj; the deadliest month was May; and the worst year was 2018. In most of the cases victims fell in an aerial environment of increased electrical conductivity in the range 1×10^{-14} to 1×10^{-9} S/m due to a past, ongoing, or sudden shower when the aerial electric field became about 20 times larger than the natural one of 100 V/m to which added about 100 times more victims' moist body conductivity, crop leaves'/thorns' conductivity in the range of ~ 0.3 to 0.9 S/m and the curvature-dependent induced electric field in victims' working tools and/or ornaments of conductivity $\sim 1 \times 10^{-7}$ to 1×10^{-8} S/m. Upstream water piracy caused regional warming and thence the increased lightning. As for the mitigation strategy, agricultural and cutting tools should be made of the poorly conducting carbon-steel. Field workers should work one behind the other maintaining the safe distance to avoid attacks from side flashes and the ground current. Females should wear beaded jewelries. Plates, glasses and cooking pots should be made of China clay and earthen wares. China clay or carbon-steel weights should be used in fishing nets. In any state of life, prostration on the ground gives the best protection. Houses should be protected by setting up lightning rods and making earthen tyle roofs. Date tree growing should be emphasized because of their lightning-favored sharply pointed thorns and leaves.

Keywords: Electric Field, Conductivity, Carbon-Steel, Earthenware, China Clay, Fishgher, Haors, Harvest, Electrical Conductivity in S/m

Introduction

Lightning and Its Subjects

Lightnings are huge electric sparks. A cloud to ground lightning is a short circuit electric discharge between the bottom layer of negatively charged clouds and the induced positively charged rising air column, at a height of 20 to 100 m, centered upon a subject on the ground, opening the path of massive electron flow to the ground. Subjects can be animals or trees from which negatively charged electrons travel to the ground making the subject tops positive. The subjects' height, shape and electrical conductivity matter in contributing the positive charge column. Figure 1 below

illustrates the shape-dependent induced charge concentrations on objects. The more the curvature or the sharper a side, the more is the charge accumulation. Also, Fig. 1 shows that an uncharged conducting object (the 6th in the row) in a uniform electric field will have the most concentrated charge at its pointed end.

Normally, electrically non-conducting subjects behave like electric conductors under the negatively charged clouds. Cosmic rays, radon gas, etc. set up a harmless electric field of 100 V/m in fair weather. In a lightning environment, the fair-weather electric field of about 100 V/m intensifies at least 20 times (Freier, 1962). Any metal objects under this condition will be electrically

polarized as shown in Fig. 1. Any human or animal either holding or being near an electrically conducting object and/or in surroundings of plants/trees with pointed leaves will be in multiple faceted risks for lightnings' strikes. A human subject's wet body resistance decreases by a factor of 100 increasing the lightning strike probability. Since air near water bodies are more conducting than dry air, a subject near or upon a water body will be in the same situation. Other than directly striking the subject, lightnings' side flashes that spread around and the ground current that transmits into the ground through the subject and spreads over the subject-centered hemisphere, can attack the subject.

Bangladesh (Fig. 2), the world's eighth-most populous country with a population of 162 million occupying an area of 148,460 sq km is located at a latitude of 23.6850° N and a longitude of 90.3563° E. In recent years, the country has been on the spotlight because of lightning strikes and the consequent losses of lives and properties. CNN news reported that lightning strikes killed 65 people in four days in Bangladesh (S. Pokharel and T. Hume, CNN, Updated 10:36 PM ET, Mon May 16, 2016). The deadliest recent day was a single rainy day in 2016 when 80 people were confirmed killed by lightning (<https://nation.com.pk/19-May-2021/lightning-strikes-kill-16-people-in-bangladesh>).

Human Subjects' Activity Spectrum

People of both sexes of all ages become victims of lightning strikes. Victims' activities can principally be divided into indoor and outdoor ones. Indoor activities include cooking, taking shower a tube-well, washing in ponds, boiling paddy, carrying fuel woods to open kitchens, indoor and outdoor courtyard works, household work,

working/standing/sheltering in homes/schools/balconies, outdoor working/playing, cleaning tin shed rooftops, resting inside rooms, feeding cattle, taking cattle to cowsheds, getting out of houses, etc. etc.

Outdoor activities include walking to/returning from destinations, taking shelters under tin sheds, trees, passenger camps; riding in vans, tilling land with tractors, sowing jute seeds, weeding out paddy/jute/onion fields, working in parbal (tiny football-shaped fruits in a vine), peanut, corn, crop, bean, or salt fields; spraying insecticide in fields; fixing deep tube-wells; picking and planting rice seedlings; harvesting paddy, carrying paddy overheads, on shoulders, in bullock carts, in buffalo carts, in trolleys, in boats; heaping up or guarding paddy in the field; cutting, washing, drying, or putting jute in warehouses; going to tend cattle and goats, tending cattle and goats, bringing goats and cattle or hens and geese home; taking care of cattle farms, having cattle cross water bodies, carrying foods for laborers in the field, eating in the field; cutting grass, carrying loads of grass overheads and on shoulders; going to/returning from schools, sitting in classrooms, getting out of classrooms in recess, standing on the corridor; standing, playing, sitting in the field; going to/returning from private tutors; fishing in ditches, rivers, canals, beels (floodplains), ponds, fishghers (fish raising ponds) and haors with rods and nets; fishing in boats, feeding fish, carrying fish to fish markets; visiting friends and relatives; standing aside streets to gossip; sitting aside streets for rest; getting kids home from playgrounds; working in brickyards; picking mangoes, guarding mango gardens, collecting mango leaves for fuel; cutting trees, travelling by boats, unloading goods in boats, collecting pebbles from rivers, etc., etc.

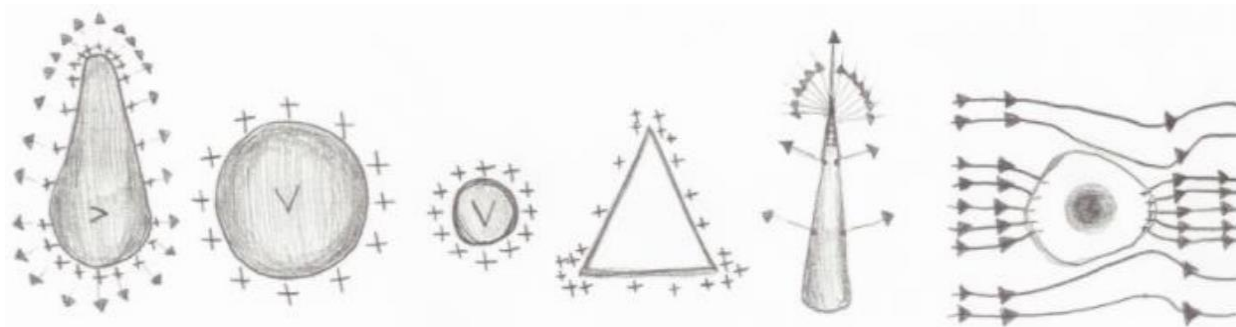


Fig. 1: From the left, (1st inset): The top part is the most curved part and has the most concentrated induced charge. (2nd inset): A round conductor will have uniform charge distribution. (3rd inset): A small round object will have more induced charge per unit area than a large round object (following https://www.schoolphysics.co.uk/age16-19/Electricity%20and%20magnetism/Electrostatics/text/Charge_distribution/index.html). (4th inset): A triangular object will have the most charge accumulation at its vertices and, so a rectangular object will have the densest charge at its corners (following <https://www.kenyaplex.com/questions/52339-describe-how-charges-are-distributed-on-differentsurface-a-conductor.aspx>). (5th inset): A very pointed conductor will have large charge accumulation at its tip. (6th inset): An uncharged conducting object in a uniform electric field will have the most concentrated charge at its pointed end (following <https://courses.lumenlearning.com/physics/chapter/18-7-conductors-and-electric-fields-in-static-equilibrium/>)

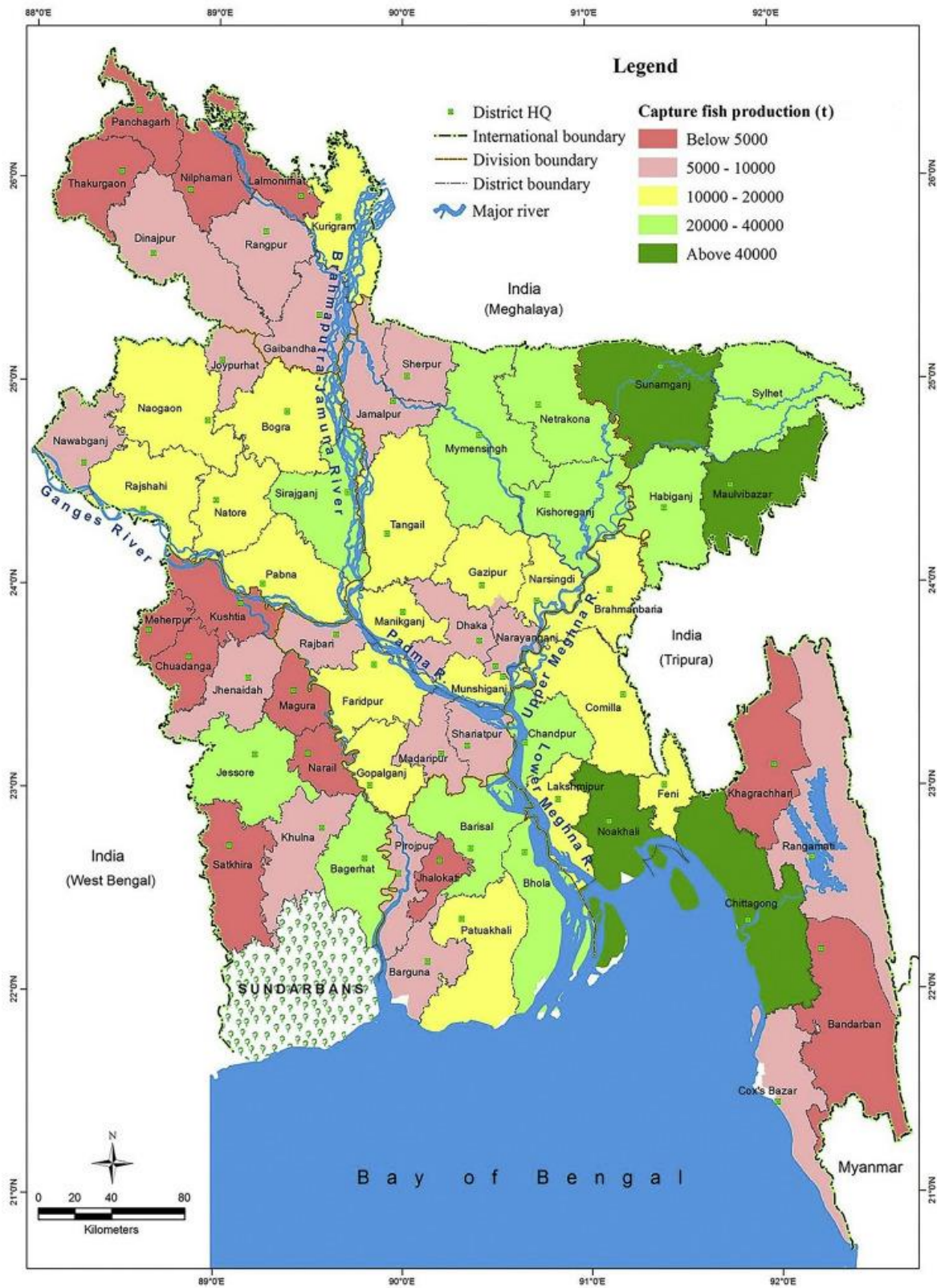


Fig. 2: Districts of Bangladesh with reference to inland open water (capture) fisheries production (Source: FRSS, 2015, reproduced with permission)

Literature Survey

In Bangladesh, the lightning information is principally available from the print and electronic news media. The two research articles (Dewan *et al.*, 2017; Holle *et al.*, 2018) published in the past years just gave the spatial, temporal and demographic statistics on lightning victims. Holle and Islam (2017) reported on the spatial, temporal and demographic information of May 2016 lightning events which were the deadliest up to that time. Biswas *et al.*, (2016) looked at the epidemiology of lightning injuries. Also, Biswas *et al.* (2020) assessed spatial lightning strikes to mitigate locational vulnerability and promote sustainable development plans for reducing the lightning disaster risk. So far, there has not been any work on the likelihood of being lightning victims based on engagements, physical wearing and carrying, and the weather based electric field increase in the environment.

The Article's Focus

This article deals with more than a decades of lightning victims' data on engagements and discusses the physical reasons for lightning strikes. The article does not consider the total number lightning generations over Bangladesh, rather it considers the lightnings that were reported because of causing deaths and injuries, and losses of properties.

Source of Data

The online Bangladesh news media *bdnews24.com* maintains lightning victims' data from 2007 up to the current time. It maintains brief news on lightning occurrences with references to clinics that gave treatments to victims certifying dead or alive followed by the statements from the local police stations and the local government chiefs. Over a decade (2007 - June 2020) of lightning-related data of dead and injured ones reported in the media *bd24.news.com* from different districts in Bangladesh were accessed. The hospitalized ones were taken as the injured ones without considering any follow-up conditions due to unavailability of the information (https://bangla.bdnews24.com/search/simple.do?jsessionid=7B56996B2F8667D0CC5EA5DBD2_A35054.C5-Pres-Ban?sortString=publishdate&searchString=%e0%a6%ac%e0%a6%9c%e0%a7%8d%e0%a6%b0%e0%a6%aa%e0%a6%be%e0%a6%a4&articleTypes=news-bn+news-district+news-kidz&pageLength=20&destinationSectionId=80&sortOrder=desc§ionId=68&publicationName=bangla&pageNumber=10)

Method of Analysis

The data were categorized in columns of years, districts and times of occurrences, engagements of the victims, the numbers of the dead and the injured ones including animals and property losses and the online references (Table 1). After the initial survey, the data were arranged

victims' broad activity-wise – harvesting, on the way, weeding, fishing, keeping indoors, tending animals, and tree shelters in which numbers of victims in groups of related engagements were added. Then the data were grouped year-wise and added to know the annual number of victims. Also, the same month's data for the years 2007-2020 were added to know the most lightning-prone month. Finally, the data were grouped district-wise for the 64 districts of Bangladesh to find the district with the highest number of lightning strikes. Separate Excel data sheets were produced district-wise, month-wise, engagement-wise and year-wise for the number of victims. The data were plotted in Excel.

Journals related to atmospheric electricity and thunderstorms were accessed for the supporting information. Online sources were explored for appropriate illustrations.

Results and Discussion

Engagement-Based Victimization

The broadly grouped engagements of victims have been plotted in Fig. 3. Harvesting has the highest fatalities. The second highest fatalities falls in the category of being outdoor on way to/returning from destinations. Weeding, fishing and indoor engagements have almost the same fatalities. The least fatalities occurs in taking shelter under trees. The highest number of injuries occurs in indoor engagements followed by fishing. Harvesting and on the way have almost the same injuries. The least injuries are in tending animals.

This result is a direct reflection of the number of people that potentially falls in the different engagement categories. The largest number of people are engaged in harvesting of different crops, the principal one being the boro paddy harvesting. On the way category covers several types of allied engagements- people going to/returning from the field on foot or on tractor (<https://www.youtube.com/watch?v=Vc6M6mjpuRg>; <https://www.youtube.com/watch?v=-dNph9EXcJQ>), in the company of a herd of animal (<https://www.tbsnews.net/economy/bathan-decline-seasonal-business-hakaluki-haor-234733>), fishermen going to/returning from fishing, people going to/returning from markets, students going to/returning from schools/tutors, travelling on animal-pulled or metaled vehicles, etc. etc. The indoor injured spike is due to the strikes upon the school children either on the balcony or in classrooms.

Crop Field Environment

Certain plant leaves are favorable for induced charges because of their sharp ends. These are rice plants (*oryza sativa*), grass (*poaceae*), onion plants (*allium cepa*), garlic (*allium sativum*) (Fig. 4 and 5), etc. Because of their shapes, rice grains can be good targets for triggering upward rising positively charged air columns. In Jessore district, a farmer heaped up harvested paddy plants in the field. A nighttime (9:30 pm on 10 May 2020) lightning strike burned all the rice plants

(<https://bangla.bdnews24.com/samagrabangladesh/article/1757415.bdnews>).

Jute plants (*corchorus olitorius*) grow up to a height of about 180 cm with leaves having tapering ends and narrowing heads. Eggplants plants (*solanum melongena*) have tiny sharp thorns. These plants can support rising air column of positive charges. In stormy weather, the 20 times enhanced electric field further boost up around curved metal tools used by workers in these fields. Electric field enhancements occur around jute harvesters, too. Jute washers work in an environment of increased conductivity of air. Also, farming tools are metal objects that have curvature and sharp ends (Fig. 6 and 7). Metal objects and metal bodies can easily develop induced charges. The presence of human subjects with them put them in a risky situation under a showery weather with lightnings. Carrying umbrellas under adverse weather conditions is dangerous (<https://www.vivaxsolutions.com/physics/gcseelctrosttinduction.aspx>)

Metallic Objects' Nearness

In indoor activities, women use curved and sharp metal tools for getting fuels, cutting meat, fishes and vegetables (Fig. 6); metal pots with curved boundaries for cooking; and metal plates, glasses, bowls, spoons, etc. with curved periphery for serving meals (Fig. 6). Fatalities while working in the kitchen and dining have been included in the list.

The distribution of induced charges on cutting tools like a *bati*, a sickle, etc. and around holding handles of some cooking pots, and on the circular periphery of utensils are illustrated in Fig. 7. In adverse weather plowing by animals, the plowman, the pair of animals with tapering horns and the metal plow blade with the narrowing end (Fig. 8) together form a potential lightning target.

Domestic Animals' Nearness

Walking with/tending animals in stormy weather is dangerous. Small ones like chickens and geese have narrow and long necks and tapering beaks (<https://www.bbc.com/bengali/news-54936896>). Chicken dry skin resistance lies in the range of 350 to 544 k Ω . Goats and sheep (<https://www.observerb.com/2015/02/23/74178.php><https://www.kalerkantho.com/online/miscellaneous/2020/04/09/896827>) and cattle have induced charge accumulation on the gradually narrowing horns with sharp ends (Fig. 9). Also, ears narrow down at the end. Many incidences of lightning hits while tending cattle, carrying cattle to field, bringing cattle home and even getting cattle in cowsheds were included in the list of engagements. At 60 Hz, the conductivities of buffalo horns is 2 nanoS/m (=2 nano Ohm.m) (<https://www.daily-bangladesh.com/country/195995>; Shaik and Siddiqui, 2015). Electrical conductivities of other domestic animals' horns may be guessed from this figure. These large animals can be easy targets because of their heights. Cattle fall in a

very risky situation if they are crossing a waterbody in a stormy weather. 28 buffaloes were killed by lightning on 25 April 2015 in Patuakhali, a district in the south of the country (<http://www.u71news.com/?page=details&article=2041230>).

Human skin offers more than 99% of the body's resistance to electric current flow. Dry human skin offers a resistance of 100 k Ω or more, but under wet condition with sweating, rain, showering and bathing, the skin may offer about 1 k Ω . Human mucous membrane offers about 100 Ω resistance and the internal body offers about 300 Ω due to the wet, relatively salty tissues beneath the skin. Unsubstantiated claims say that human hair conducts electricity whereas hair experts provide ample evidence that it is an insulator. Since lightnings turn insulators to conductors, human hair and animal hair/fur will play the same role – will become upright due to repulsion for being positively charged. (<https://stock.adobe.com/ee/search?k=static+hair>; <https://freerangeamerican.us/possible-lightning-struck-elk/>) (Tulachan *et al.*, 2016).

Dry cattle skin resistance is 375 k Ω (Lange, 1967a; 1967b) and that of wet skin is 1.1 k Ω . Their internal resistance lies in the range of 350 to 544 k Ω . Thus, electrical resistances of human and animal bodies mostly lie in a few hundreds to less than two thousand kilo Ohms.

Fatalities and injuries occur in raising and serving cows. A cow's anatomy is presented in Fig. 10. At 60 Hz current frequency, the impedances of the various pathways of current in a cow's body are mentioned in Table 2. Humans have higher resistance than dairy cows because of the latter's nearly always contact with moisture - eat with moist mouth, hooves remain in contact with urine, water and feces (USDA, 1991). The impedances may give an idea of lightning attraction to cows and the cowman.

Trees that have sharp edges in their leaves are coconut (*cocos nucifera*), date (*phoenix dactylifera*), palm (*phoenix dactylifera*), royal palm (*roystonea regia*, <https://www.backyardnature.net/yucatan/royal-pm.htm>) and pine (*pinus*) (Fig. 11). Out of these, date tree leaves have the hardest and sharpest ends. These trees have, even, sharp thorns. Among this group, date trees will be the first to catch lightning. Mango tree buds carrying mangoes hang down, but the ones having no mangoes stay upright and have tapering ends in their branches. It is a common occurrence to be struck by lightnings in picking mangoes in stormy weather with lightnings.

Carrying Jewelries

In both indoor and outdoor, women use some kind of metal jewelries that are beautified with curvatures and gaps and some even with sharpness which are characteristics of attractive lightning subjects because of induced charges (Fig. 12). Women have been struck with lightnings in courtyard work relating to boiling, cooking, cutting, cleaning, etc. in open areas.

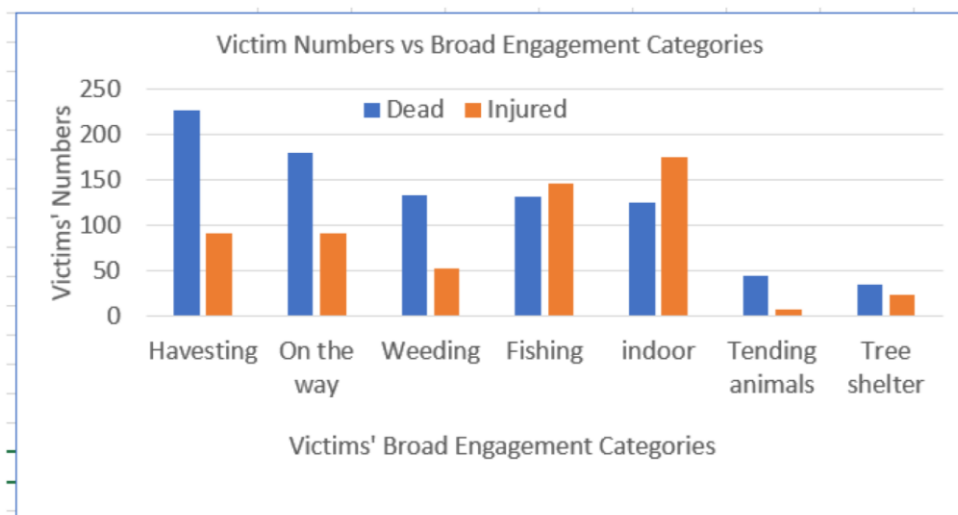


Fig. 3: Engagement-based victimization



Fig. 4: From the left, (1st inset): Rice harvesting using sickles (pictured in Fig. 6); (2nd inset): A harvestable rice field; (3rd inset): Young rice plants where weeding is done; and (4th inset): A grass field. Rice plants and grass all have leaves with sharp tapering ends



Fig. 5: From the left, (1st inset): An onion field; (2nd inset): A garlic field; (3rd inset): Jute cutting with sickles; (4th inset): An eggplant field



Fig. 6: From the left, (1st inset): A *boti* used in cutting fish, meat, fruits and vegetables; a small sickle used in cutting fruits, vegetable and light branches of trees; a large sickle used in cutting fish, meat, fruits, vegetables, branches of trees and harvesting crops; and a straight *daa* used in cutting meat, bamboos, hard branches of trees and dry branches for fuels; (2nd inset): A curved *daa* with sharp concave side; (3rd inset): A saw with sharp and pointed teeth used in cutting trees and piecing wood; (4th inset): A round rimmed cooking utensil

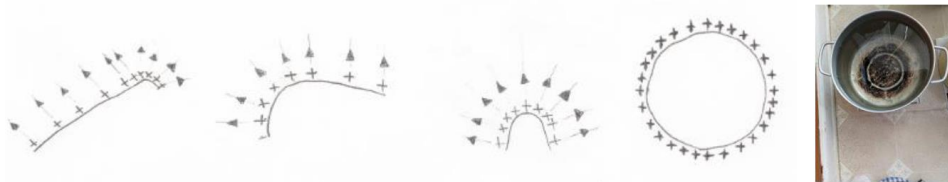


Fig. 7: From the left, (1st inset): Induced charge distribution on the top and the rest part of a *boti*; (2nd inset): Induced charge distribution on a sickle; (3rd inset): Induced charge distribution on a *korhai* handle; (4th inset): Induced charge distribution on the rim of a *korhai* or any other circular metal pot; (5th inset): An image of a *korhai*



Fig. 8: From the left, (1st inset): A *kodal* used for loosening, removing and digging soil; (2nd inset): an axe for cutting trees, wood, etc.; (3rd inset): plowing by bulls a watery land for planting rice seedlings; (4th inset): plowing a rice harvested land. Animal-pulled country plows' metal blades are about 50 cm long, 20 cm end width, 3 cm thick with sharp and tapering tips



Fig. 9: From the left, (1st inset): Ducks in a waterbody; (2nd inset): A goat; (3rd inset): A cow; and (4th inset): A buffalo

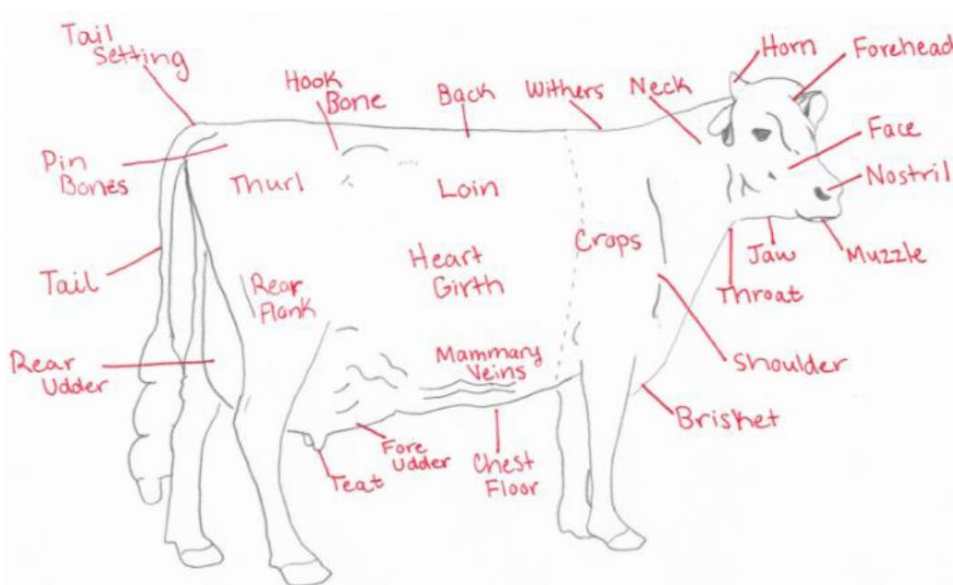


Fig. 10: The cow anatomy (following <https://animalcorner.org/cow-anatomy/>)



Fig. 11: From the left, (1st inset): Coconut trees; (2nd inset): A date tree; (3rd inset): A palm tree; and (4th inset): An old and (5th inset:) a young mango trees carrying buds



Fig. 12: From the left, (1st inset): A necklace and earrings; (2nd inset:) Bangles and a finger ring

Table 1: Sample Initial tabulation of data for part of June of 2007

Date: Yr 2007	Place	Time and Engagement	Numbers	Source
June 5	Chapai Nababganj	Dawn lighting	2 killed	https://bangla.bdnews24.com/bangladesh/article387431.bdnews
June 5	Shibganj in Nababganj	Dawn lightning	4 killed	
June 5	Gournadi Upojila in Barisal	Sitting on the balcony	2 women killed	
June 5	Manikganj Upojila in Manikganj	Paddy harvesting at 7 am	1 killed	
June 5	Douloutpur Upojila in Manikganj	Sitting on the balcony	1 killed	
June 5	Mirpur Upojila in Kustia	Working in rice field	1 killed	
June 5	Bheramara Upojila in Kustia	Walking to the market	2 wounded	
June 5	Bheramara in Kustia	Working in the room	1 woman wounded	
June 5	Fakirhut Upojila in Bagerhut Dist	Sitting on the balcony	1 eleven yr killed	
June 5	Charbhadrasan in Faridpur	While keeping two cows in the cowshed	1 farmer and 2 cows killed	

Table 2: Bovine Inter-organ Impedances

Pathway	Subjects	Frequency (Hz)	Resistance (Ohm)	
			Mean (Ohm)	Range (Ohm)
Mouth to all hooves	70	60	350	324-393 (Craine <i>et al.</i> , 1970)
	28	60	361	244-525 (Norell <i>et al.</i> , 1983)
Mouth to rear hooves	28	60	476	347-776 (Norell <i>et al.</i> , 1983)
Mouth to front hooves	28	60	624	420-851 (Norell <i>et al.</i> , 1983)
Front leg to rear leg	5	60	300	250-405 (Lefcourt, 1982)
	13	60	362	302-412 (Lefcourt <i>et al.</i> , 1985)
Front to rear hooves	28	60	734	496-1152 (Norell <i>et al.</i> , 1983)
Rump to all hooves	7	50	680	420-1220 (Whittlestone <i>et al.</i> , 1975)
Chest to all hooves	5	50	980	700-1230 (Whittlestone <i>et al.</i> , 1975)
	?	50	1000	? (Woolford 1972)
Teat to mouth	28	60	433	294-713 (Norell <i>et al.</i> , 1983)
	4	50	880	640-1150 (Whittlestone <i>et al.</i> , 1975)
Teat to rear hooves	28	60	594	402-953 (Norell <i>et al.</i> , 1983)
Teat to front hooves	28	60	874	593-1508 (Norell <i>et al.</i> , 1983)
All teats to all hooves	6	50	1320	860-1960 (Whittlestone <i>et al.</i> , 1975)
	?	50	1000	? (Phillips <i>et al.</i> , 1963)
Udder to all hooves	12	60	1700	650-3000 (Drenkard <i>et al.</i> , 1985)

Sheltering Under Corrugated Tin Sheds

Incidents in which subjects were inside rooms, praying in mosques, sheltering under sheds, being in school buildings, cleaning rooftops, etc. were included in the list. In all these cases, roofs were made of corrugated tin (which is steel - iron alloyed with commonly 0.3% carbon with electrical conductivity of $\sim 10^7$ to 10^7 S/m) (Fig. 13). In the wavy ups and downs of corrugated tins, induced charges accumulate both on the top and the bottom sides. So, corrugated tin roofs cannot give protection against lightning. On 11 August 2012, 13 Muslim worshippers were killed and 15 injured when a lightning struck a mosque in a remote village in northwest Bangladesh (<https://www.daily-sun.com/post/568530/Death-toll-hits-17-in-C%E2%80%99nawabganj-lightning-strike%27afterhttps://tribune.com.pk/story/420728/13-die-aslightningstrikes-bangladesh-mosque-during-taraweeh>).

Cart-Vehicle Transportation

Riding in open metal vehicles or on rooftops of vehicles on land or on water or on animal-pulled vehicles under stormy with lightnings or drizzling with lightnings is not safe (<https://www.alamy.com/chittagong-bangladesh-december-22-2017-typical-steet-life-with-rickshaw-traffic-in-chittagong-bangladesh-image347475348.html>):<https://www.banglanews24.com/national/news/bd/671003.details>). Fatalities from lightning strikes on animal-pulled carts and engine-driven vehicles under such conditions have been included in the list of engagements (<https://bangla.bdnews24.com/samagrabangladesh/article1330111.bdnews>).

Waterbodies' Nearness

In fishing, numbers of dead and injured ones are almost the same (<http://en.bdfish.org/2010/09/fishing-technique-rural-areas-northern-bangladesh-monsoon/>). Fishing hooks are made of metal with sharp tips. Fishing rods have metal control system. Fishing nets have metal sinkers as weights (Fig. 14). Subjects were victimized in all ways of fishing at the onset of or during a bad weather. Fatalities occurred in fishghers where nets were used with metallic small cylindrical sinkers.

Water always evaporates from water bodies. And moist air is better conductor of electricity than dry air. For example, the conductivity is found to be 1.1×10^{-14} S/m in 80-90% relative humidity in the region of Somali current in the western Indian ocean (Kamra *et al.*, 1997). The marine air above the equatorial Indian ocean has a conductivity of 2.3×10^{-14} S/m where the relative humidity is 70-80%. The author was attacked by lightning side flashes that travelled from a lightning-struck date tree across a nearly 75- m wide water body to the north of the lightning spot. Life was as usual on the other sides of the lightning spot that were not separated water bodies (Adel,

2016). Air resistivity lies in the range of 10^9 to 10^{15} Ohm.m and conductivity in the range of 10^{-15} to 10^{-9} S/m at 20°C (Serway, 1998). Out of a group of seven workers four died while eating lunch under a straw shed beside a waterbody. Also, two goats died (<https://bangla.bdnews24.com/samagrabangladesh/article1398521.bdnews>).

Sheltering Under a Tree

The world trees evaporate more water than the world's rivers discharge. So, air is moist over plants and treetops. It is not wise to seek shelter under trees or work in dry or water-logged crop fields with metal tools under adverse weather conditions to be lightning favored for multiple reasons. Several cases have been counted in preparing the victims' list.

Annual Number of Lightning Strikes and the Increasing Trend

The highest number of lightning incidences occurred in 2018 (Fig. 15). There is an increasing trend in lightning strikes up to 2018. The low number in 2017 might be related to data acquisition and reporting to the media if the reasons for increasing lightning strikes were in keeping with those in the preceding and the following years. Other online media may be consulted to check the truth of the statement on the media's role. Since the objective is to search for the engagement-related physical reasons of the fatalities and injuries, other news media were not consulted for an explanation. The fact that there have been subjects hit by lightning even when staying inside a room, excludes the fact that lightning targets depend on how many potential subjects are outdoor. However, regionally created circumstances like turning localized sources of water into distributed ones may increase the number of lightning as evidenced from NASA's image (Adel, 2013a). Ground heating causes the rise of warm moist air. As the sun heats up the ground in the warm season rapidly increasing environmental lapse rate (5 K/km) surpasses the dry adiabatic cooling rate (9.8 K/km) in a shallow layer that becomes turbulent. As the day advances, the layer grows deeper (Henry and Heinke, 1996). As the hot and humid air rises up from a hugely distributed area, it expands because of the drop of atmospheric pressure. Due to expansion, the temperature of the air mass drops according to the dry adiabatic cooling. Cumulus clouds form first from the rising hot and humid air (Fig. 16). Moisture condensation increases the temperature. The inside temperature of cumulus clouds becomes hotter than the ambient outside temperature. This results in agitation inside the clouds promoting higher altitudes because the motion reduces pressure and increases the buoyancy according to Bernoulli's equation:

$$P + \frac{1}{2} \rho v^2 + \rho gy = \text{constant}$$

which indicates the sum of the pressure P , the kinetic energy per unit volume $\frac{1}{2} \rho v^2$ and the potential energy per unit volume ρgy of fluid motion. The agitation leads to charge separation due to friction between tiny ice crystals in the cloud with the increase of relative motion, The video in the link <https://www.weather.gov/safety/lightning-science-electrification> shows droplets acquire greater charges than when they are at rest (Gunn, 1954). The faster the uplifting hot and moist air, the more the occurrences of lightnings (Sanders, 2014; <https://www.weather.gov/jetstream/lightning>).

One relevant information for increased lightning in 2018 might be that the irrigated area was 5556614 hectares in 2017–2018 rabi season which is 0.53 % higher than 2016–2017 rabi season irrigated area of 5527266 hectares. And 73.44% of total irrigated area i.e., an area 4081041 hectares was done by groundwater (BADDC, 2019) more than 40% of which evaporates in the air. This could be a partial explanation if it crossed any sensitive critical limit i. e., the threshold value which is present in all physical occurrences.

Dewan *et al.* (2017) explain the increasing trend is due to the increase of cellular phone services in the country (Fig. 17) by 47% in less than five years. The increase was from 87 million in January 2012 to 128 million in July 2016 - it was a growth of 10% per year (<http://www.btrc.gov.bd/content/mobile-phonesubscribers-bangladesh-july-2016>). This explanation cannot be tenable because of the fluctuations (viz., the dips in 2013, 2017, 2019, and 2020) observed in annual number of disastrous

lightnings. Also, news media have always had area-based reporters to cover news items even though reporting would be late. However, the increasing population in the country from 107 million in 1990 to 163 million in 2016 that shows a 52% change in a growth at the rate of 2% per year could be a plausible partial reason because people's movements have increased with the population increase and their dwelling places have increased.

Thompson reported of a 12% increase in lightnings for each degree Celsius rise of temperature (Romps *et al.*, 2014; Thompson, 2014). The upstream water piracy-caused summertime maximum temperature plot (Fig. 18) shows, at least, 4 degree Celsius rise. This indicates about 50% increase in lightnings. The temperature increase has increased the relative humidity (Fig. 19) consequent upon the heavy withdrawals of groundwater following Indian upstream water piracy from the Bangladesh Gangetic ecosystem (Fig. 20) using many tricks, bullying and false promises resulting in domino effects (Adel, 2013b, 2013c, 2015a, 2015b, 2015c, 2015d, 2015e). Two-thirds of the original Ganges discharge are pirated. The entire Ring of Dams and Barrages is shown in Fig. 21. According to Bangladesh's Met Office, prior to 1981, the country saw lightnings strikes on average nine days each May. Since that time, the country has seen strikes an average of 12 days each May (<https://in.reuters.com/article/bangladesh-lightning-disaster-idINKCN0Z81U4>). The year 1981 is near the threshold time of the summertime temperature increase as shown in Fig. 18.



Fig. 13: Corrugated tin shed roofs. Brickbuilt walls have corrugated tin sheds



Fig. 14: From the left, (1st inset): Fishing hooks; (2nd inset): Weight (sinkers) of a throw net; (3rd inset): About to be thrown a throw net; (4th inset): A cast net is sinking in water

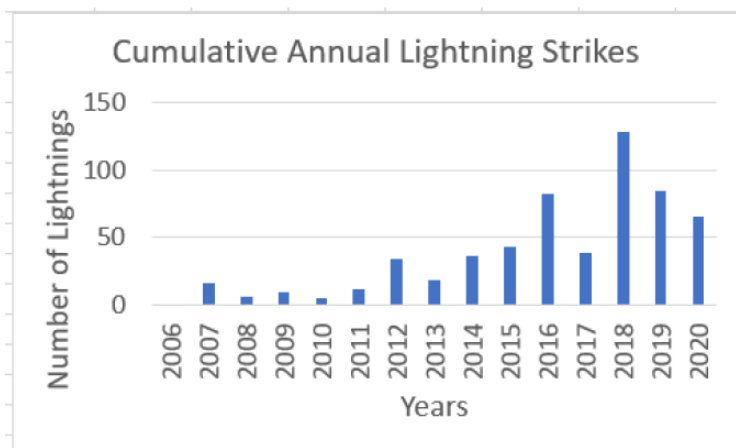


Fig. 15: Cumulating annual lightning strikes

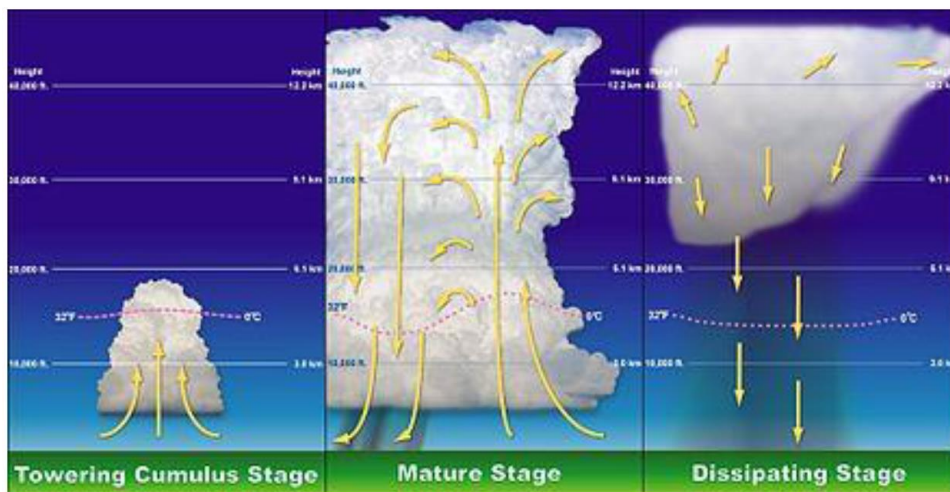


Fig. 16: The graphic on the left shows the rise of warm, moist air due to heating of the ground surface (NOAA, 5 January 2010)

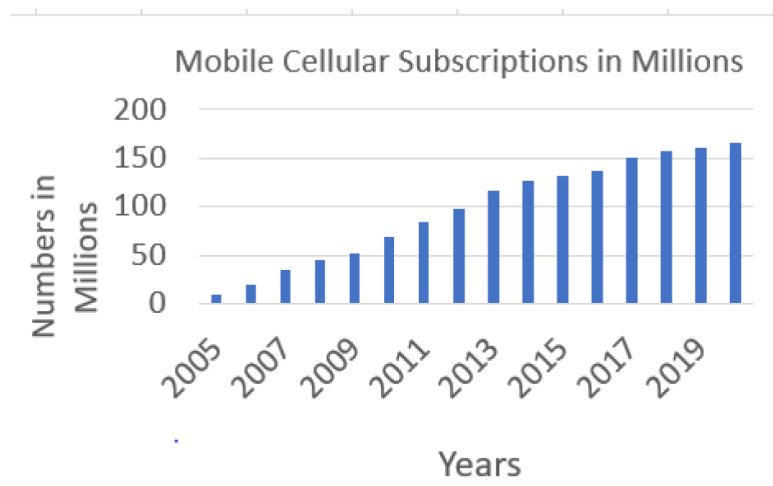


Fig. 17: Increase of cellular phone subscribers during 2005 -2018 (<https://www.statista.com/statistics/497091/number-of-mobile-cellular-subscriptions-in-bangladesh/>)

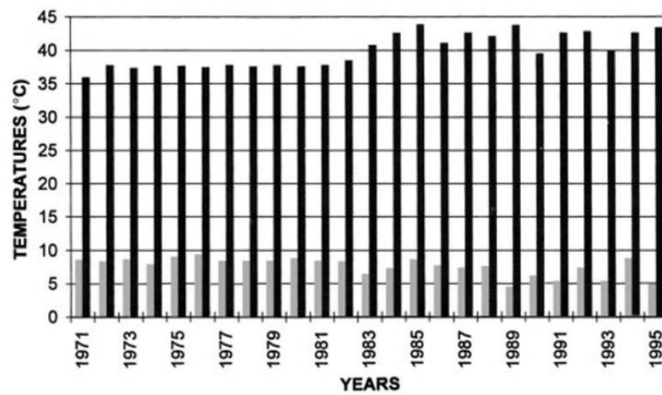


Fig. 18: Plot of annual maximum and minimum temperatures versus year s for the project site (Adel, 2002)

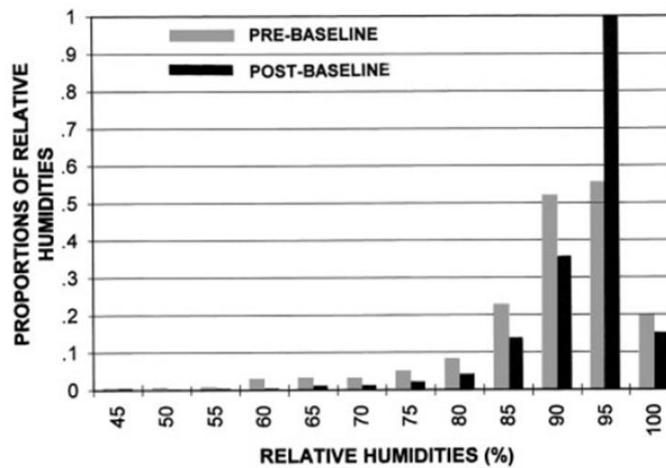


Fig.19: Illustration of the proportions of the minimum relative humidity for pre-and post-baseline periods (Adel, 2002)

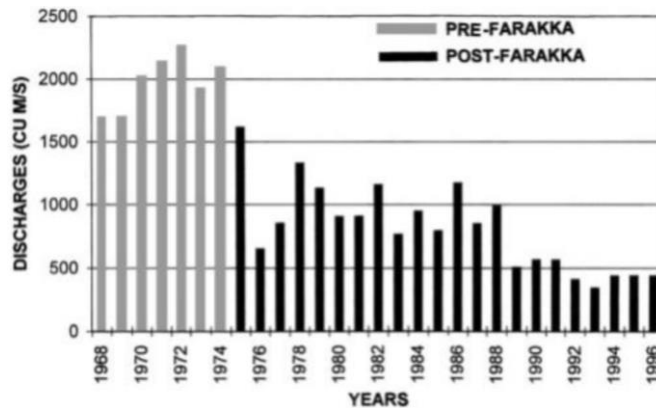


Fig. 20: Illustration of the average annual discharge rate of the Ganges through Bangladesh (Hebblethwaite, 1997), the drastic result of Indian water piracy from the Ganges since 1975 through false promises, bullying and tricks

The two main classes of devices for widespread irrigation in Bangladesh are - motorized pumps that include deep tube wells, shallow tube wells, turbine pumps, low lift pumps, etc. and manual pumps that include dons, swing baskets, treadle pumps, hand tube wells, etc.

(<http://en.banglapedia.org/index.php/Irrigation>). The countrywide irrigation systems use 26,704 deep tube wells, 4,69,22 6 shallow tubewells, 56,829 low lift pumps, 1,42132 manual pumps and more than 5,65,000 indigenous water lifting devices with an efficiency of only 30% (<https://www.google.com/search?sxsrf=ALeKk03q6d8Y>

4SloIxOmQaJ2N-ff3eEf3A:1626373742979&source=univ&tbm=isch&q=irrigation+in+Bangladesh&sa=X&ved=2ahUKEwiR_OKp2uXxAhVGc60KHSMcCJkQ4216BAgLEAQ&biw=1152&bih=601). The irrigation increase during 2005 through 2017 is shown in Fig. 22. Irrigation turns points or hidden sources of water into widespread distributed ones. At least 40% of this water evaporates into the atmosphere which was not occurring when the Ganges would bring flood water to floodplains to recharge groundwater. During hot days of May, brisk evaporation of this water occurs.

Riskiest Month May

May tops the list of cumulative monthly lightning strikes (Fig. 23). The reason is related to the distributed sources water used in irrigation. Groundwater withdrawals starts even from winter months. May covers Bengali months of almost mid-Baishakh to mid-Jaistha when it is very hot. Nor'wester occurrences are highest during these months. Since surface water sources are dry in these months, there are massive withdrawals of groundwater for irrigation and pisciculture (Fig. 22). Groundwater withdrawals add to the generation of lightning clouds. A new pattern has been created in the on-going piracy period. The previous balances of energy

and water have been disrupted. Lightning takes a heavy toll in India, too, (Adel, 2018) where numerous large sizes reservoirs and the irrigation there from over wide areas contribute more evaporation from distributed water sources than before. These anthropogenic activities are blamed for the observed weather changes. NASA's image of clouds over Indian reservoirs may be cited as a proof (Adel, 2013a).

Sunamganj Embraces Maximum Losses

Sunamganj (upper north-east corner in Fig. 2) is the riskiest district due to its physical features. People in this district go out for fishing and agricultural work. More people are outdoors there to attend multifarious activities. It has the highest number of haors (133) out of as many as 423 large and small haors in seven districts of Bangladesh. Haors are characterized by either stagnant water or flash flood water during June through November. They have bowl or saucer shaped depressions. In the wet season, they look like an archipelago of seas and settlements look like isolated islands. In the dry season they dry up except the deep ones (<https://en.wikipedia.org/wiki/Haor>). They hold little water in the winter season and are confined to small areas and their large areas are used in paddy and other crop production. These seasonal and perennial water bodies are connected to canals, rivers and other haors.

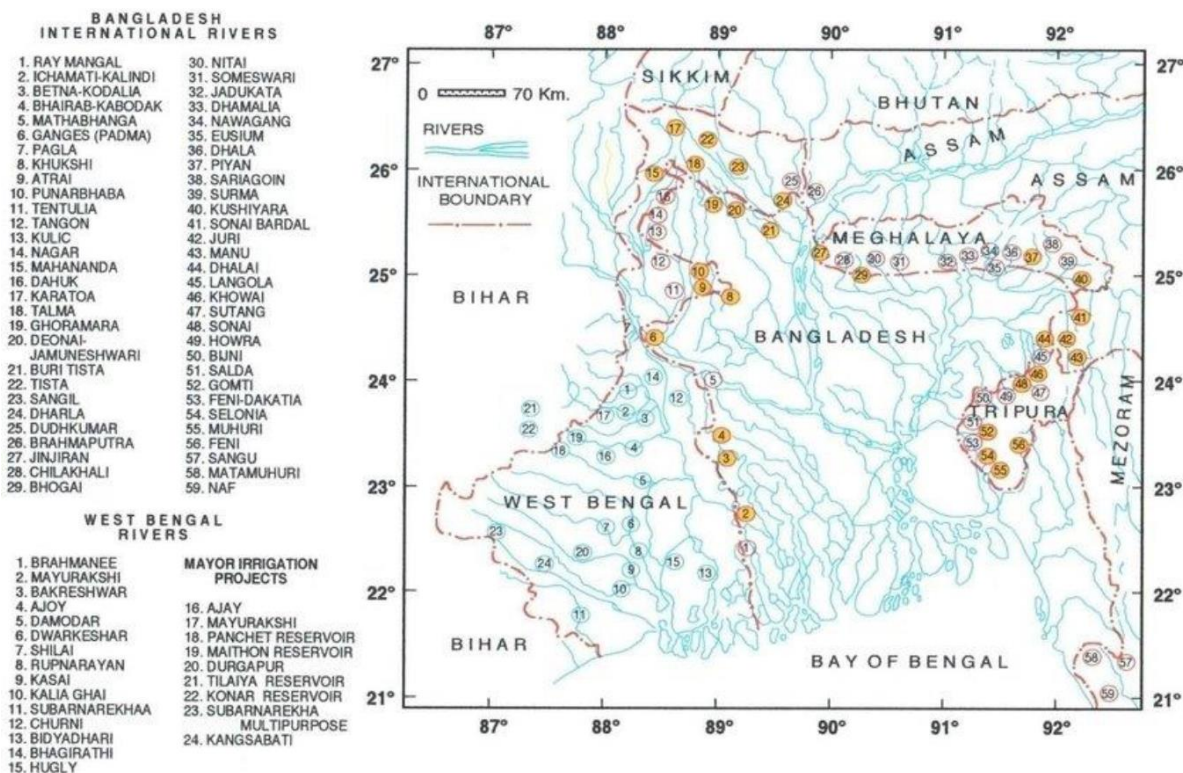


Fig. 21: Bangladesh, the dam-locked delta. Left side top shows the names of rivers. Water piracy goes upon, at least, the yellow-spotted ones on the map. Left side bottom has the list of West Bengal rivers and the dams and reservoirs on the tributaries of the Hooghly River (Adel, 2002)

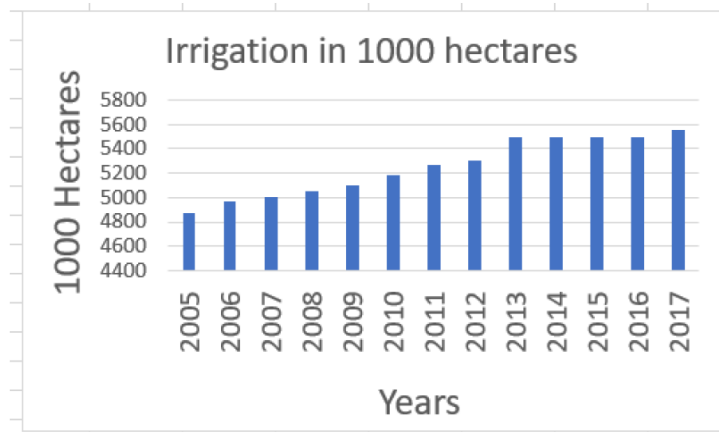


Fig. 22: Irrigation increase in the Ganges delta (<https://knoema.com/atlas/Bangladesh/topics/Land-Use/Area/Total-area-equipped-for-irrigation#:~:text=In%20>)

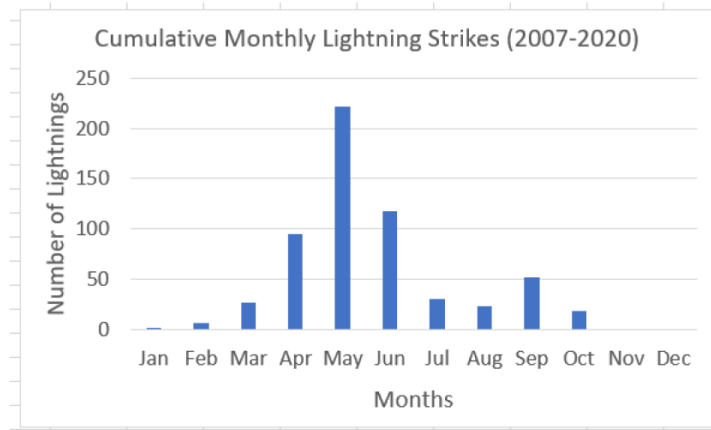


Fig. 23: May is the lightning month

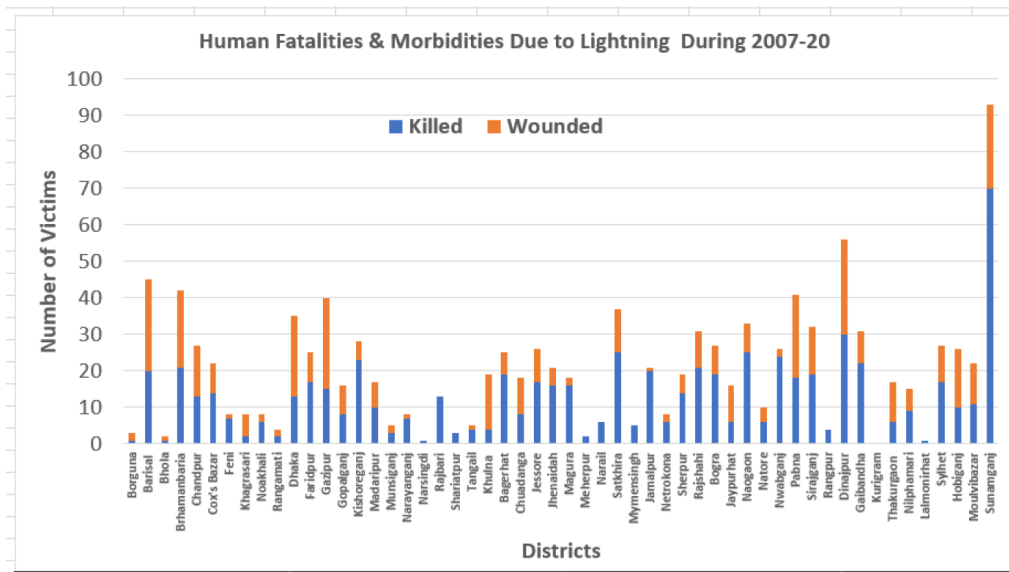


Fig. 24: District-wise lightning fatalities and injured ones

Boro paddy is grown during the months of November through April using irrigation. Out of the total cultivated areas of 1.26 million hectares cultivated land in the haor districts, 0.68 million hectares fall under haor area and about 80% of the haor area is used for Boro cultivation. Sunamganj has the highest acreage of land (0.18 million hectares) area under haor and the highest acreage (0.14 million hectares) of cultivated land area under haor. Also, Sunamganj has the highest total Boro cropped area of 136,000 hectares. And the typical input in Boro cultivation in haor area are human labor 282 mandays/ha, animal labor 89 hr/ha, power tiller 16 hr/ha and seeds 107 kg/ha (Alam *et al.*, 2010). Also, haors are natural fisheries resources. Fishes in the haors have great diversities. Various types of gears are used to catch various fishes depending on people's skills and interests. Fishing is the profession of fishermen to support their livelihoods and other people for partial support to run families. In a typical haor, 51 indigenous and exotica fishes comprise rare, common, and abundant classes. To catch these fish, people use gears like the current jal, the ber jal, the vassal/khorajal, the dharma jal, the jhaki jal and the thela jal among fish nets. Also, people use tengra, koi, gui, polo, dori, kon and ronga among the fish traps and barshi and hand borshi among hooks and lines. Peak fishing season from June/July through October/November. Other than the coastal districts (Suravi *et al.*, 2017), Sunamganj has the highest annual fish catch in a typical year - 94,277 metric tons in 2016-17 (FRSS, 2017; Shamsuzzaman *et al.*, 2017).

Mitigation

Alternative Materials

The very lifestyle of these deltaic people, possibly, make them comparatively vulnerable to lightnings. In indoor engagements, women of all ages wear some metallic jewelry either in hand, neck, ear, or nose. Kitchen utensils - cooking pots, spoons, plates, glasses, etc. and different forms of cutting tools including sickles - all are made of metals.

Female students wear metallic jewelry, use wrist watches and may carry cell phones. In one incidence 20 female students were wounded as they waited on the school balcony for rain to stop before leaving for home after school dismissal (<https://bangla.bdnews24.com/bangladesh/article552608.bdnews>). They were potential targets even if they did not have any metallic articles with them. The reason for the incidence could be a lightning that struck a nearby site/object and the side flashes from the strike reached them. The author including a few of his classmates were hurt by lightning side flashes while working together in an open-door dormitory room located beside and facing a huge pond across which a date tree was struck by lightning on a cloudy day.

To circumvent the metallic stuff usage, earthenware or China clay cooking pots, plates and glasses, and wooden spoons and other sticks may be used. Dry wood

that has an electrical conductivity of 10^{-16} to 10^{-14} S/m and resistivity of 10^{14} to 10^{16} Ohm.m at 20°C Celsius can be used to make stirring sticks. Damp wood shows a conductivity of 10^{-4} to 10^{-3} S/m and a resistivity of 10^3 to 10^4 Ohm.m at 20°C (<http://www.transmission-line.net/2011/07/electrical-properties-of-wood-poles.html>). Aluminum has 75 trillion times more, iron has 20 trillion times more, and silver has 120 trillion times more electrical conductivities than clay of electrical conductivity $\sim 5 \times 10^{-5}$ to 5×10^{-4} S/m (<https://www.rfcafe.com/references/electrical/resistivity.htm>). Clay and earthenware pots, glasses and bowls may be used to replace the metallic ones. And metallic ornaments may be replaced by beaded ones that can be made of materials like stone, bone, shell, glass, plastic, wood, or pearl. Also, cell phones and key bunches may be placed in sacs of rubber that has an electrical conductivity of 10^{-14} S/m or plastic that has an electrical conductivity of 10^{-17} to 10^{-16} S/m. Umbrellas must not be carried in adverse weather days.

The electrical conductivity of iron at 20°C is 10^7 S/m. On the contrary, it is 1.43×10^{-7} S/m for carbon-steel. So, tools made of carbon-steel will be about 70 trillion times less conductive than iron tools (<https://www.thoughtco.com/table-of-electrical-resistivity-conductivity-608499>). Carbon-steel contains 2 to 2.5% more carbon than pure steel (<https://monroeengineering.com/blog/pros-and-cons-of-carbon-steel-what-you-should-know/>). Farming equipment for field work and household cutting tools may be made of carbon-steel. The introduction of carbon-steel tools for agricultural field work and household use has the possibility of reducing lightning strikes. Nails and other metal products used in house building may be made of carbon-steel. Clay has an electrical conductivity of the order a millionth S/m. Earthen tiled roofs may be planned instead of tinned roofs. Cast net users for fishing should replace the iron weights with carbon-steel weights or China clay weights. Bells on cattle's necks may be made of carbon-steel instead of other metals. Fence building metallic materials around properties should be made of carbon-steel. It may be mentioned that nearly two dozen cows were instantly electrocuted in northern Texas when a metal fence they were lined up against was struck by a lightning (<https://www.newsweek.com/electrocuted-cows-row-1459229#:~:text=Nearly%20two%20dozen%20cows%20were,Annona%2C%20Texas%2C%20last%20month.>). In building passengers/passersby shelters, the metallic parts should be made of carbon-steel. It is a good idea to use carbon-steel parts/bodies in vehicles and tractors instead of other metals. Blades of animal-pulled plows should be made of carbon-steel. Metallic parts in umbrellas, too, should be made of carbon-steel.

Prostration the Safest Shelter from Lightning

Figure 25 shows the Muslim prayer prostration where seven limbs touch the ground. These are the two toes, the two knees, the two hands, and the forehead-nose. After a lightning strike, the ground current flows in a hemispherical space centered on the lightning site, if the ground is homogenous. Circular arcs of equipotential lines have been drawn outward from the lightning target site in Fig. 25. The more the distance between the two equipotential lines, the more will be the potential difference between the lines, and the more current will flow between the lines. The three main circuits are on the left and right sides of the victim's body - one between the left toes via left foot and left knee, one between the left knee via the left thigh, the left side middle body, left hand and the left palm and one between the left palm via the left hand, left neck side and nose. An electric circuit is complete between two limbs through touching the ground as in the case of toes and limbs. Three similar circuits are created on the right side of the body. The distance between the toes and the knee is barely a knee size (35-40 cm) and the potential difference for a knee-size distance apart limbs cannot be that large to cause fatality. In a Muslim prayer position, the distance between the knee and the palm becomes less than one half of the knee-size. So, there will be even lesser current flow through the longest path from the knee through the thigh, the middle body part and the hand. About the third circuit, it can be said that basically, no current will flow from the palm to the nose because these two parts lie on the same potential line. Theoretically speaking, no current flows through the body if the two feet touch each other, knees touch elbows (hands), palms touch each other and the forehead in a squeezed position because the successive inter-limb distances zero out - the entire body will be at the same potential. In practice, the least current may flow through the body.

In the normal prostration position with unsqueezed body, there could develop a circuit from the left knee to the right palm across the body. This path is longer and so, involves more resistance than the path of the left knee to left palm, resulting in a lesser or no current. The two knees being on the same equipotential line, no current is expected to flow from left knee to the right knee via the front genital part. Also, the two palms will pass through the same equipotential resulting in no current flow from left palm via the hand and shoulder to the right palm. The nose and the forehead that touch the ground remain so close that little current flow may be expected. The Muslim prayer position is a very stable and comfortable position for all ages, sexes, and body weights and sizes that can be used on any terrain of land. This position reduces our height to less than the sitting height. This position offers shortened inter-limb distances which reduce interlimb voltages and consequently, the current (Adel, 2012, 2013b). The above facts are applicable if the lightning strikes ahead, behind, or any corner of the prostrating subject.

In the delta, the tall trees include date trees, palm trees, and coconut trees. Out of these, date trees have sharp thorns and sharp leaf tips. Also, they are more

watery than others and become the preferred targets (Adel, 2012, 2016, 2020).

Lightning flash can jump from a tree stem to an animal sheltering under the tree since it searches for the less resistive path to get into the ground. Metal objects are less resistive than animal bodies. And animal bodies are less resistive than trees which are less resistive than air. If the sheltered person is not far from the tree stem, he/she can be a victim of ground current. The current that goes into the ground following the tree trunk and then the roots can spread out over a hemispherical area centered on the trunk if the ground conductivity becomes homogenous in all directions. If the person is standing, he/she should stand touching two feet so that there appears little or no voltage difference between the two feet. The two feet can be separated if standing on the same equipotential line which remains unknown. If the person wants to step back, he/she jump off with the two feet together avoiding any potential difference between the two feet at the place of landing. Any potential difference can make current flow through his/her body. An easy solution to this uncomfortable and dangerous posture is to fall on prostration on the ground, preferably touching two feet together, two knees together, and touching any two fingers of the two palms. This posture offers the least current flow through the body.

Four-footed animals may lie down on one side with four legs touching each other and the neck and the head raised and the tail over the body. Animal horns should be covered with thick plastic covers. These animals may be trained by their grooms. Many domestic animals die due to lightnings devastating their owners.

Precautions in Fieldwork

Farmers and workers in the field may be attacked by direct lightning strikes or from either the ground current or the side flashes or from both of a nearby lightning-hit site. Also, some group members may be indirectly attacked by the above ways while others are hit directly. In bad weathers, it is not safe to weeding out crop fields, harvesting paddy, cutting grass, cutting jute, retting jute, washing jute, removing dirt, etc. in a group. If they need to do those works at all, certain rules need to be followed. In case of weeding, a row can be formed not laterally but on ahead-and-behind basis maintaining the standard distance between individuals each of whom will keep the least possible distance between their two feet and that between the two hands. The weeding tool is to be made of carbon-steel. If lightning strikes any nearby place or any of workers from the group, all other individuals will have to fall in prostration touching two feet together, two knees together and two thumbs from two palms together. This posture lets the minimum current flow through the body because of making the interlimb distance the least possible to reduce the interlimb voltage differences and thus saves from any ground current.



Fig. 25: Prostration is the best protection against lightning strikes (<http://www.wikihow.com/Pray-in-Islam>, reproduced with permission)

Also, it saves from the side flashes because of the lowered body height. Workers are recommended to have highly insulated footwear and palm wear. Group workers in the field should rehearse this practice to get used to.

If in open space the body tingles or the hair becomes upright, that place becomes risky for immediate lightning strike. The only means at this time is to fall in prostration in the way described above. Negatively charged clouds overhead induces positive charge in the body. An electric field is set up between the cloud and the body. Positively charged hairs become upright due to mutual repulsion among them.

Conclusion

It seems that the vulnerability of the Bangladeshi lightning victims lies in their very lifestyles under the condition of the upstream water piracy-caused summertime temperature rise. It is very unfortunate that while the CO₂-induced climate change receives a wide publicity, this upstream water piracy-induced climate change that is happening under the very nose is totally ignored. If these people do not want to change their state by raising voices like going to International Court of Justice, etc. no external agent is going to do it for them.

Recommendation

A change in the lifestyle of the deltaic people along with the usage of carbon-steel tools instead of iron tools, jewelries made of beads instead of metals and earthen wares utensils instead of metallic ones, wooden sticks in cooking instead of metallic ones, earthen tiled roofs instead of tin, and China clay weights instead of iron weights in cast nets, reforestation instead of deforestation, and planting of date trees, and limiting indoor and outdoor

activities on cloudy days can reduce the losses of lives and properties due to lightning strikes. Houses may be secured by setting up lightning rods. And the most important point is to be aware of the weather forecast before planning for outdoor works. Also, the falling into prostration should be rehearsed at home, schools, offices, in the field, etc. periodically like the fire drill in a building. Domestic animals, too, should undergo rehearsals for their protection, Centers may be set up for training domestic animals. Although the article has been prepared with the lightning victim data from Bangladesh, the same mitigation procedure will work for all countries in the world.

Acknowledgement

Sincere thanks to *bdnews 24.com* for the data sources and to those whose beautiful illustrations have made the article readable and graspable. Special thanks to Saiyeeda Hossain who drew some illustrations.

Ethics

The author is not aware of any ethical issues that may arise after publication of the manuscript. He has voluntarily tried to save the society with the least loss by investigating the causes of the increased lightning strikes and suggesting the mitigation strategies. It is up to the society to accept or reject his suggestions.

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