



Lightning incidence: Causes, impacts, and mitigation strategies from an agroforestry perspective

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ABSTRACT: Lightning is a powerful atmospheric phenomenon that poses significant risks to human life, livestock, biodiversity, and rural infrastructure. With increasing thunderstorm frequency linked to climate change and environmental degradation. Lightning has emerged as a major natural hazard, causing thousands of deaths annually, along with significant economic and ecological losses. Its impacts are severe and multidimensional: humans suffer burns, neurological damage, memory loss, cardiac arrest, and long-term psychological disorders. Crops and trees experience tissue combustion, vascular damage, wilting, and reduced productivity. Livestock and wildlife often face mass fatalities due to direct strikes and ground currents, and avian populations experience sudden mortality and habitat destruction. The disruption of ecological processes and rural livelihoods further intensifies vulnerability. Effective adaptation and mitigation require integrated approaches including lightning protection systems, early warning technologies, mobile-based alert applications, community awareness programs, improved land-use planning, and resilient agroforestry practices. This paper presents an overview of lightning, causes, types, impacts, and a comprehensive set of mitigation strategies, emphasizing the need for coordinated efforts to safeguard communities and agro-ecosystems from lightning-related threats.

Opinion Piece

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1. INTRODUCTION

Lightning is a powerful natural atmospheric phenomenon characterized by a sudden electrostatic discharge that occurs during thunderstorms. It is one of the most dangerous weather-related events, generating extremely high temperatures and electrical energy capable of causing severe damage to human life, livestock, crops, and property (Shelly, 2024). Globally, lightning causes more fatalities than many other natural hazards, such as earthquakes or floods, particularly in tropical and subtropical regions. India, due to its geographic location and monsoon-driven climate, is highly vulnerable to lightning incidents. Lightning strikes significantly affect agricultural laborers in the country, causing a substantial number of deaths each year (Figure 1). The frequency of thunderstorms and lightning has shown an upward trend as a result of global warming and increasing air pollution. Casualties are particularly high among rural populations, as agricultural workers and farmers often labor in open fields during the monsoon season, when lightning

activity is at its peak (Figure 2). This exposure increases the risk of fatal strikes, with adults comprising the majority of victims. Recent incidents highlight the urgent need for enhanced lightning safety measures, particularly for those involved in agricultural activities.

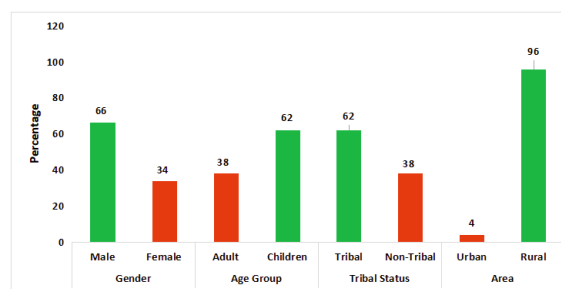


Figure 1. Distribution of lightning-related deaths in India by gender, age group, tribal status, and rural–urban population. Males, adults, non-tribal, and rural populations were most affected (Source: Annual Lightning Report 2020-21).

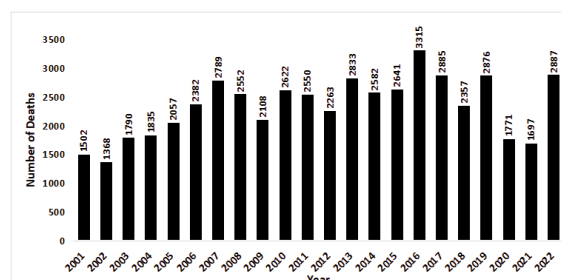


Figure 2. Annual lightning-related deaths in India from 2001 to 2022 (Source- www.ncrb.gov.in)

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Lightning strikes cause numerous casualties among humans (Table 1). In addition to human casualties, lightning also leads to significant losses in agriculture and forestry. Crops in open fields may be burned or destroyed by strikes, leading to reduced yields and economic losses for farming communities. Trees are natural conductors, which in turn affects biodiversity and vital ecosystem services. The dual threat of human casualties and damage to vegetation underscores the importance of studying lightning incidence and developing effective mitigation strategies.

2. TYPES OF LIGHTNING

Lightning can be broadly classified into Cloud-to-Ground (CG), Cloud-to-Air (CA), Ground-to-Cloud (GC), Intra-Cloud (IC), and Cloud-to-Cloud (CC) discharges. Among these, cloud-to-ground lightning is the most dangerous, as it directly impacts humans, animals, crops, and infrastructure (Figure 3). Intra-cloud lightning, which occurs within a single cloud, is

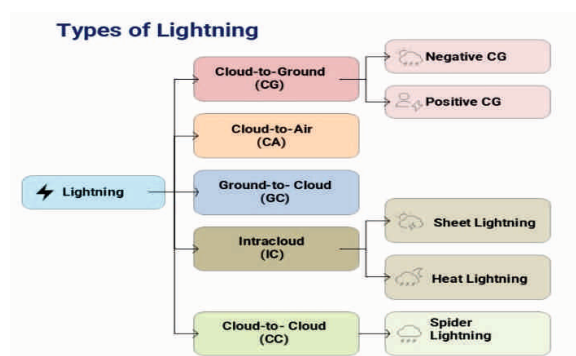


Figure 3. Classification of different types of lightning based on their discharge pathways (Rakov, 2007; <https://en.wikipedia.org/wiki/Lightning>, Akinyemi *et al.*, 2014)

the most common, while cloud-to-cloud and cloud-to-air are less frequent but still significant atmospheric events.

3. IMPACT OF LIGHTNING:

Lightning has widespread impacts on humans, agriculture, and biodiversity due to its intense heat, electrical energy, and shockwaves. Human fatalities are most common in rural areas, especially among farmers working in open fields during the monsoon. In agriculture, lightning can cause charring, lodging, and burning of cereals, pulses, and oilseed crops, while orchards and plantations may suffer vascular injury, canopy damage, and tree death. Electrical current or lightning travels from the tree's trunk through its roots before dissipating in the earth. Without considerable above-ground damage, a tree may deteriorate and eventually die as a result of severe electrical damage to its roots (Donahue 2014). According to Anderson and Anderson (1968), the tree's root system sustained significant physiological damage as a result of lightning, which gradually reduced hydrostatic pressure from the top down the bole. Livestock and wild animals grazing in open areas are highly vulnerable, often leading to multiple fatalities in a single event. Birds, especially those roosting in colonies or inhabiting wetlands, are also at high risk of electrocution and sudden deaths. These losses reduce agricultural productivity, threaten food security, and disturb ecological balance as well as rural livelihoods.

3.1 Agriculture: Plants serve as natural connectors for the establishment of the earth-to-cloud circuit of a lightning bolt, so helping the transfer of electrical charges between the earth's surface and the cloud. Tall vegetation

Table 1: Impacts of Lightning on the human body in percentages.

Impact on Body Part	Percentage	Impact on Body Part	Percentage
Memory Deficits & Loss	52 %	Depression	32 %
Attention Deficits	41 %	Inability to Sit Long	32%
Sleep Disturbance	44 %	External Burns	32%
Numbness	36 %	Severe Headaches	32%
Dizziness	38 %	Fear of Crowds	29 %
Easily Fatigued	37 %	Storm Phobia	29 %
Stiffness in Joints	35%	Inability to Cope	29 %
Irritability Temper Loss	34 %	General Weakness	29 %
Photophobia	34%	Unable to Work	29 %
Loss of Strength/Weakness	34%	Reduced Libido	26 %
Muscle Spasms	34%	Confusion	25 %
Chronic Fatigue	32%	Coordination Problems	28 %
Hearing Loss	25%		

Source: Kithil (1995)

offers advantageous pathways for the movement of electrons in the event of a lightning strike. Plants possess aqueous solutions containing ions that exhibit electrical conductivity. The presence of salts, soil minerals, and dissolved gases in water leads to the formation of charged ions. During a lightning strike, the upward movement of positively charged ions in the soil water and the plant itself occurs, causing burns and explosions in the plant.

The different impacts on agriculture are detailed below

- **Heat Damage:** Lightning produces intense heat, with temperatures exceeding 50,000 degrees Fahrenheit in a few milliseconds (www.nssl.noaa.gov). The application of heat causes the conversion of plant fluids into steam, resulting in the combustion of plant cells and tissues. This process leads to wilting, necrosis, and the scorching of various plant parts such as roots, stems, branches, and fruits. This intense heat causes instantaneous combustion and charring of plant tissues, resulting in leaf scorching, stem collapse, and desiccation of surrounding vegetation (Nelson, 2008). In crops, high heat exposure can denature proteins, disrupt chlorophyll, and impair photosynthetic activity, leading to reduced productivity. Trees often exhibit longitudinal cracks or bark explosions as internal moisture vaporizes rapidly. The extreme thermal stress can also sterilize localized soil zones, reducing microbial activity essential for nutrient cycling. Such heat-induced injuries significantly compromise plant growth, survival, and yield
- **Shock Wave Damage:** The fast expansion of air resulting from high temperatures generates shock waves, characterized by pressures that are 10 to 100 times greater than the pressure at sea level (Nelson, 2008). The occurrence of shock waves may result in the bursting of plant stems, the release of fruits, and the division of tree trunks.
- **Indications of Lightning Strikes:** Quick withering or collapse of plants, followed by structural damage or carbonization of interior tissues. The appearance of symptoms is prompt, developing within a few days rather than weeks, coinciding with the occurrence of recent thunderstorms. Lightning damage may be identified by the presence of circular patches of injured plants in fields or orchards,

premature loss of green fruit, burns, unusual scars, blackening of organs, and blackened or fried roots.

- **Impact on Surrounding Plants:** The occurrence of many ascending ground-to-cloud streamers emerging sequentially facing a solitary descending cloud-to-ground stepped leader has the potential to impact clusters of neighbouring plants. Lightning strikes in the vicinity of plants generate extreme heat, electrical discharge, and shockwaves that can severely damage surrounding vegetation. The sudden surge of current through the soil alters its electrochemical properties, leading to root injury, disruption of water and nutrient uptake, and in some cases, complete plant mortality. Trees adjacent to the strike point often exhibit bark splitting, leaf scorching, or vascular tissue collapse due to rapid vaporization of internal fluids. Herbaceous plants may show wilting, necrosis, or localized burn patches in the field. Soil microorganisms and rhizospheric interactions are also disturbed, indirectly influencing plant health. Collectively, these effects reduce crop vigor, lower productivity, and alter the micro-ecosystem around the strike site.

- 3.2 Cattle/animals:** Lightning strikes can be deadly for cattle and other animals, especially when they are grouped in open fields (Ebrahim, *et al.*, 2024). A single strike can kill multiple animals at once due to ground current spreading through the soil. Injuries may include burns, internal damage, or sudden death (Ebrahim, *et al.*, 2024). Proper shelter during storms is crucial to protect livestock. The impact of lightning strikes on cattle and animals is mentioned below

Direct Strikes

- Animals or livestock living in open fields are susceptible to direct impact from lightning.
- Direct impacts may lead to instant fatality as a consequence of the substantial electrical energy that crosses their bodies, resulting in internal burns, organ impairment, and damage to the nervous system.

Indirect Injuries

- Animals in close range to lightning strikes may encounter shock waves and blast injuries that are comparable to those experienced by people, resulting in blunt-force trauma and the possibility of hearing loss.

- Ground currents, sometimes referred to as step potentials, have the potential to impact animals that are positioned on or in close contact to the ground. This may result in injuries or even death as a consequence of the elevated voltage that traverses their bodies.

Psychological Impact

- Lightning strikes have the potential to induce nervousness and pain in animals, resulting in increased levels of panic and consequent stampedes, particularly among herds or groups.
- The enormous thunder that accompanies lightning strikes can shock animals, leading to erratic behavior and maybe resulting in harm to themselves or others.

Secondary Effects:

- Lightning strikes may result in fires that pose a hazard to the habitats or shelters of animals, possibly leading to habitat loss, injuries, or deaths.
- Fires caused by lightning may destroy plants, hence diminishing food resources for animals and disturbing ecological processes.

Long-Term Effects

- Anyone who has experienced lightning strikes may endure bodily damage or psychological trauma, which may have a significant impact on their general health and well-being.
- Lightning strikes can have significant economic effects for livestock owners, including the loss of valuable cattle, financial burdens associated with medical treatment for injured animals, and negative impacts on property or infrastructure.

3.3 Birds: Lightning strikes can cause direct mortality in birds, especially in large flocks roosting on trees or flying during storms. The intense electrical discharge and shockwaves can lead to internal injuries, burns, or disorientation. In some cases, lightning also damages nesting habitats and reduces local bird populations. Such events, though rare, highlight the vulnerability of avian species to extreme weather phenomena associated with climate variability. The impact of lightning strikes on birds is mentioned below

Direct strikes

- Direct lightning strikes can expose bird

species, especially those that rest or build nests in higher locations, such as trees, towers, or other tall, buildings.

- Bird species that are of considerable size or have the ability to fly at great heights, such as birds of prey and those that undertake long-distance migrations, may face an elevated level of danger during storm events.
- A direct lightning strike may be deadly because of the huge quantity of energy it carries.

Habitat destruction

- Habitat destruction refers to the process of damaging or destroying the natural environment where organisms live.
- Lightning has the potential to start fires or cause harm to trees that are essential for development and providing shelter.
- The indirect effect might have a prolonged influence on bird populations by diminishing the amount of habitat or food supplies, particularly in forests where some species extensively depend on certain tree species for reproduction.

Disturbance and stress

- Thunderstorms may cause disturbance to nesting birds due to the loud noise and bright light, which may result in stress or abandonment of their nests.

Effect on Population

- Although isolated lightning strikes may not have an important impact on bird populations as a whole, they may have an effect on local populations, particularly those that are already at risk or in danger of disappearing.
- The cumulative impact of losing reproducing adults, nests, or habitat can be significant, especially in cases where birds have a limited number of nesting locations or food supplies.

4. ADAPTATION AND MITIGATION STRATEGIES

Adaptation and mitigation strategies for lightning incidence aim to reduce risks to life, property, and the environment by combining structural, technological, and behavioral measures. Adaptation focuses on increasing resilience through the incorporation of lightning protection systems in buildings, towers, and

critical infrastructure; integrating lightning risk considerations into urban and land-use planning; promoting safe agricultural practices and tree management; and enhancing public education and awareness so that communities can adopt appropriate safety behavior during thunderstorms. Mitigation strategies emphasize reducing impacts through the implementation of early warning systems based on weather forecasting, the use of lightning detection networks for real-time monitoring and alerts, enforcement of building regulations mandating lightning protection in high-risk areas, continued research and development to improve protection technologies, community preparedness programs involving training and drills, and the use of mobile applications to disseminate timely warnings and safety guidance.

5. MOBILE APP FOR AVOIDING LIGHTNING INCIDENCE

In the present era, mobile phones are most commonly used by most citizens and farmers in the country. Several mobile-based applications have been developed to provide weather information and lightning incidence. Therefore, people can use these applications to avoid the hazards caused by lightning incidents. The following are the important mobile-based services along with their basic details (Table 2).

6. GOVERNMENT SCHEMES & LEGISLATIVE/POLICY MOVEMENT

The different government schemes assist the farmers in crop losses occurring due to natural lightning. Under Pradhan Mantri Fasal Bima Yojana (PMFBY), farmers are assisted when crop losses occur due to natural fire by lightning. The farmer has 72 hours to inform the insurance company via the Crop Insurance App, Krishi Rakshak Portal & Helpline, directly to the insurance company via its dedicated toll-free number, or through the relevant bank, local agriculture department, government, or district officials.

Assistance is provided when the affected area is greater than 25% of the total insured crop area. Despite crops, farmers can have their own insurance under Pradhan Mantri Suraksha Bima Yojana, where Rs. 2 Lakh is given in case of death and total and irrecoverable loss of both eyes/hands/feet while Rs. 1 Lakh is provided when the total and irrecoverable loss of sight of one eye/hand/foot.

7. CONCLUSION

Lightning is an increasingly severe natural hazard threatening human life, agriculture, livestock, and birds, especially in India. Its intense heat, electrical discharge, and shockwaves cause fatalities, plant tissue destruction, livestock deaths, and habitat damage. Rising lightning frequency, driven by climate change, heightens risks for rural communities working in open fields. The paper explains lightning types, mechanisms, and diverse impacts, emphasizing the vulnerability of agroforestry and agricultural systems. It highlights the importance of mitigation measures such as protection devices, early warning systems, mobile apps, community preparedness, and resilient land-use planning. Strengthened awareness and agroforestry-based strategies can significantly reduce lightning-associated losses.

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Table 2. List of mobile apps related to lightning incidence

Name of App	Country	Compatibility
My Lightning Tracker & Alerts	Netherland	iOS
Lightning Alarm Weather Plaza	Netherland	APK, iOS
Clime: NOAA Weather Radar Live	India	APK, iOS
Damini: Lightning Alert	India	APK, iOS
Vajrapath	India	APK
SIDILU	India	APK, iOS
Mausam	India	APK, iOS
Mausam - Indian Weather App	India	APK
Live weather: Weather forecast	--	APK
Weather Live - Local Forecast	USA	iOS, iPad, and Apple Watch.

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