Lightning - A Potential Cause of House Fires during the Pre-monsoon Season: A Case Study in Nepal

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Abstract—**The first study of possible lightning-caused house fires in Nepal has been developed. The locations and times of 13 house fires have been identified and matched with lightning location data from the Global Lightning Dataset GLD360 network from 2015 to 2019. It was found that closer to the fire locations, lightning stroke density was greater than further away. This result suggests that many of the fires attributed to electrical surges may have been initiated by lightning.**

Keywords—Nepal, house fires, lightning, electrical surges

I. Introduction

Lightning formation is associated with atmospheric convection in cumulonimbus clouds [1]. Lightning flashes are generated through buildup, separation, and transfer procedures of electric charges between cloud particles [1]. Lightning is the most important natural wildfire ignition source worldwide [2], and cloud-to-ground (CG) lightning is the primary ignition source of wildfires. There have been several studies on the wildfires that have been ignited by lightning flashes [3-6] and the references therein. In boreal forests of North America, lightning accounts for the majority of fire ignitions and about 56% of the burned area [7, 8]. We often come across the media reports on house fires being triggered by lightning, e.g. [9, 10]. However, systematic investigation of house fires triggered by lightning is very scarce. A study of home fires caused by electrical faults carried out for the years 2012-2016 over the USA reports 44,800 house fires that claimed 440 civilian lives and left 1,250 injured [11]. Another subsequent investigation carried out for the period 2015-2021 reports 46,700 house fires causing 390 civilian deaths and 1,330 injuries due to electrical failure and malfunctioning [12]. Although the aforementioned two reports [11, 12] are representative investigations, a report from the fire brigade of Kathmandu Metropolitan city for the year 2020/2021 shows that 80% of the house fires that the fire brigade responded were due to electrical faults. It is therefore, one can infer that electrical failure or malfunction are the major causes of house fires in the urban areas. There can be several reasons for electrical failures that ignite fires, and electrical over-voltages and surges contribute to a larger number of fire incidents. Such over-voltages and surges often result from lightning discharges.

House fires in Nepal are commonplace, particularly in the pre-monsoon season [9, 10]. Such house fires often lead to engulf the entire human settlement in the area of the incident causing tremendous loss of human lives, livestock, and physical property and hence huge economic loss for a nation. Recent studies have examined deaths and injuries due to lightning in Nepal [13, 14], and thunderstorms specifically in Nepal have been examined in several projects [13, 14, 15, 16, 17].

In the past few years, most of the house fires are reported to have been triggered by electrical short-circuits. However, these electrical faults often are induced by electrical surges produced by lightning flashes in the close vicinity, though the role of lightning in such incidents has not been the subject of investigation. To the best of our knowledge, this is the first such study for Nepal.

II. Methodology and Analysis

In this study, lightning has been investigated as a possible cause of house fire incidents during the pre-monsoon season over Nepal. For the analysis, lightning data were obtained from Vaisala's Global Lightning Detection GLD360 network. For each discharge, the network records the date, time, location, multiplicity, polarity, peak amplitude (Ip), and type of event (intra-cloud - IC or cloud-to-ground - CG). For the period of study, the GLD 360 network over Nepal has an average location accuracy of one to three km, a > 60% CG flash detection rate, and stroke times that are accurate within a few microseconds [20].

Reported house fires were extracted from the DRR portal of the National Emergency Operation Center (NEOC), Ministry of Home Affairs, government of Nepal [21]. For this study, 13 house fire incidents were selected as the reference points and concentric circles with radii of 2, 4, 6, 8 and 10 km were drawn around the fire points. Lightning densities over each circle were computed for the day in which the house fire incident took place. The stroke density for every house fire that contained at least one flash was analyzed for every 2 km fixed radius from the fire start points. First, a sum of the number of strokes that fell within 2 km of the fire radius was computed for each fire for the entire day that was closest in space and time to the fire ignition point. Stroke density was computed by taking the total number of strokes within the fire radius for 24 h of the day in which the closest lightning stroke occurred and dividing it by the fixed area (e.g., a 2 km fixed radius would be 4π or 12.6 km^2 and that for a 4 km fixed radius would be 50.3 km^2 and so forth). This resulted in an average stroke density across the entire search radius or fire footprint for the day in strokes per square km per day. The fixed radii around the fire point were calculated using the Haversine formula given by

$$d = 2r\, arcsine\left(\left(hav(\varphi_2 - \varphi_1)\right) + \cos(\varphi_2)\, cos(\varphi_1)\ hav(\lambda_2 - \lambda_1)\right)^{\frac{1}{2}}$$

Where,

d- is the distance between the two points along a great circle of the sphere (see spherical distance)
r- is the radius of the sphere.
φ_1, φ_2 - are the latitude of point 1 and latitude of point 2 (in radians),
λ_1, λ_2- are the longitude of point 1 and longitude of point 2 (in radians)
and
$Hav(\theta)= \sin^2\theta/2$

To locate the house fire points on Nepal's map, a shapefile of Nepal obtained from Department of Survey, government of Nepal, was used. Based on the information obtained from DRR portal we located the house fire points on Nepal's map as depicted in Fig. 1.

III. RESULTS AND DISCUSSION

In this study, we investigated the association of lightning strokes with house fires over the various districts of Nepal, to seek the likelihood of lightning surges contributing to the fires. For this purpose, clearly identified house fire points were selected around which the various circles with different radial distances were drawn and lightning densities were obtained for each concentric circular area. A composite map of the 13 house fire points and lightning density around each point is depicted in Fig. 2.

Fig. 1. Locations of 95 reported house fire points during the pre-monsoon between 2015 and 2019 according to the Disaster Risk Reduction portal under the Ministry of Home Affairs in the Government of Nepal.

Fig. 2. Composite map of selected house fire incidents and lightning stroke density for the day of 13 fires from among the total 95 fire incidents across Nepal during the pre-monsoon between 2015 and 2019.

For the selected 13 house fire points in the various districts, lightning strokes that were recorded by GLD360 were plotted as shown in Fig. 3 (a) followed by the lightning stroke density over each the district with 10x10 km^2 area as shown in Fig. 3 (b). After locating the house fire point within the district, lightning stroke densities around the house were obtained for various radial distances as shown in Fig. 3 (c).

Fig. 3 (a). Lightning stroke density over the whole Makawanpur district, which was the most lightning affected district [13] for the period under consideration during the 24 hrs of 2016/04/07.

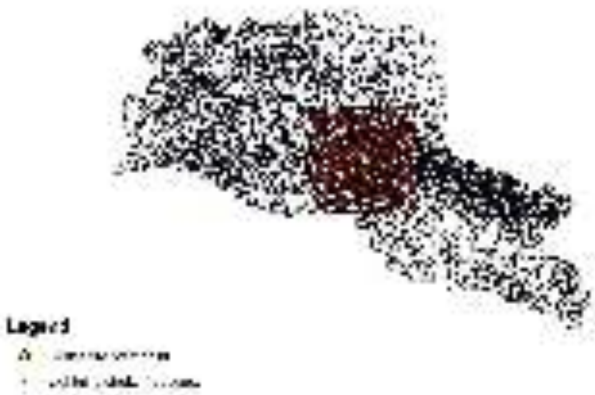

Fig. 3(b). Lightning density with a house fire that was ignited on the same day as in Fig. 3 (a).

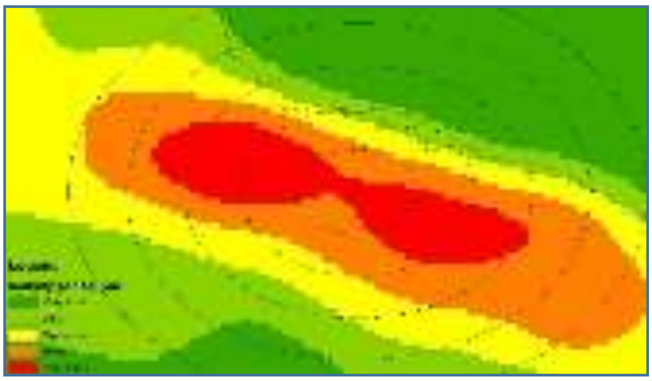

Fig. 3 (c) Lightning stroke density around the fire point at radii of 2, 4, 6, 8 and 10 km. Maximum lightning density is seen within six km of the fire point.

Lightning stroke densities around the selected 13 fire points were similarly computed over the circles at various radii. Shown in Table 1 are the computed values of lightning density (per sq km) over the circles under consideration for 13 districts. From Table 1, it can be seen that lightning stroke density for the first 2 km from the fire point is highest followed by the next circle with 2 km radius (i.e. within 2-4 km).

The ranges of lightning stroke density and an average stroke density were extracted for each circle and are depicted in Table 2. As is seen from Table 2, maximum lightning density has been observed within the first circular area (i.e. within 2 km) with a range of 1.08 km^{-2} and 1.91 km^{-2} and an average value of 1.49 km^{-2}. Also seen from the Table 2 is the trend average stroke density that decreases with radius. The minimum average stroke density is observed for the circular area of radius 8-10 km.

A graph showing the relation between the average lightning stroke density and radii of the circles was plotted as shown in \Fig. 4. For all the 13 house fires under consideration, lightning stroke density was found to be highest within the first km radial distances.

TABLE 1. LIGHTNING STROKE DENSITIES (KM^{-2}) OVER THE CIRCULAR AREA OF VARIOUS RADII FROM THE FIRE POINTS.

Districts	Radii of the circles (km)				
	0-2	2-4	4-6	6-8	8-10
Makawanpur	1.67	0.90	0.81	0.63	0.32
Kaski	1.08	1.01	0.87	0.54	0.41
Dhading	1.29	0.91	0.79	0.76	0.23
Kailali	1.13	0.86	0.89	0.69	0.54
Morang	1.76	1.12	0.99	0.73	0.48
Nawalpur	1.46	0.87	0.86	0.66	0.30
Udayapur	1.636	1.03	0.93	0.90	0.27
Illam	1.59	0.93	0.87	0.74	0.32
Jhapa	1.91	0.97	0.91	0.81	0.53
Sunsari	1.47	0.89	0.73	0.73	0.12
Tanahu	1.53	0.91	0.86	0.70	0.21
Baglung	1.76	0.92	0.88	0.69	0.15

TABLE 2. AVERAGE AND RANGE OF LIGHTNING STROKE DENSITY OVER THE CIRCULAR AREA OF VARIOUS RADII.

Radius (km)	Flash density range (km^{-2})	Average stroke density (km^{-2})
0-2	1.08-1.91	1.495
2-4	0.86-1.12	0.99
4-6	0.73-0.99	0.86
6-8	0.63-0.90	0.76
8-10	0.15-0.54	0.34

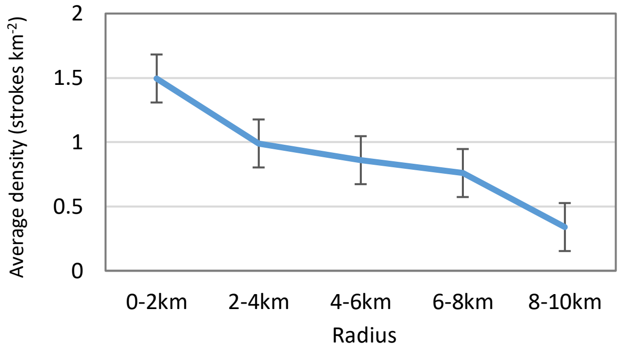

Fig. 4. Average lightning stroke density versus radial distance of the lightning strokes from the reported fire locations

Our investigation, using the lightning and fire data for the pre-monsoon season for 13 fires, shows that lightning stroke density within a radial distance of 2 km from the place of fire incidents is higher than that of the next 2 kilometers. The lightning stroke density in the closest radial distance of 2 km was found to vary from 1.08 to 1.91 strokes km^{-2}, whereas the density in the next 2 km was found to vary from 0.86 to 1.12. Our preliminary investigation shows that lightning-generated electrical surges can be the potential cause of house fires during the pre-monsoon season. It is to be noted that we have chosen the pre-monsoon for our investigation because lightning is prevalent during this season. Since, information on the location and time of house fire was obtained from the Disaster Risk Reduction (DRR) portal, the exact location (Lat-Long) and the time of fire break out are relatively vague. Although from the study it can be speculated that lightning might have triggered these house fires, more investigation is required for further confirmation of the outcome of this study by taking a closer look into the precise locations of the houses and times of the fire breakouts.

IV. SUMMARY

Lightning has become a major disaster in Nepal that claims over 100 human lives and at least 1,000 livestock each year. The economic loss incurred due to indirect effects of lightning has been largely underestimated. However, lightning is also a major threat to electronic and electrical appliances, and often leads to fire ignition and hence to house fires. As, a matter fact, the excessive use of electronic equipment particularly in the digital world the risk of electrical hazards has gone up since the solid-state devices used in such electronic equipment are extremely susceptible to the electrical surges created by lightning. Although, over current protective devices (OCPD) are generally used in low voltage electrical installations, the use of surge protective devices is very rare in Nepal and hence the protective measures against the electrical surge is very poor. The result of this work will be very useful to take necessary protective/preventive measures to mitigate the electrical fire hazards due to lightning, such as installing the surge protective devices while adopting the equipotential bonding techniques, and also to estimate the economic loss so caused.

Reported house fires during the pre-monsoons between 2015 and 2019 were examined to determine the number of events that could be associated with a lightning stroke. In total, 95 house fire incidents were recorded during this period of which 13 cases were selected for the analysis in this study.

The key observations were as follows:

1. Considering the house fire point as the center of concentric circles of radii 2, 4, 6, 8 and 10 km, lightning density within each circle was analyzed. From the analysis, it was found that at least one lightning stroke occurred within 2 km from the house fire point.
2. Lightning stroke density within a radial distance of 2 km from the place of fire incident is higher than that within the next 2 kilometers.
3. Both of the above observations indicate that lightning might have played a significant role in inducing the house fires under consideration.

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