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Research Article

People Deaths and Injuries Caused by Lightning in Himalayan Region, Nepal

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Several natural disasters such as lightning, flood, fire, epidemics, and landslides frequently occur in the Himalayan region, of Nepal. The altitude of this region ranges from 59 m to "8848.86 m"—the height of Mount Everest—along with a distance of just 160 km. As a result, there is a considerable (i.e., nearly 95°C) variation in temperature in the region. Moreover, Nepal has a heterogeneous topography. All these features influence various natural disasters including lightning activity. This paper is aimed at analyzing the variations of lightning within and across the years from January 2011 to December 2021—a total of 11 years. For this, the data were taken from the Disaster Risk Reduction (DRR) portal of the Ministry of Home Affairs (MOHA). The analysis showed that there were no lightning events in November, and the lightning density was higher in the premonsoon period of study in this region. It also showed that the number of injured people is about thrice the death of the people due to the lightning. The null occurrence of lightning in November in the Himalayan region is a contribution novel to this field.

1. Introduction

The country of the Mount Everest, Nepal, lies in the northern hemisphere of latitude 26.37°N to 30.45°N and longitude 80.066°E to 88.2°E in a Himalayan region. The altitude of the country ranges heterogeneously from 59 m to 8848.86 m. The land of the lowest altitude lies in the Terai while that of the highest altitude (i.e., Mount Everest) lies in the Himalayan region. The air distance between them is about 160 km, and the temperature difference is about 95°C. Due to the variation of temperature in a short range of distance, there is the diversity in climate and the variation of weather phenomena [1, 2]. Water naturally flows from high altitude to low altitude with high speed due to the vast difference in altitude within the short range of distance. This causes frequent disasters such as floods and landslides resulting in the loss of human lives and cattle with the destruction of physical properties of billions of dollars [3].

In the case of lightning, various scholars, such as Malan [4], Rakov and Uman [5], and Mac Gorman and Rust [6], have explained that huge energy is released even if it is a more common natural activity in the atmosphere. The primary source of lightning is the cumulonimbus which produces thunderstorms, and it produces the energy and the power in the order of more than a hundred megawatts. They also reported that more than 24000 people were globally affected by lightning. The number of injured people due to this phenomenon of lightning was more than the casualties. Even Rakov and Uman [5] mentioned that thunderstorms produce within a minute more than 100 lightning flashes globally. Besides human casualties, the death of animals and sophisticated parts of electronic, military, and medical equipment can be destroyed by radiation produced due to lightning. Similarly, the communication and transmission lines get affected by electromagnetic radiation due to direct or indirect strikes of lightning. Gomes et al. [7] explained that besides the direct and indirect strike of the lightning, there may be death or injury to the people depending on the various factors. These factors may be the distance, step potential, current magnitudes, and so on. They also reported that the lightning causes harm to the human beings and domestic animals when they are in open agricultural fields and take shelter under tall trees

Table 1: Death of people due to natural disasters in Himalayan regions.

Year	Lightning	Landslides	Fires	Floods	Earthquake	Others	Total
2011	76	110	25	126	6	81	424
2012	118	60	77	9	1	178	443
2013	147	87	59	131	—	32	456
2014	97	113	67	129	—	97	503
2015	103	138	75	0	8962	26	9304
2016	118	148	63	101	—	56	486
2017	85	70	63	166	—	106	490
2018	75	91	87	17	—	208	478
2019	94	86	78	73	—	89	420
2020	82	303	57	42	—	75	559
2021	55	179	95	63	0	111	503
Total	1050	1385	746	857	8969	1059	14066

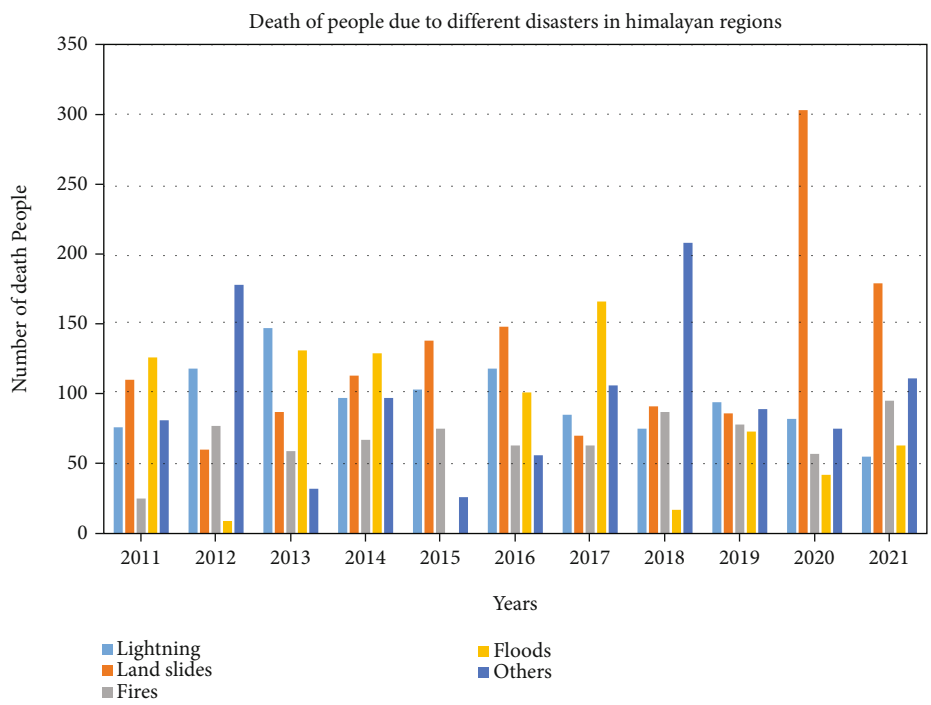


Figure 1: Death of people due to different disasters in Himalayan regions during the period of January 2011 to December 2021.

to avoid the rain. Barros and Lang [8] reported that the effect of lightning in the Himalayan region is not well documented due to various factors even though the lightning signatures of the region are of very much interest to the scientific community of the world. Gomes [9] reported that lightning is taken as a disaster because of the geological scenario in the context of Sri Lanka in the mountainous region, and casualties of people are not reported accurately due to the scattered information on the Himalayan region.

Berger [10] has classified lightning into cloud-to-cloud and cloud-to-ground discharges. The author has further categorized the latter into positive and negative lightning. Moreover, Krehbiel [11] has added the types of lightning: if the positive charge transfers from the cloud to the ground, that is called positive lightning; and if the negative charge of the cloud transfers to the ground, that is called negative lightning. In the thunderstorm, the tripole charge structure in which positive and negative charges are equal in number lies at the upper and central part of the cloud, respectively; some pocket positive charge remains at the bottom part of the thunderstorm [12, 13]. Uman [14] explained that positive lightning discharge is stronger than the negative lightning discharge, and Rakov and Uman [5] added the same argument showing that the phenomena occur due to charge transfer so that high current flow in the positive lightning results in the temperature up to 30,000 K. Baral and Mackerras [15], Adhikari et al. [16], and Adhikari [17] reported that more positive lightning occurs in the hill and mountainous region.

Table 2: The number of the casualty of the human beings, number of lightning events, and number of humans injured due to the lightning disaster in the Himalayan regions.

Time in year	Number of the dead people	Number of incidents	Number of injured people	Total estimated cost NRs
2011	76	120	138	3530000
2012	118	210	267	4070000
2013	147	213	286	2812000
2014	97	177	227	10446000
2015	103	148	187	1000000
2016	118	206	240	3321000
2017	85	188	251	9125000
2018	75	244	300	5562000
2019	94	383	451	12208000
2020	82	305	310	9158000
2021	55	208	193	17777760
Total	1050	2402	2850	79009760

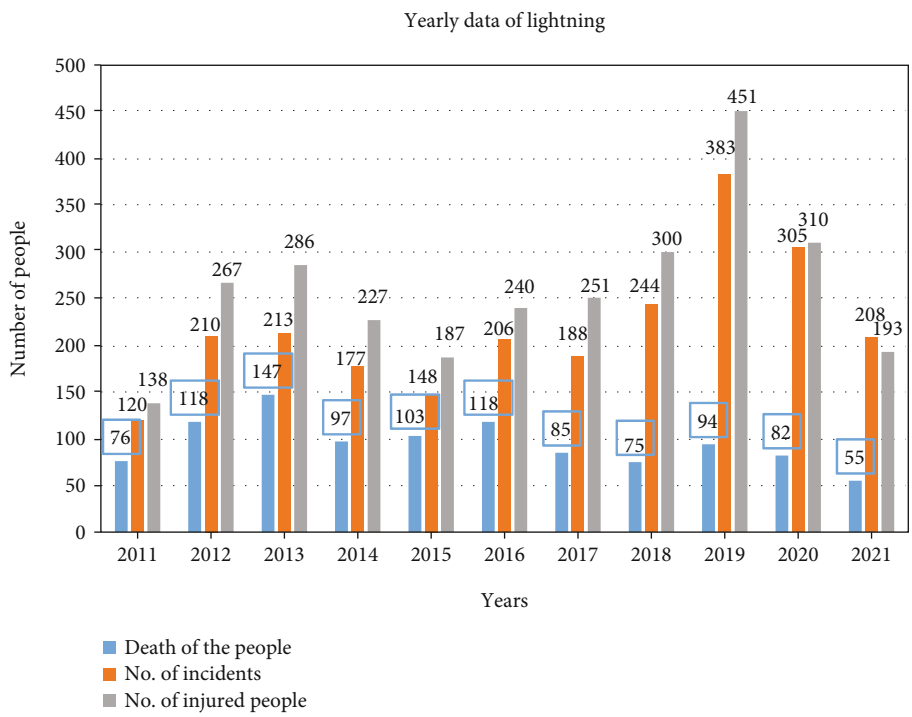


Figure 2: The bar diagram of the yearly distribution of lightning since January 2011.

2. Methodology

There are different methods of measuring the phenomenon of lightning such as photography, electric field measurement, magnetic field measurement, and acoustic measurements. The radiations of various wavelengths and DC to gigahertz frequencies were produced due to the phenomenon of lightning discharge. However, for the current research paper, the data were taken from a secondary source, namely, the Disaster Risk Reduction (DRR) portal of the Ministry of Home Affairs (MOHA). The lightning activities from January 2011 to December 2021 were analyzed in terms of their inter- and intra-annual variations and their distribution over Nepal's hill and mountainous region.

3. Observation and Discussion

Nepal is one of the underdeveloped countries with the highest risk of disaster due to its geographical structure. The northern upper part of Nepal includes the rugged mountainous region covered by the high Himalayas, the lower southern part consists of plain Terai, and in between the two lies

Table 3: Monthly lightning in the Himalayan region within the period of January 2011 to December 2021.

Year	No. of event	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
	Death	—	2	5	0	1	—	—	0	5	1	0	14
January	Incident	—	3	7	1	2	—	—	0	23	11	1	48
	Injured	—	10	16	1	2	—	—	0	46	8	0	83
	Death	—	2	13	0	10	2	0	0	9	6	2	44
February	Incident	—	9	14	6	21	2	0	4	47	18	10	131
	Injured	—	27	15	15	37	—	0	24	57	8	11	194
	Death	—	3	20	3	14	10	2	14	2	4	4	76
March	Incident	—	6	26	12	24	15	23	32	21	45	18	222
	Injured	—	18	74	15	13	18	33	31	29	44	20	295
	Death	5	22	25	7	17	5	21	24	15	14	13	168
April	Incident	11	51	51	17	21	13	37	62	56	69	63	451
	Injured	9	102	80	25	22	26	45	66	110	100	41	626
	Death	15	27	12	26	21	26	25	11	9	15	8	195
May	Incident	23	30	17	40	27	50	65	32	51	46	38	419
	Injured	31	50	23	45	54	43	96	46	56	45	47	536
	Death	14	20	28	28	22	32	10	17	24	17	13	203
June	Incident	19	21	37	48	25	51	19	58	54	32	31	395
	Injured	19	21	28	64	18	68	24	72	45	27	29	415
	Death	13	12	11	4	5	2	11	6	11	7	4	86
July	Incident	22	26	14	9	10	2	16	19	40	23	8	189
	Injured	22	10	8	19	5	6	17	14	31	26	2	160
	Death	5	16	18	4	5	17	7	0	13	7	4	96
August	Incident	9	30	25	9	6	40	12	3	50	23	5	212
	Injured	19	12	24	3	13	43	21	8	47	24	6	220
	Death	17	12	13	18	2	18	9	3	4	11	6	113
September	Incident	25	19	19	25	3	25	11	30	29	35	30	251
	Injured	21	17	16	34	—	31	8	31	26	23	33	240
	Death	7	2	1	4	6	6	0	0	2	0	1	29
October	Incident	11	2	2	5	9	8	5	2	12	3	4	63
	Injured	17	—	2	4	23	5	7	5	4	5	4	76
	Death	—	—	—	—	—	—	—	—	—	—	—	—
November	Incident	—	—	—	—	—	—	—	—	—	—	—	—
	Injured	—	—	—	—	—	—	—	—	—	—	—	—
	Death	—	—	1	3	—	—	—	0	—	—	—	4
December	Incident	—	—	1	5	—	—	—	2	—	—	—	8
	Injured	—	—	—	1	—	—	—	3	—	—	—	4
	Death	76	118	147	97	103	118	85	75	94	82	55	1050
Total	Incident	120	210	213	177	148	206	188	244	383	305	208	2402
	Injured	138	267	286	227	187	240	251	300	451	310	193	2850

the hilly region. Disasters such as floods, landslides, thunderbolts, thunderstorms, and fires occur frequently in such a geographical structure [3, 18]. Fire in the dry season and flood in the rainy season are the disasters in the Terai belt of Nepal. The Terai region also consists of thick forests, and therefore, people suffer from the terror of wild animals. Landslides, floods, and epidemics in the rainy season are the main disasters in the hilly region while glacier lake outburst and avalanches are the potential disasters in the Himalayan region. However, thunderstorms and lightning phenomena occur all over the country irrespective of the particular region. In the Himalayan region, more than 250 animals were killed due to a single flash of lightning [19]. The phenomena of lightning in this geographical structure are very important. As mentioned earlier, the current, as well as temperature in the process of lightning, is very high, and within a very short time, it affects considerably. Here, the scenario of only the death of the human beings due to the natural disaster in Nepal during the studied period is shown in Table 1.

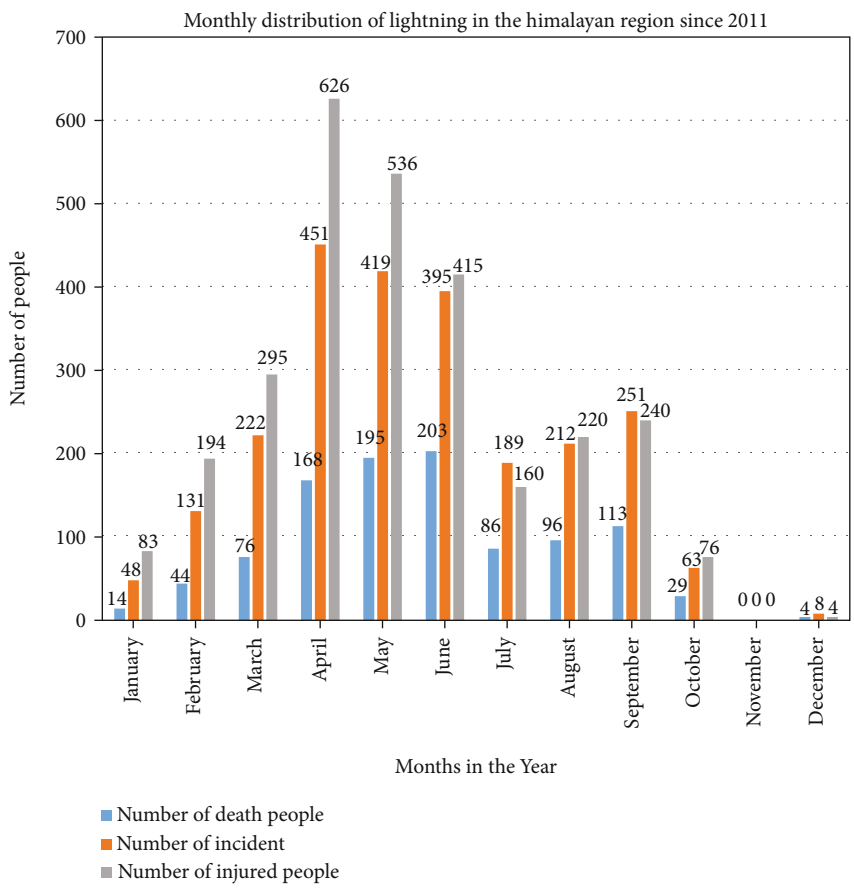


Figure 3: The bar diagram of the monthly distribution of lightning in the Himalayan region during the period from January 2011 to December 2021.

The death of people due to different disasters in Himalayan regions during the period is shown in Figure 1.

From January 2011 to December 2021, one thousand and fifty people were killed due to the lightning thunderbolt in Nepal but the number of injured people was about three times, that is, 2850. Even the loss of human beings was not exactly reported due to several reasons, then animals and the loss of properties were also not exactly collected. But the National Emergency Operation Center, Ministry of Home Affairs (NEOC, MOHA), reported the data in which the injured people and loss of property are presented here in Table 2. Among the disaster, lightning is one of them in Nepal and found that about 100 people on average lost their lives per annum and the injured number of people is about three times the death of the people. The number of the casualty of human beings, the number of lightning events, and several humans injured during this period are presented here. The bar diagram of the distribution of the lightning is expressed in Figure 2.

From 2011 to 2021, the number of incidents of the lightning phenomena and the number of injured and dead people were observed and analyzed the monthly distribution of the lightning within the period. As already mentioned, the data reported here is only the human loss and injured in the incidents of lightning. There is no mention of the death and injured number of animals or other exactly. There was a huge number of animals killed due to a single stroke in the high mountainous region [19]. In the mentioned period, one thousand and fifty people were killed due to the lightning thunderbolt in Nepal, and two thousand eight hundred and fifty were injured. In this period, the number of lightning incidents is two thousand four hundred and two. About 2400 people were killed annually in the world, but about more than 100 people on average were killed in Nepal only, as shown in Table 2 from the DRR portal. From 2012 to continue five years, 118, 147, 97, 103, and 118, respectively, were the number of people killed by it, indicating that lightning is the main disaster in Nepal. Since 2017, the casualty is going on decreasing order but the number of injured people is highly increased. It may be due to some awareness programs conducted in some local areas and the people know about how to survive the direct strike of the lightning. Not only the casualty of the people but there were also more incidents and the injured number was about three times of the casualty. The number of incidents and a number of dead and injured people due to lightning in twelve months with seasonal variations were observed and analyzed here which is shown in Table 3. The bar diagram of the monthly distribution of lightning during the period 2011 to 2021 is expressed in Figure 3.

The number of incidents, number of dead and injured people due to lightning events since 2011, and monthly

Table 4: The distribution of the lightning phenomena and severe thunderstorms over the seventy-seven districts of Nepal during the period of January 2011 to December 2021.

Districts	Number of dead people	Number of incidents	Number of injured people	Ranked of districts based on the lightning incidents	Remarks
Achham	15	50	124	9	
Arghakhanchi	8	24	14	45	
Baglung	19	46	76	16	
Baitadi	6	26	60	40	
Bajhang	3	18	24	58	
Bajura	8	22	22	48	
Banke	6	16	14	62	
Bara	21	36	35	26	
Bardiya	8	23	11	47	
Bhaktapur	1	7	8	68	
Bhojpur	16	45	29	19	
Chitwan	12	28	35	38	
Dadeldhura	5	21	50	51	
Dailekh	9	38	45	22	
Dang	21	47	28	14	
Darchula	3	28	32	39	
Dhading	21	35	44	30	
Dhankuta	11	24	25	43	
Dhanusha	12	17	23	60	
Dolakha	20	37	57	24	
Dolpa	0	1	6	75	2013-4-26
Doti	9	20	31	53	
Gorkha	6	14	12	63	
Gulmi	18	45	81	18	
Humla	0	7	0	69	In 2012 only
Ilam	16	47	31	15	
Jajarkot	8	20	22	54	
Jhapa	29	84	52	2	
Jumla	5	12	10	65	
Kailali	19	33	33	32	
Kalikot	4	11	24	66	
Kanchanpur	16	31	38	34	
Kapilbastu	8	18	2	56	
Kaski	13	36	24	29	
Kathmandu	1	6	6	71	
Kavrepalanchowk	23	38	39	21	
Khotang	25	64	102	5	
Lalitpur	3	6	4	70	
Lamjung	14	35	31	31	
Mahottari	11	17	13	61	
Makawanpur	75	157	277	1	
Manang	0	0	0	—	No lightning
Morang	49	77	47	3	
Mugu	2	5	11	72	
Mustang	0	0	0	—	

Table 4: Continued.

Districts	Number of dead people	Number of incidents	Number of injured people	Ranked of districts based on the lightning incidents	Remarks
					No lightning
Myagdi	6	21	63	50	
Nawalpur	1	5	7	73	
Nuwakot	24	49	50	11	
Okhaldhunga	33	56	69	6	
Parasi	11	9	14	67	
Palpa	5	18	23	57	
Panchthar	9	23	30	46	
Parbat	8	29	48	37	
Parsa	22	37	21	23	
Pyuthan	16	46	78	17	
Ramechhap	12	20	24	52	
Rasuwa	0	2	2	74	
Rautahat	17	21	8	49	
Rolpa	19	44	37	20	
Rukum East	5	12	11	64	
Rukum West	8	48	84	12	
Rupendehi	15	19	16	55	
Salyan	6	26	40	41	
Saptari	29	47	36	13	
Sarlahi	17	24	12	42	
Sankhuwasabha	16	52	39	8	
Shyanja	8	31	24	36	
Sindhuli	26	52	69	7	
Sindhupalchowk	19	36	66	28	
Siraha	13	17	11	59	
Solukhumbu	25	49	71	10	
Sunsari	20	36	29	27	
Surkhet	8	37	47	25	
Tanahu	16	31	44	33	
Taplejung	9	31	30	35	
Terhathum	8	24	28	44	
Udayapur	39	74	62	4	

distribution with seasonal variation of lightning were observed and analyzed here. From this data, there are no lightning events in November during this period of eleven years and the maximum lightning occurs during the pre-monsoon period. From this table, the maximum number of lightning incidents occurred in April, May, and June, in the premonsoon period, and the casualties, as well as the death of the people, were also high in the same period. The number of injured people in April in the premonsoon period is the maximum that can be seen in Figure 3. The number of injured people is about three times higher than the number of dead people on average, but in the premonsoon period, it is also very high. To observe the distribution of the lightning phenomena and severe thunderstorm over different regions, all over the country, the seventy-seven districts of Nepal are considered as a sample area. Again, the lightning phenomena were observed and analyzed in the data available on the DRR portal for seventy-seven districts. The observed data are presented here in Table 4, and the distribution of the lightning phenomena and severe thunderstorms over the seventy-seven districts of Nepal is represented by a bar diagram in Figure 4.

In our scenario, 48% of the population settled in the Terai region of altitudes 59 m to 600 m with only seventeen percent of the land area from east to west. On analyzing the above-observed data, in the high Himalayan region of an altitude of more than 5000 m, the fatalities are very rare due to both the reason of low population and low lightning flash density. The fatality rate is very low because it may be difficult to record and not approach the events. The main

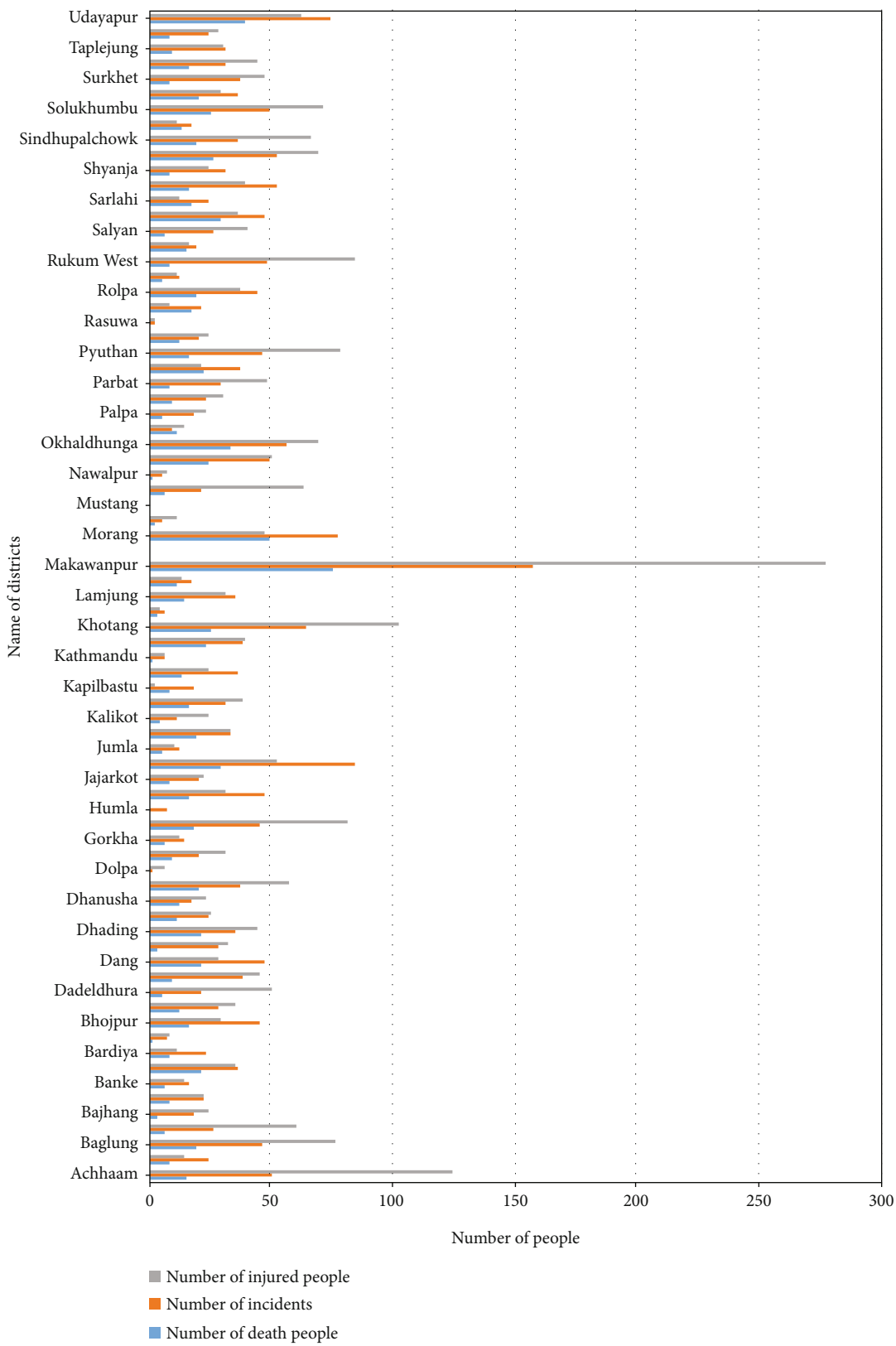


Figure 4: The bar diagram of the distribution of the lightning phenomena and severe thunderstorms over the seventy-seven districts of Nepal during the period of January 2011 to December 2021.

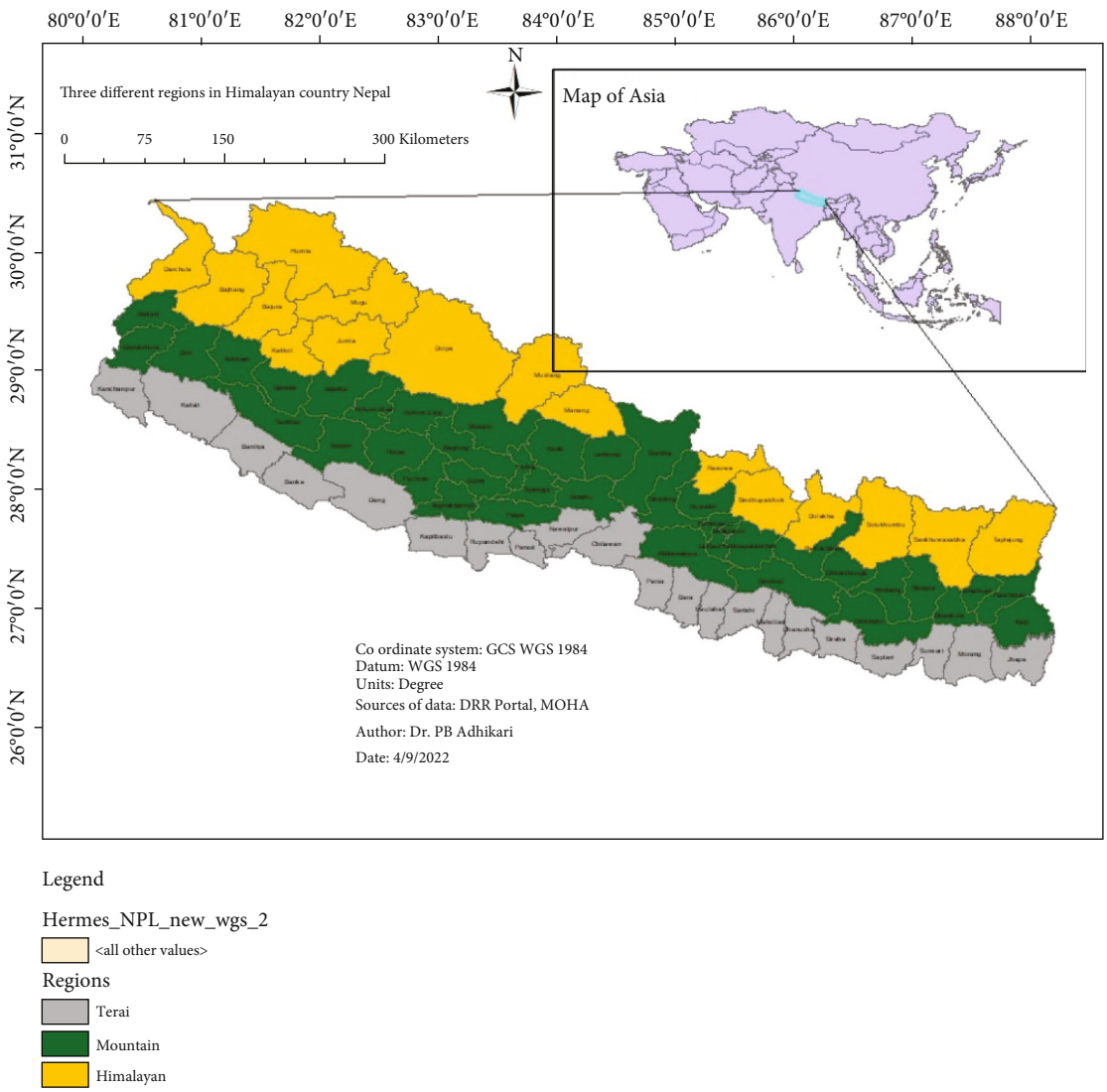


Figure 5: The three different regions—Terai, Mountain, and Himalayan in Nepal as shown by a different color of very small breadth and elongated from east to west. Using the software of ARCGIS mapping Nepal is also shown in the inset of the map of Asia with latitude and longitude.

affected area due to lightning thunderstorms is in the central part of hilly mountains regions, which covers more than 68% of the total area, having altitude ranges from 600 m to 5000 m. This area of the mountainous region of very small breadth and is elongated from east to west as shown in Figure 5 using the software of ArcGIS mapping. Nepal is also shown in the inset of the map of Asia. The fatalities and injuries due to lightning thunderstorms over this area have both significantly higher populations and higher lightning flash density.

To observe the lightning distribution and severe thunderstorms over different districts of Nepal in different regions, it should be analyzed and have to determine the place at which the effect of lightning is more vulnerable all over the country. To determine the district-wise effect of thunderstorms all over the country, the incident of lightning events and the resultant human death and injuries were observed and analyzed. The number of human deaths and injuries due to lightning is represented in pie diagrams inside the map of Nepal by using the software of Arc map where the size of the pie diagram varies representing the variation in the number of lightning events as shown in Figure 6. The incident of lightning and the death of the people due to the lightning thunderstorm in the seventy-seven districts are presented here with the different colors in Figure 7 by using the software of Arc map.

From analyzing the observation data of seventy-seven districts, the lightning thunderstorm occurred maximum in Makawanpur district in which the number of lightning events is up to 157 incidents in this studied period, and in Jhapa district occurred 84 incidents with the second-highest rank. Similarly, the higher lightning events to the lower lightning events that occurred among the 77 districts were ranked that is also expressed in Table 4. Among the seventy-seven districts, two districts, Manang and Mustang, have no lightning phenomena during this studied period. Lightning injuries and deaths may not be accurately reported because lightning most often strikes not the large

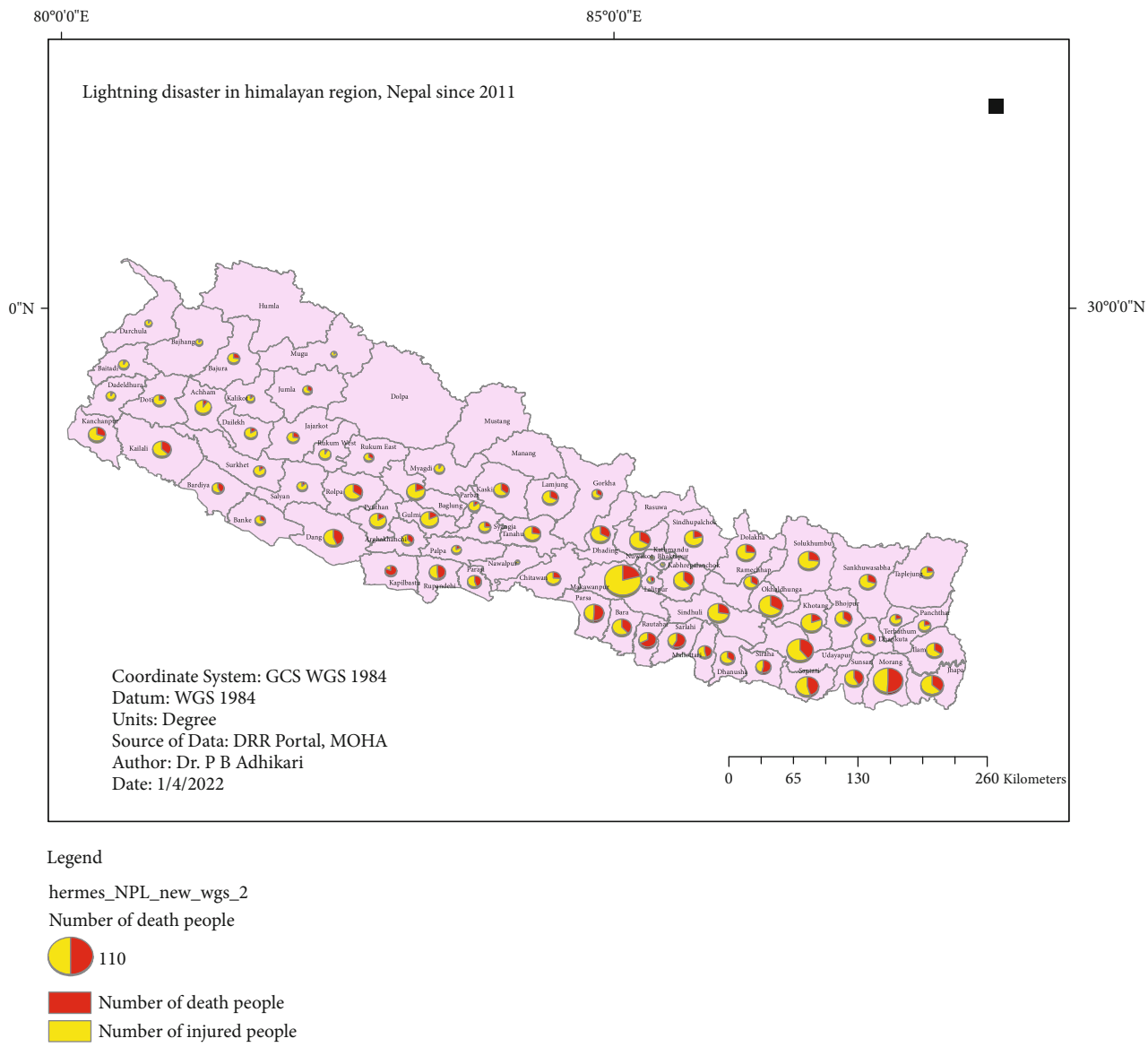
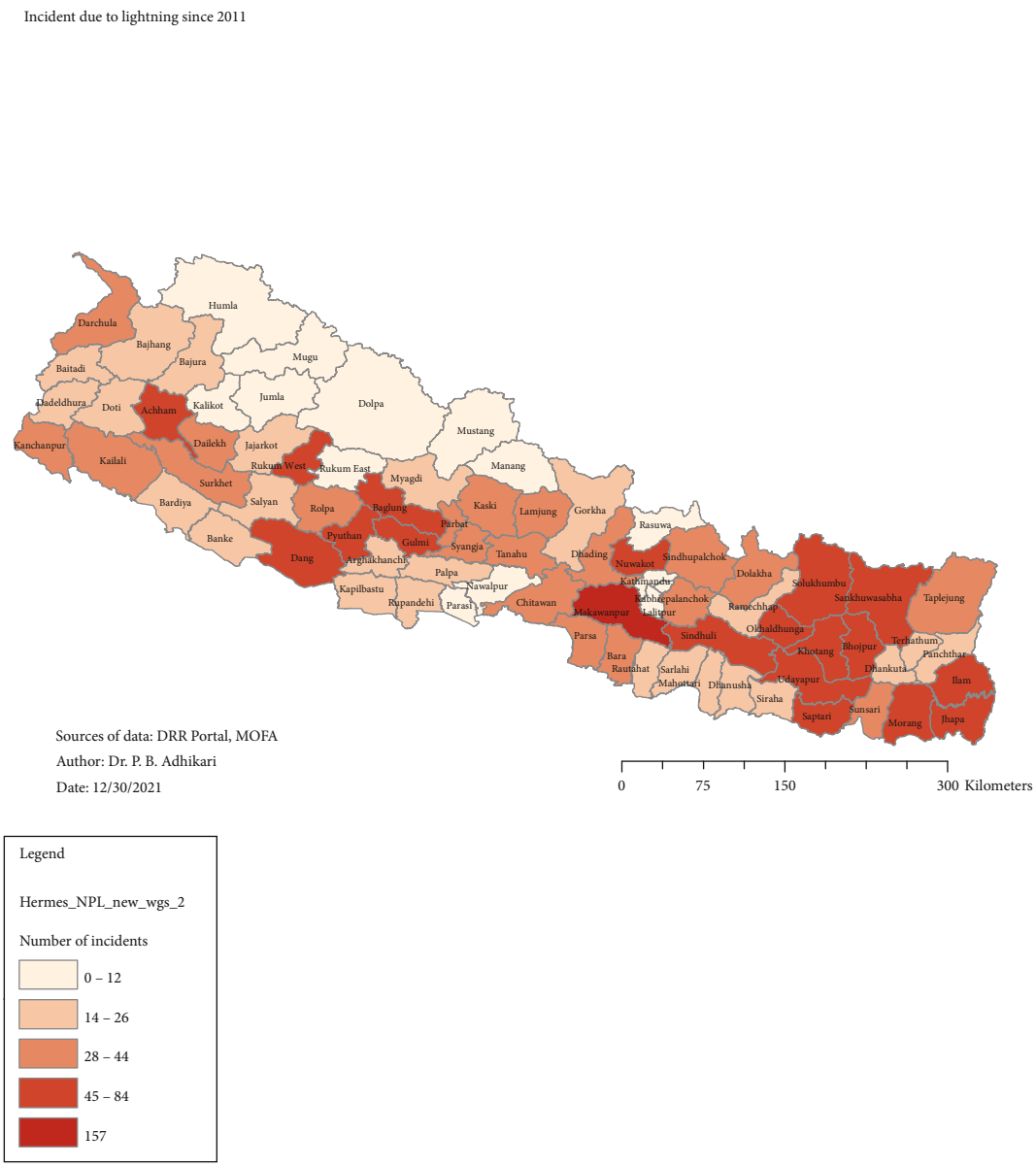


Figure 6: The representation of the death of the people and the number of injured people due to lightning are proportionally represented in the diagram and the size of the pie diagram represents the number of lightning events.

groups but only the individuals, and the information, therefore, is scattered and mostly uncounted. As already mentioned, the same scenario mostly can be seen in the mountainous Himalayan region like Nepal. Similarly, the three districts Dolpa, Rasuwa, and Humla have no casualties during this period even though there are some lightning events in a rank as shown in Table 4.

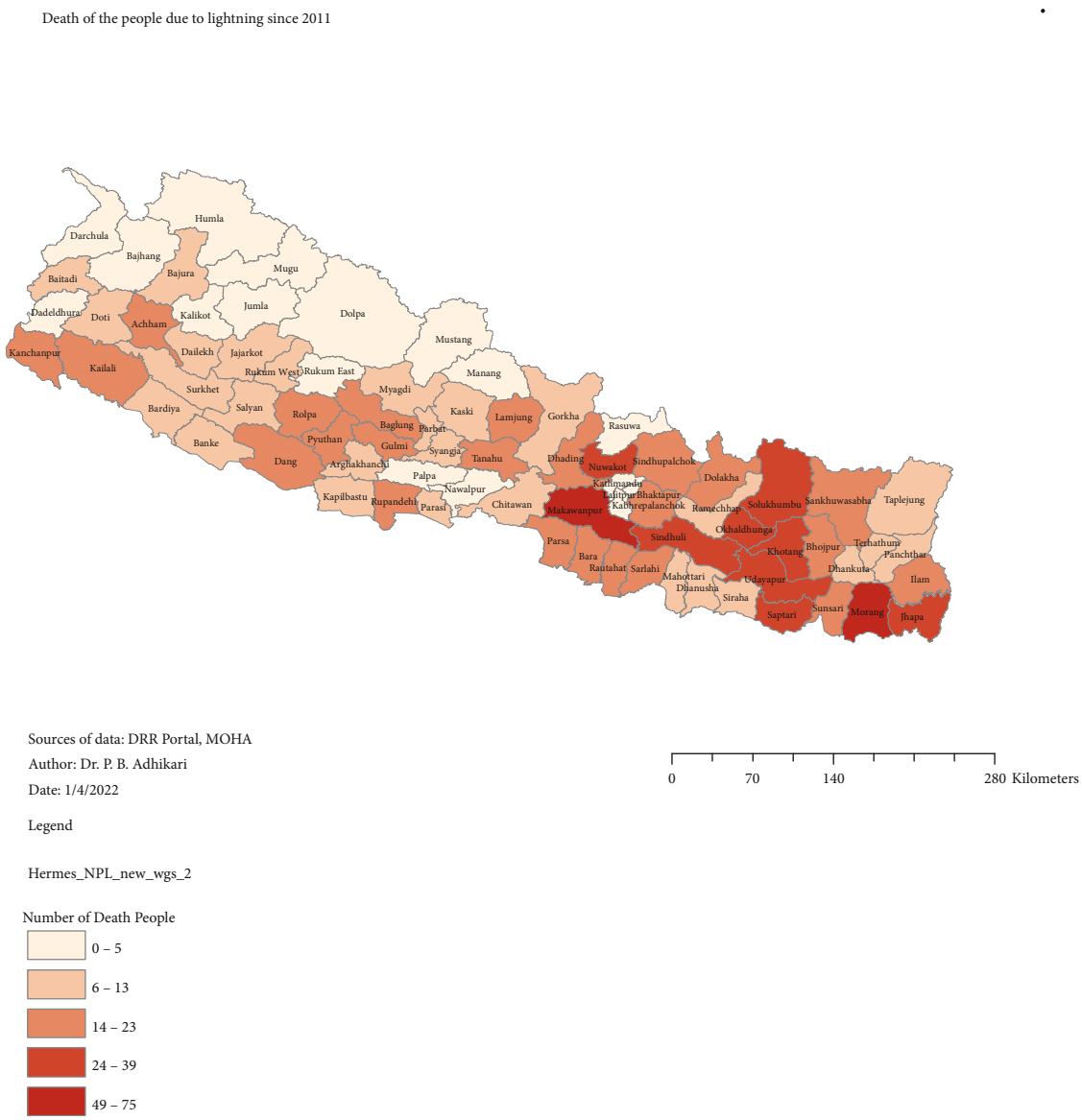
4. Result and Discussion

Lightning is one of the major disasters based on the casualty of the people, loss of domestic animals, causing fires in the huge jungle, and many more. Due to lightning hazards, there are so many direct and indirect effects, unknowingly damaging television, computer, radio, phone, refrigerator, electronic gazettes, various equipment, and medical equipment, causing a fire in building due to high voltage, etc. So it is very dangerous and people should take precautions about it. During the lightning, there is a huge amount of current and high temperature in a transient so it can damage and cause loss of huge property, domestic animals, and human beings; hence, it is taken as a disaster. The distribution of the lightning phenomena and severe thunderstorms over the seventy-seven districts of Nepal was observed and analyzed from the data available on the DRR portal. The number of incidents and number of dead and injured people due to lightning events are expressed with the interannual variations, represented in Figure 2. The distribution of the lightning phenomena and severe thunderstorms during the period of January 2011 to December 2021 observed that the number of injured people is about three times higher than the number of dead people on average, and this value is higher in the premonsoon period. More than 100 people lost their lives annually before 2016 and after then slightly



(a)

Figure 7: Continued.



(b)

Figure 7: (a) The incident of the lightning and (b) the death of the people due to the lightning thunderstorm in the seventy-seven districts are presented with a color map.

decreased the number of casualties. But the number of events of lightning even increased after 2016 as well, but the death of people decreased and the number of injured people increased. Here, the number of injured people is generally linearly proportional to several incidents, but after conducting some awareness programs on the hazard area, then maybe the number of casualties decreased. It means the awareness program may be very useful, and it should be conducted not only for the layman but also for the electronic and electrical engineers, medical persons, technicians, etc.

The monthly distribution of the lightning phenomena was also analyzed during this period over the mountainous country, Nepal. The number of incidents, number of death, and number of injured people due to lightning events were expressed monthly with seasonal variation and analyzed as shown in Figure 3. During this period of eleven years, the weather phenomena are calm after the rainy season and there is no charge formation during this period; hence, there are no lightning events in November. During the premonsoon period, there are more sunny days which warm the air as well as the atmosphere. The more water drops evaporate from the earth's surface and charge developed in the thunderstorm during this activity; hence, the maximum lightning occurs during the premonsoon period. About three months before the monsoon is the premonsoon period in which the maximum number of lightning occurred. The lightning events occurred maximum in April, May, and June, and the casualties were also in the same period. The lightning discharge phenomenon that occurred between the cloud and ground is called CG

lightning. The charge of the cloud can transfer to the ground during this period, and hence, more observations of the lightning occurred.

5. Conclusion

Lightning is the main disaster in mountainous regions. In our scenario, the altitude of the country ranges heterogeneously from 59 m to 8848.86 m. The land of the lowest altitude lies in the Terai while that of the highest altitude lies in the Himalayan region. The air distance between them is about 160 km, and the temperature difference is about 95°C. Due to the variation of temperature in a short range of distance, there is the diversity in climate and the variation of weather phenomena. The heterogeneous rugged topographical features of Nepal influence the environment and frequently occur lightning. The number of incidents, number of dead and injured people due to lightning events since 2011, and monthly as well as annual distribution of lightning were observed and analyzed. There are no lightning events in November during this period of eleven years, and the maximum lightning occurs during the premonsoon period. The maximum number of lightning occurred in April, May, and June, and the casualties were also high. The number of injured people is found about three times higher than the number of dead people. The distribution of the lightning phenomena and severe thunderstorms over different regions of seventy-seven districts of Nepal is also observed and analyzed based on the data available on the DRR portal.

Data Availability

The author can provide the data and materials at any time for the journal or editors if required.

Ethical Approval

I have taken full responsibility for the manuscript according to the ethical responsibilities mentioned in the journal.

Consent

I am a single author so I would like to give consent to participate and publish the manuscript in your journal.

Conflicts of Interest

There is no conflict of interest.

Authors' Contributions

All the material preparation, data collection and analysis, and preparation of the full manuscript were performed by a single author.

Supplementary Materials

The author provided the data of all seventy-seven districts, in rank, maximum lightning of 25 districts and minimum lightning of 21 districts, and maximum lightning in Makawanpur and Jhapa during this period, and their representation in the graph is submitted in the supplementary file. *(Supplementary Materials)*

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