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Lives on Churiya range and Lesser Himalayas are extremely prone to the Lightning Hazards

Shriram Sharma
Department of Physics, Amrit Campus, Tribhuvan University
Kathmandu, Nepal
ramhome2@hotmail.com, sharmasr@amritcampus.edu.np

Ronald L. Holle
Holle Meteorology and Photography Oro Valley, Arizona, USA
rholle@earthlink.net

Mary Ann Cooper
African Centres for Lightning and Electromagnetics Network
Chicago, Illinois, USA
macooper@uic.edu

***Abstract*—Of natural disasters in Nepal, lightning is the second highest killer after earthquakes. According to the data available from the Disaster Risk Reduction (DRR) portal of the Ministry of Home Affairs (MoFA), an average of 108 people are killed by lightning each year. As would be expected, fatalities over the high mountains are rare due to both low population and low lightning flash density. Surprisingly, most fatalities and injuries are reported over the hilly areas of the Siwalik and lesser Himalayas in the middle of Nepal, despite the southern region having both a significantly higher population and higher lightning flash density.**

Keywords-Fatalities, Siwalik lightning, Nepal, lightning injury, lightning casualty, lightning fatality, lightning safety.

I. INTRODUCTION

Exact numbers on fatalities and injuries from lightning are not available for most countries. One estimate of global fatalities is several thousand [1], another 6000 fatalities per year [2], and the third 24,000 fatalities per year [3]. Holle and Lopez [3] also estimated 240,000 people injured each year based on lightning stroke density and populations in the tropical and subtropical areas of the world. Holle found fatality rates in developed countries are much lower than in lesser-developed countries [4].

Fatality rates were highest in Malawi (84 deaths per million people per year) and lowest in developed countries such as the UK, Austria and Japan. These differences in fatality rates have been attributed to several factors common in developing countries:

1) Fewer lightning-safe homes, workplaces, schools, and other facilities than in more developed countries.
2) High rate of labor-intensive manual agriculture.
3) Lack of awareness or data about the lightning threat, how to avoid injury, and medical treatment.
4) Fewer easily available fully enclosed metal-topped vehicles or similar safe enclosures.

Reference [1] developed an empirical formula to estimate the annual fatality rate in any given region. The equation takes factors into account such as lightning ground flash density, population density, literacy, fraction of urban population, etc. However, when this formula was applied to Mongolia, it was unsuccessful in estimating the fatality rate. It was suggested in [5] that other parameters including landscape topography may have a significant influence on annual deaths due to lightning.

Although lightning is a threat to people and livestock, particularly in the developing world, this natural hazard has largely been ignored in many countries. Lightning injury data are unavailable in the literature for most developing countries. In Nepal, too, lightning hazards in the past have been largely underrated, even though it is a one of most frequent and dangerous natural hazards that people encounter.

II. GEOGRAPHY AND WEATHER PATTERNS OF NEPAL

Nepal is a country of diversified geographical configuration with altitudes as low as 59 m to as high as 8848 m above mean sea level (Fig. 1). Over 83% of Nepal is hilly or mountainous, including the world's highest peak, Mt. Everest, and eight other peaks over 8000 m. The Himalayan peaks cover the northern part of Nepal. The southern strip is a plain, whereas much of the middle area is covered by hills. This geographic structure plays a vital role in the observed meteorological effects.

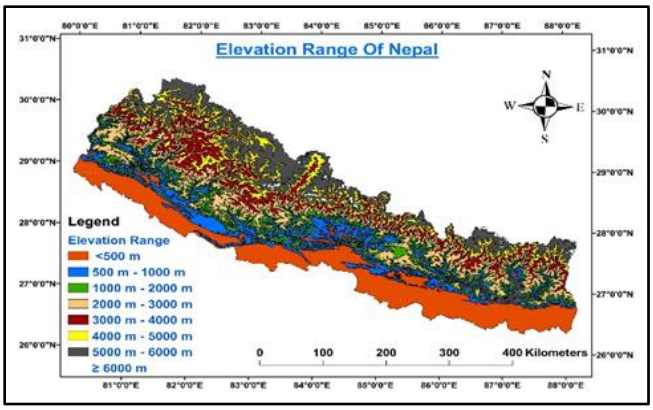

Figure 1. Topographic map of Nepal with elevation.

Nepal is topographically divided into three regions. The Himalayas and its foothills make up the northern border of the country and cover 16% of the total land area. This is the least inhabited region of Nepal with less than 8% of the population. Most permanent settlements in Nepal are at less than 400 m altitude. The Mahabharat range and the Churia hills in the middle of the country cover about 65% of the total land area and are home to about 44% of population. The Terai southern part of Nepal is an extension of the Gangetic plains and covers 17% of the total land area with 48% of the population for the highest population density.

Monsoons occur during July and August with heavy rainfall resulting in landslides, floods, and inundations. Thunderstorms and lightning occur mostly during the pre- and post-monsoon periods. The meteorological changes occurring in the Himalayan range have a role in the occurrence of lightning flashes. Thunderstorms generally begin in March (the pre-monsoon season) and cease by August (post-monsoon). The pre-monsoon is the most active lightning period followed by the post-monsoon period, although monsoonal thunderstorms are also prevalent. Winter lightning is very rare, although lightning casualties and incidents have been reported.

Lightning occurs almost everywhere over Nepal, although it is relatively infrequent over the high mountains. In contrast, the southeast part of the country receives the highest number of lightning strokes followed by the Chure range (Fig. 2). This is the range of hills that extends from Indus river of Pakistan in the west to the Brahmaputra river of India in the east. These Chure hills, also known as Siwalik hills, are the southernmost foothills of Himalayas, shaped like a hedge with an average elevation of 600 m to 1220 m above sea level.

The atmospheric structure and hydro-meteorological processes along the southern slopes of the Himalayas are not well known or well documented, mainly because of the rugged and remote terrain. Also, the mountain range lies within several developing countries, such as Nepal, that do not have the resources to carry out sophisticated meteorological studies [6]. Lightning stroke density, as measured by the Global Lightning dataset (GLD360), is over 18 strokes km^{-2} y^{-1} along the southern Nepal border, typically 4 to 8 strokes km^{-2} y^{-1} in the central region, with very small densities over the northern mountainous border. These densities from GLD360 are estimated to be 70% of the actual cloud-to-ground flash values.

In this study, we analyze the distribution of lightning activities over Nepal and compare the association of lightning fatalities with the altitude and population density.

III. Lightning Data and Fatality Information

A. *Occurrence of Lightning*

Lightning activity over Nepal has been continuously monitored in recent years by the Global Lightning Dataset GLD360 network that is owned and operated by Vaisala, Inc. [7]. Figure 2 shows the spatial distribution of nearly 3 million strokes per year for Nepal and adjacent regions. The location accuracy of GLD360 during the three years of the map in Fig. 2 is about 3 km. The detection efficiency of cloud-to-ground flashes is about 70% for this region and time period.

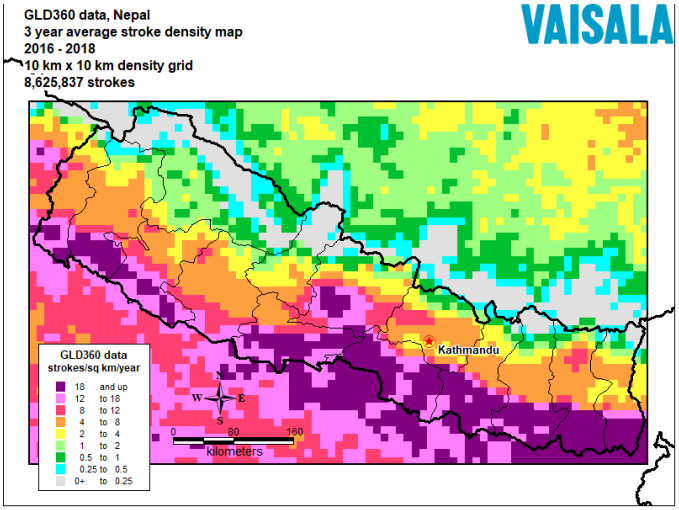

Figure 2. Average annual lightning stroke density over Nepal and adjacent regions at 10×10 km resolution from Vaisala's Global Lightning Dataset GLD360 network from 2016-2018. A total of 8,625,837 strokes were detected in the three years.

Fig. 2 shows that the southern border of all of Nepal receives more lightning than elsewhere in the region. In particular, the southeastern plains region of Nepal receives the most lightning strokes followed by the southern part of the central region over the Siwalik or Chure range. The high mountains, stretching along the northern border with China from east to west, have considerably fewer lightning strokes.

The maximum at the base of the high mountains is attributable to the major elevation change that faces the influx of low-level moisture from the south during the pre-monsoon and monsoon seasons. This maximum has been observed to occur over all the Indian Subcontinent [8]. To the north of the band of maximum lightning, the frequency reduces quickly as the low-level moisture impinging on the mountain slopes is depleted. At the highest elevations, almost no thunderstorms exist because no low-level atmospheric water vapor content is present. All three of these features are evident in Colombia [9], Venezuela, East Africa, the Andes, and Southeast Asia [10].

B. *Fatalities from Lightning*

Fortunately, lightning is becoming recognized as one of the major natural hazards in Nepal, claiming over 100 lives each year. Data obtained from the Disaster Risk Reduction (DRR) portal of Ministry of Home Affairs (MoHA), Nepal, show an average 108 people killed by lightning each year and 262 people injured (Fig. 3). It can be safely assumed that the data obtained from the DRR portal underestimate the true number as has been observed in many countries, including the United States. [11].

The largest number of casualties (131) was recorded in the year 2012/13 and the least number (68) in 2018/19. During the last eight years, 841 people were killed, and 2095 people injured by lightning for a fatality rate of 3.7 deaths per million people per year. This rate is higher than in many other countries [4].

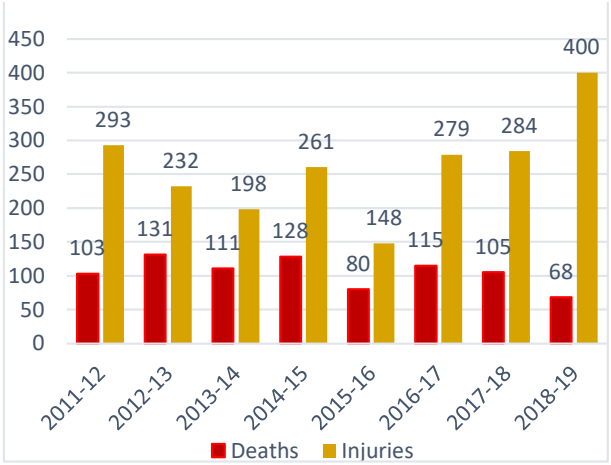

Figure 3. Annual lightning fatalities and injuries in Nepal from 2011 through 2019.

C. *Population Density*

Fig. 4 shows the population density over the 77 districts of Nepal according to the 2011 census. As can be seen, the southern plains districts are the most densely populated, followed by the hilly districts, with the mountainous region sparsely populated.

Fig. 5 shows the spatial distribution of lightning fatalities in Nepal. Out of 841 fatalities, 515 were reported from the hilly region, 286 fatalities from the Terai plains region, and 40 fatalities from the mountainous districts. Of these 40 fatalities, none were reported from the high mountains above 6000m. Clearly, most of the fatalities are reported from the lesser Himalayas and Siwalik hills region.

Using only the numbers for the plains (Terai) region, the fatality rate is 2.68 deaths per million people per year. However, the fatality rate for the hilly (lesser Himalayas and Siwalik) region, is 5.28 deaths per million people per year – twice that of the plains region.

IV. Discussion and Conclusions

Most of Nepal is clad with high hills and mountains. The mountainous region has both a sparse population and minimal lightning occurrence, resulting in fewer fatalities, as would be expected. The fatality rate of the middle hilly region is twice that of the southern plains region, despite the plains region having both a considerably higher population density combined with a significantly higher lightning stroke density.

There are likely two reasons for this disparity. Most people in the hilly regions live in houses with roofs thatched with hay and similar material. Such houses provide no protection against lightning [12, 13]. Further, the people living on the hills tend to make their livelihood from labor-intensive agriculture and other outdoor activities, fully exposed to thunderstorms. Combining the factors of housing and activity, these people have no or few safe areas to seek refuge and are exposed to all lightning without safe alternatives to choose from.

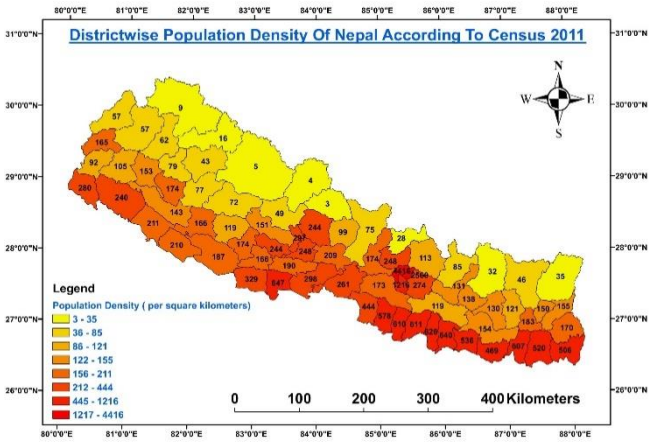

Figure 4. Population density of Nepal over all the districts using 2011 census data.

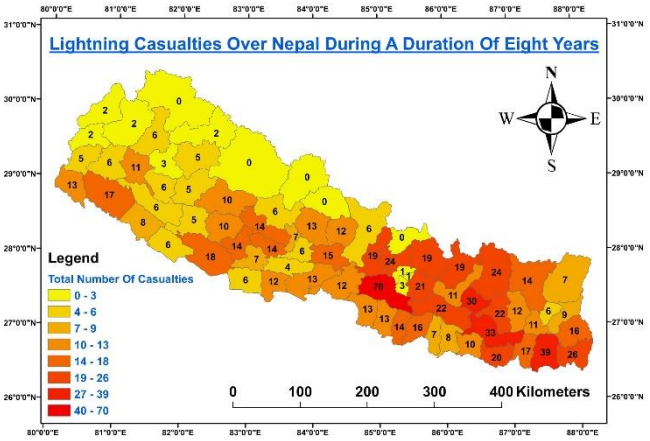

Figure 5. Spatial distribution of lightning fatalities over the 77 districts of Nepal.

Although there are some urban and suburban areas in the hilly region, lightning fatalities in these urbanized areas, where the houses are constructed with steel reinforcement or iron components, are negligible.

Clearly, there is an acute need for the development of effective, inexpensive lightning protection systems to be installed for each house, particularly in the hilly region [12, 13]. Additionally, extensive lightning awareness-raising and safety programs should be conducted throughout the hilly regions.

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References

[1] Gomes, C., and M. Z. A. ab Kadir, "A theoretical approach to estimate the annual lightning hazards on human beings," Atmospheric Research, 101, 2011, pp. 719–725, doi:10.1016/j.atmosres.2011.04.020

[2] Cardoso, I., O. Pinto Jr., I. R. C. A. Pinto, and R. L. Holle, "A new approach to estimate the annual number of global lightning fatalities", paper presented at 14th Intl. Conf. on Atmospheric Electricity, Rio de Janeiro, Brazil, IUGG/IAMAS Intl. Commission on Atmospheric Electricity, 2011, 4 pp.

[3] Holle, R. L., and R. E. López, "A comparison of current lightning death rates in the U.S. with other locations and times," paper

presented at Intl. Conf. on Lightning and Static Electricity, Blackpool, United Kingdom, Royal Aeronautical Society, P103-34 KMS, 2003, 7 pp.

[4] Holle, R. L., "A summary of recent national-scale lightning fatality studies," Weather, Climate, and Society, 8, 2016, pp. 35-42.

[5] Doljinsuren M., and C. Gomes, "Lightning incidents in Mongolia," Geomatics, Natural Hazards and Risk, 6 (8), 2015, pp. 686-701.

[6] Barros A. P., and T. J. Lang, "Monitoring the monsoon in the Himalayas: Observations in central Nepal," Monthly Weather Review, 131, 2003, pp. 1408-1427.

[7] Said, R. K., U. Inan, and K. L. Cummins, "Long-range lightning geolocation using a VLF radio atmospheric waveform bank," J. Geophys. Res., 115, 2010, D23108, doi:10.1029/2010JD013863.

[8] Nag, A., R. L. Holle, and M. Murphy, "Cloud-to-ground lightning over the Indian subcontinent," paper presented at 8th Conf. on the Meteorological Applications of Lightning Data, Seattle, Washington, Amer. Meteor. Soc., 2017, 6 pp.

[14] societies and problematic environments," paper presented at Intl. Conf. on Lightning Protection, Vienna, Austria, 2012, 11 pp.

[9] Navarrete-Aldana, N., M. A. Cooper, and R. L. Holle, "Lightning fatalities in Colombia from 2000 to 2009," Natural Hazards, 74, 2014, pp. 1349-1362.

[10] Holle, R. L., and M. J. Murphy, "Lightning over three tropical lakes and the Strait of Malacca: Exploratory analyses," Monthly Weather Review, 145, 2017, pp. 4559-4573.

[11] López, R. E., R. L. Holle, T. Heitkamp, M. Boyson, M. Cherington, and K. Langford, "The underreporting of lightning injuries and deaths in Colorado," Bull. Amer. Meteor. Soc., 74, 1993, pp. 2171-2178.

[12] Cooper M. A. and Holle R. L., "Reducing Lightning Injuries Worldwide," Springer Natural Hazards, New York, 2018, 233 pp., ISSN 2365-0656, ISBN 978-3-319-77561-6.

[13] Gomes C., M. Z. A. ab Kadir, and M. A. Cooper, "Lightning safety scheme for sheltering structures in low-income