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The temporal trends of lightning strikes and their impact on public safety in Nepal

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Abstract

Nepal is a landlocked country with high topographical variation having lowest point 59m and the highest point 8848.86m from the sea level that leads to the high variation in the temperature, climatic condition, and environment that generally resulting in Nepal to suffering from different natural disaster. Lightning is considered to be the major natural disaster that cannot be controlled. It affects the infrastructures, heritages, national monuments, tall towers of telecommunications and electricity as well as people. This study aims to investigate the effects of lightning on people. The data are extracted from Disaster Risk Reduction (DRR) portal which includes the number of the people's death and injured in last thirteen years due to lightning, annually and monthly. The number of injured individuals exceeded the number of the fatalities by nearly three-fold and no instances of lightning were observed throughout the month of November.

Keywords
Natural disaster, lightning, death, injured, DRR .

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1 Introduction

Nepal being famous for its highest mountains, rich biodiversity, and diverse climate is also susceptible to natural disasters. Among these, lightning poses a significant threat. The country's terrain is segmented into three primary regions: the Himalayan, Hilly, and Terai regions, with elevations ranging from 59 meters to the staggering height of 8,848.86 meters above sea level. This variation in altitude from very low land 59 m to the highest peak, 8848.86 m within the range of 160 Km, contributes to a temperature difference between the lowest land Terai and top of the Mount Everest is about 95°C which impacts weather phenomena in this region [1].

The temperature in the troposphere decreases with altitude. Due to this temperature variation, ice crystals and super-cooled water droplets move upward and downward inside the cloud that leads to the separation of electric charges. This charge separation results in the lightning phenomenon [2]. When flashes of lightning occur along with sound, it's commonly referred to as thunderbolts. The

occurrence of thunderbolts is observed during pre-monsoon season [3].

When there's a flow of positive charge from the cloud to the ground, it's termed as positive lightning while negative lightning refers the movement of negative charge from the cloud [4]. Of these two types, positive lightning is deemed more hazardous than negative lightning because it involves a higher current flow and temperature reaching around 30,000K [5–7].

Lightning activity is observed throughout Nepal but it is seen relatively less over the high mountain regions while higher lightning activity was observed at the base of the high mountains, this attributes to the significant altitudinal changes [8]. lightning tends to happen primarily during the rainy season because the negative charge at the bottom of clouds is attracted to the positive charge on the Earth. The base of the cloud becomes negatively charged as the water droplets become heavier. In order to compute the death rate caused by the lightning an empirical formula was introduced that was considered to be failed later on [9].

When examining the lightning occurrence database, it was noted that April and May were the primary months when lightning incidents predominantly occurred in Nepal and found that lightning activity was least observed during morning period between 5:00 to 12:00 across the year [10] while lightning activity was observed high in afternoon and around midnight [11]. Later on, in the year 2022, it was seen that in different region the occurrence of the lightning was also different as in hilly region, the month in which lightning occurred more was May but in context of southern Terai the month was June [12]. Further analysis revealed that our country Nepal is highly vulnerable to lightning due to the large amount of atmospheric water vapor originating from the Indian Ocean and the strong orographic lifting of this moist air [13].

When discussing the impact of lightning, it's evident that it has diverse effects on both individuals and infrastructure. Survivors often endure lifelong injuries, disabilities, psychological trauma, and mental health disorder [9]. Not only do people suffer, but lightning also causes infrastructure failures, power cuts, building damage, and data loss in developing countries, leading to economic crises [14]. Lightning can be deadly, cause fire, and ruin electronics, while its electromagnetic radiation also harms advanced equipment and infrastructure [15, 16].

Lightning activity also has significant impact on total electron content (TEC). In pre-monsoon season significant variations in TEC were observed corresponding to lightning stroke density [17, 18]. According to a study, Makwanpur district recorded the highest frequency of lightning thunderstorms in Nepal followed by Jhapa whereas no lightning events were recorded in Manang and Mustang [19]. To reduce such effects further study was done using lightning location data, a continuous lightning-induced power outage early warning method was devised for closely monitored transmissions channels, improving efficiency and helping power companies make better decisions [20].

And this study aims to understand the effects of lightning on people and infrastructure, analyze the occurrence pattern, and illustrate the monthly distribution of lightning occurrences in Nepal.

2 Methodology

Lightning is the major problem that has been faced all over the world not only in Nepal. Lightning is the phenomenon observed due to orographic barrier. Data extraction is performed using available online tools and databases provided by the respective organizations. The data can be taken/observed through the various means. But in this paper the data from the year 2011 A.D. to 2023 A.D. are observed through the help of Disaster Risk Reduction (DRR) portal, a comprehensive database containing records of natural disaster in Nepal. The dataset was obtained from the DRR portal and subsequently organized into a table. The table includes annual information on lightning incidents, the number of fatalities, and the number of injured individuals during the study period. Bar charts and line graphs were created using Python to facilitate visual comparison and trend analysis. In addition, Pearson correlation analysis and linear regression were conducted to investigate the linear relationship between annual lightning incidents and fatalities. The fatality rate was calculated separately and illustrated using a line graph.

3 Results and discussion

Lightning is a natural hazard that frequently impacts human life, often resulting in injuries and fatalities. This study investigates the patterns of lightning strikes and the associated deaths and injuries. Trends were analyzed using the available dataset. Table 1 presents data collected from 2011 to 2023 A.D., including the annual and monthly distribution of fatalities caused by lightning, along with the total number of lightning incidents recorded in Nepal during the study period.

Over these thirteen years, 2,930 lightning incidents were reported, leading to 1,180 deaths. The data indicates that the number of fatalities gradually increases from January, reaches its peak in June, and then shows a declining trend, with no deaths recorded in November throughout the study period. A similar pattern is observed in lightning incidents; however, another study reported that lightning strikes were highest in May [10]. This contradicts our result as fatalities are higher in the month of June. So, it cannot be directly said that in the month of June lightning strikes frequently, because of higher fatalities. However, April and May also show relatively higher number of deaths compared to other months. The above information is plotted in the graph to visualize the data in Figure 1.

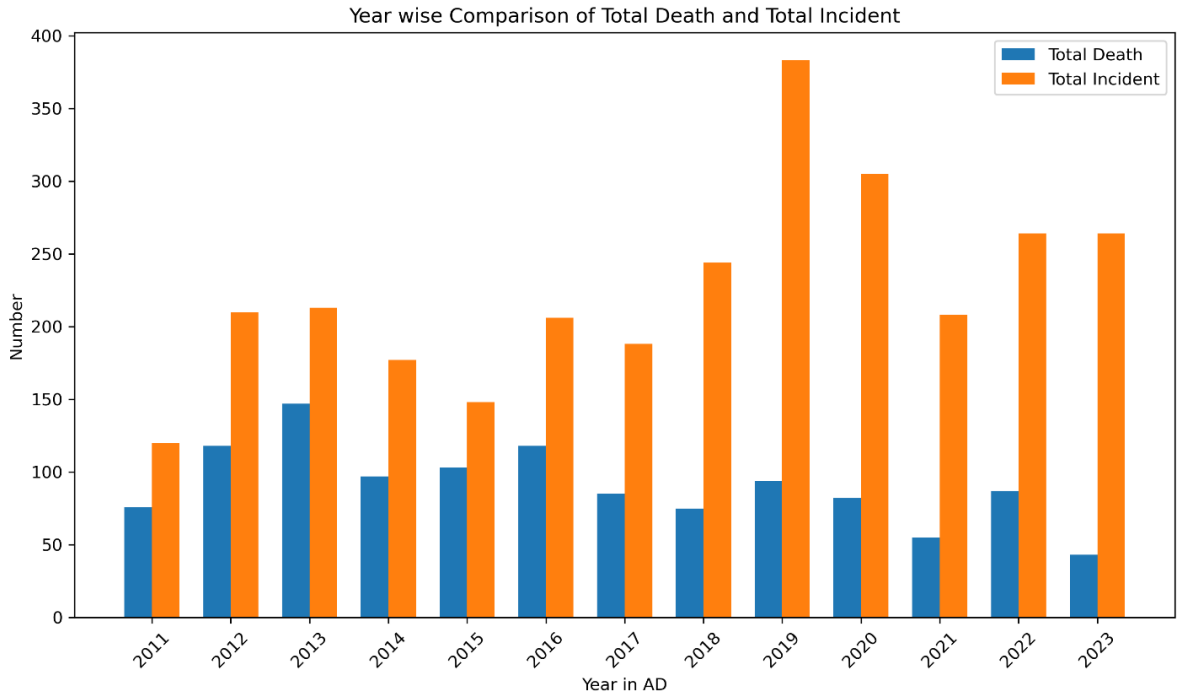

Figure 1: Total death versus total incident of lightning during the year 2011-2023.

Table 1: Death of people and number of incidents of lightning

Year	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total Death	Total incident
2011	0	0	0	5	15	14	13	5	17	7	0	0	76	120
2012	2	2	3	22	27	20	12	16	12	2	0	0	118	210
2013	5	13	20	25	12	28	11	18	13	1	0	1	147	213
2014	0	0	3	7	26	28	4	4	18	4	0	3	97	177
2015	1	10	14	17	21	22	5	5	2	6	0	0	103	148
2016	0	2	10	5	26	32	2	17	18	6	0	0	118	206
2017	0	0	2	21	25	10	11	7	9	0	0	0	85	188
2018	0	0	14	24	11	17	6	0	3	0	0	0	75	244
2019	5	9	2	15	9	24	11	13	4	2	0	0	94	383
2020	1	6	4	14	15	17	7	7	11	0	0	0	82	305
2021	0	2	4	13	8	13	4	4	6	1	0	0	55	208
2022	1	2	0	9	15	18	17	8	12	5	0	0	87	264
2023	0	0	4	3	6	11	10	1	8	0	0	0	43	264
Total	**15**	**46**	**80**	**180**	**216**	**254**	**113**	**105**	**133**	**34**	**0**	**4**	**1180**	**2930**

Figure 1 shows the fluctuations in both total death rate and total incident rate over the year from 2011 A.D. to 2023 A.D. The death rate shows an initial increase until 2013 A.D, both rates fluctuated thereafter. In the bar graph, the death rate remains consistently lower than the incident rate annually, with the death rate being one threefold of incident rate in each year. Particularly, 2019 A.D. witnesses a significant increase in incident rate compared to other years. Overall, 2019 A.D. marks the highest incident rate, while 2023 A.D. records the lowest number of deaths. Likewise, a bar graph showing the percentage of deaths by month was constructed to identify the month with higher lightning risk in

Figure 2.

Figure 2 shows month wise percentage distribution of deaths caused by lightning in Nepal from 2011 to 2023. Month-wise percentage distribution of lightning was calculated as the ratio of total death of the people in a single month to the total number of death people during the whole study periods expressed as a percentage

$$\text{Month-wise percentage distribution} = \frac{\text{Total number of people died in a single month}}{\text{Total number of people died during study period}} \times 100\% \quad (1)$$

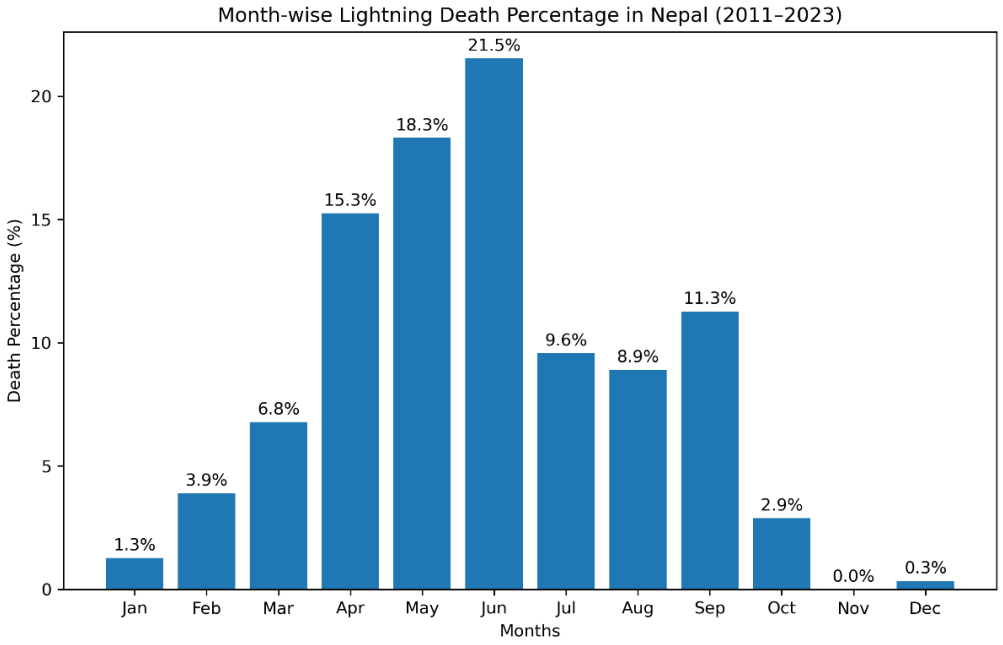

Figure 2: Month-wise percentage distribution of lightning fatalities over study period.

Table 2: Number of dead people versus injured people

Year (in A.D.)	**Death of people** (in Year)	**Injured people** (in Year)
2011	76	138
2012	118	267
2013	147	286
2014	97	227
2015	103	187
2016	118	240
2017	85	251
2018	75	300
2019	94	451
2020	82	310
2021	55	193
2022	87	223
2023	43	217
Total	**1180**	**3290**

This graph indicates (Figure 2) how much each month contributes to total deaths caused due to lightning period during the study period. A clear seasonal pattern can be observed from the graph. From the graph it is clear that lightning fatalities are lowest during winter season as thunderstorm is minimal during this time. From March (6.8%) lightning fatalities start to increase as pre-monsoon approaches. The highest percentage of lightning deaths occur on the month of June (21.5%) and after that the percentage gradually declines. The percentage drops in October (2.9%) and becomes almost negligible after that. Similarly, a comparable pattern was observed in India, where lightning fatalities increased gradually from March and peak in June and then declined slowly after June [21]. Similar seasonal patterns in lightning mortality were also noted in other research that indicated more lightning fatalities during summer as outdoor activities are increased along with longer daylight hours causing likeliness of peoples interaction with lightning event [20]. This may explain the increased number of lightning-caused causalities during these months. Table 2 provides data on total deaths and injuries to further understand the impact of light-

ning on people.

Table 2 represents the comparison between the fatalities caused by lightning and the number of individuals who survived lightning strikes but sustained injuries. It clearly shows that the people who are injured are always more than the one who are dead in every year. In 2013 A.D, there were 147 deaths, marking the highest number, whereas in 2023, the lowest number. Similarly, the highest number of injuries occurred in 2019 A.D, with 451 reported cases, and lowest number of injuries occurred in 2011 A.D, with 138 reported cases. More than 100 people are being injured annually from lightning. The total number of deaths and injuries can be clearly observed and compared from Figure 3.

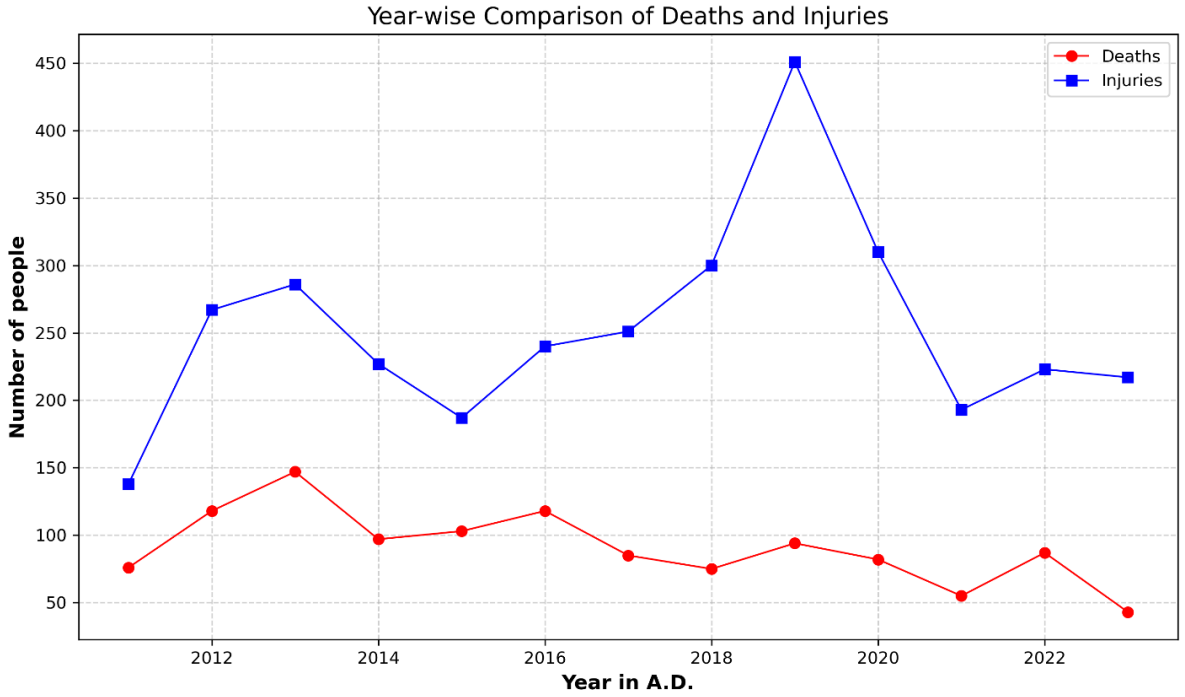

Figure 3: Comparison of death of people and the injured ones.

Figure 3 shows notable trends and patterns in death rates and injured rates over the specified period of time. There is no any year where the number of the injured people is less than the people who lost their life because of the lightning. There appears to be a fluctuating trend in both deaths and injuries, with no consistent linear pattern observed. Instead, the graph illustrates various peaks and valleys, indicating periods of increased and decreased rates. The trend of fatality rate can be analyzed from Figure 4. The Fatality rate is the ratio of the total number of death of people to the number of incidents expressed in percentage

$$\text{Fatality Rate} = \frac{\text{Total number of death of people}}{\text{Total number of incidents}} \times 100\% \quad (2)$$

Figure 4 provides the information about the variation of fatality rate due to lightning during the study period. The fatality rate becomes relatively high from 2011 A.D. to 2016 A.D., ranging between 55% to 70% with highest value recorded in 2015 A.D. This pattern suggests that lightning incidents were dangerous during early years of study. The rate gradually started to decrease and reached the lowest value in 2023 A.D. This decreasing trend may indicate improvements in disaster management strategies and increase public awareness about lightning safety. Although lightning incidents continue to occur, the reduced fatality rate suggests progress in mitigating lightning-related deaths in Nepal. Moreover, analysis of lightning patterns in South Asia also indicates that the lightning fatality rate has shown a decreasing trend over time compared to other countries which supports this result [22]. The relation between lightning incidents and deaths makes analysis clear by providing correlation value. This information can be analyzed from Figure 5.

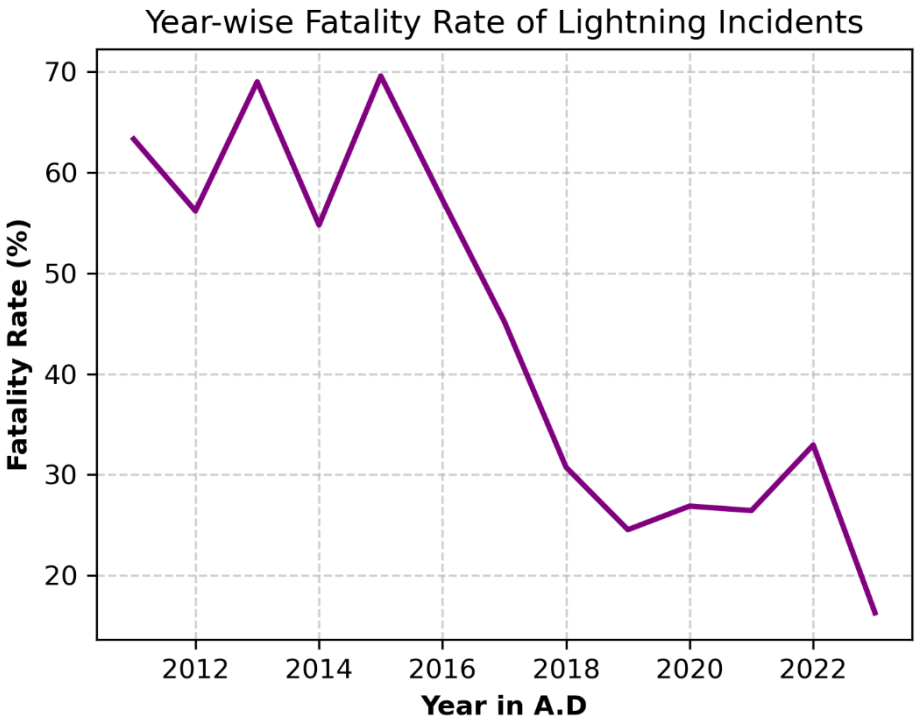

Figure 4: Trend of fatality rate from 2011 A.D. to 2023 A.D.

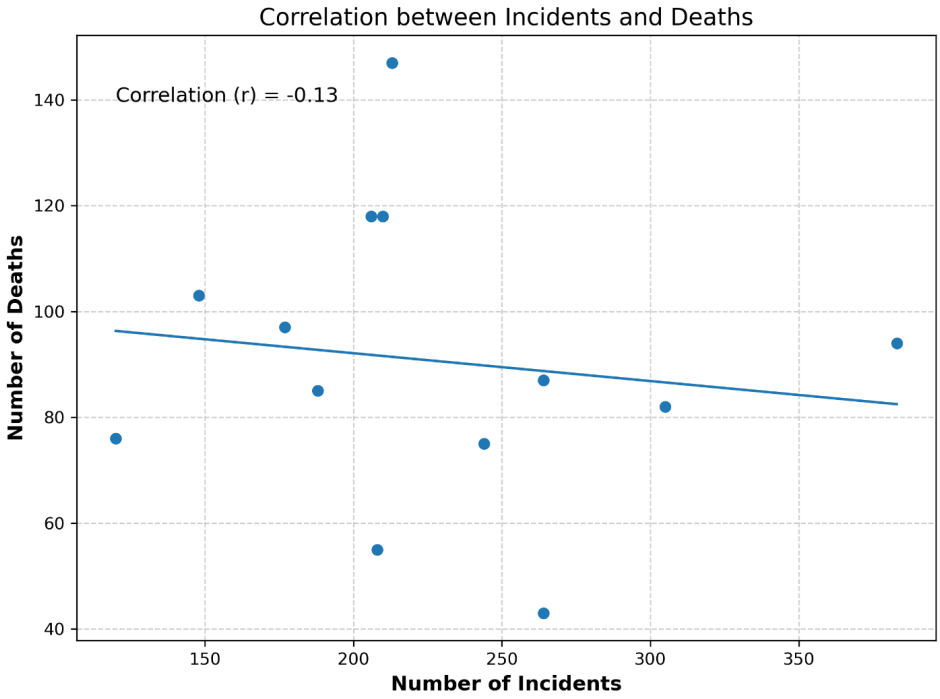

Figure 5: Correlation between annual lightning incidents and deaths.

Figure 5 demonstrates the relationship between the annual number of lightning incidents and the corresponding number of deaths recorded during the study period. The Pearson correlation coefficient is found to be -0.13 which suggests a very weak correlation between the variables. Furthermore, it indicates that an increase in the number of lightning incidents does not necessarily depend on an in-

crease in the number of deaths. Therefore, although lightning incidents remain relatively frequent, the weak relationship between incidents and fatalities suggests that mitigation strategies and increased awareness may help to reduce the loss of human life.

4 Conclusion

This study analyzed the variation of lightning incidents and associated fatalities in Nepal from 2011 A.D. to 2023 A.D. The analysis reported a total of 2930 lightning events in which 1180 people lost their lives and 3290 people were injured. Fatalities were highly observed in the month of July while zero fatality was recorded in November. Throughout the study period, the number of injured people due to lightning was consistently higher than the number of fatalities in every year with total injuries being nearly three times higher than the deaths. Although the number of lightning incidents varied from year to year, the fatality rate showed a declining trend and the correlation analysis revealed a weak negative relationship between number of lightning incidents and number of deaths in recent years that reflects progress in mitigation and response strategies.

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