

The fatalities and injuries due to avalanche effect in the Himalayan Region, Nepal

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Abstract

Snow avalanches present the major natural hazard in Himalayan region of Nepal. The loss of human life is the main effect of avalanche. The records and casualties compared with European countries which help to analyze the hazard in the mountain region and can be recommend to the public people of this area about the avalanche condition, prevention from it and dissemination of information. On analyzing the statistics of avalanche fatality in the high mountain of Asia from 1895 to 2022, the fatality number was 59 at Annapurna and Dhaulagiri mountain peaks. Different highest peak of mountains attract tourist and the massive amount of snow create an avalanche, which is one of the most devastating hazards in Himalayan. This fatality events, and fatality rates of Nepal and European countries from 1971 to 2022 analyzes the collected data from the Des-Inventor data-set, Disaster Risk Reduction (DRR) portal of the government of Nepal. The European avalanche warning system is used in the government of Europe using the geographic information system (ArcGIS) tools. This study recommends the establishment of an avalanche warning system with proper tools in the western Himalayan to save the life of humans and property.

Keywords

Nepal, Disaster, Snow avalanche, Arc GIS tool, High Mountain of Asia.

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1 Introduction

Nepal is one of the Asian countries having latitude in the northern hemisphere from 26° 22' N to 30° 27' N and elongated along east-west with a longitude 80° 4' E to 88° 12' E. There are three regions: Himalayan, hilly, and terai. Nepal contains eight of the ten top highest mountain peaks, including Mount Everest, Annapurna, etc. The naturally beautiful country with full of wonderful peaks of the mountain range, scenery of glorious nature,

and lakes, there are ample amazing snowfalls that attract many tourists to visit. Along with the glorious scenario, Nepal is also susceptible to different natural hazards such as landslides, floods, thunderstorms, lightning, avalanche, earthquakes, and so on. Nepal is facing several types of disaster which has damage human life and community. Koenig and Schultz's (2016) state that, a large number of the mass casualties with wounded and dead peo-

ple within a short period [1]. They also reported that it is very difficult to give medical service because it is associated with the sudden rush of mass casualties and associated with mass panic and usually large-scale movement of the population. Disaster disrupts the normal life of people, organizations, community [2]. It brings great loss in the people health which immediately poses stressful circumstance in people to handle situation for which it is not usually fully prepared. The growth of world population has increased the concentration in hazardous surroundings which focus on severity of disasters. National Snow and Ice Data Center, (2021) reported that avalanche is a natural disaster which is unpredictable and causes many injuries, loss of life, and social and economic destruction [3]. Avalanche is a mass of snow, ice, and rock that collapses sliding down a mountain which harms the traveler, mountain dwellers, their work, transport, vegetation, and timber. It plays a vital role in forming sculptures and weathering the world's most wondrous peaks. Avalanches, earthquakes, tornadoes, tidal waves, tsunamis, hurricanes, volcanic eruptions, landslides, are natural disaster [4]. Nepal, due to its unique geographical character, faces natural disasters every year which cause massive harm to lives and property [5]. Schweizer et al., (2003) reported that the result of a complex interaction between snowpack, terrain, and meteorological weather condition creating the avalanche [6]. It can be classified into two models using the complex interaction between terrain, snowpack, and meteorological condition and from the physical and mechanical mechanisms of avalanche formation. Most avalanches that cause injury to people are caused by the victims themselves. They also added that there are many ways to determine the snow avalanche. The avalanches occur on the slopes of 35 to 40 degrees because the force of gravity is generally insufficient to cause an avalanche beyond this value. It is influenced by the weather and can be prevented by vegetation on the slope. After heavy snowfall and the additional snow adds the stress and forms the Avalanche and forms its different types [7]. Singh and Ganju, (2002) explained about calamity present in the western Himalayan of India, and how snow avalanches initiate and its effects on the lives of civil and military people in the winter season [8]. They found that potential near avalanche sites got triggered due to snow metrological factors. Reuter and Schweizer (2009) reviewed avalanche triggering through the sound wave citeref9. They performed that some myths believed that avalanches can be triggered by noise. Dixon et al., (2013) studied avalanche destruction around Glacier National Park (GNP), Montana, on the United States at Canadian border [10]. They examined the damage to transportation, property

with injured and dead people from avalanches from 1949 to 1997. McClung (2016) considered avalanche activity in the high Mountain in Asia and analyzed and reviewed the statistics of avalanche fatalities [11]. He concluded that the reduction of the fatal avalanche in the high mountains of Asia can be governed by human action and their decision. Chabot and Kaba (2016) studied avalanche hazards in Afghanistan, Pakistan, and Tajikistan and made a strong plan to reduce fatalities from avalanche hazards including in remote areas too [12]. Fujita et al., (2017) considered snow amplified by an earthquake which was occurred in 2015 causing induced calamity of torrential slides in Langtang region in Nepal [13]. They studied the co-seismic avalanches and rock falls along with their cause and destruction which occurred in the 2015 Gorkha earthquake destroying the Langtang village. Amanambu (2018) reported about avalanche activity in the western Tianshan Mountains of China and studied on the features of its triggering factors. They found that snow avalanches pose a major danger to road safety in mountainous places [14]. Thakuri & Koirala (2019) studied mountaineering in Nepal with its effects and challenges including avalanches caused [15]. They considered the climate change occurring through the different types of natural hazards emerging in the mountain region. They got that snow avalanches had caused many deaths in the Himalayan region which harmed the ascents in mountaineering. Schweizer et al., (2020) considered avalanche occurrence and avalanche danger level. They got that in the snow covered mountain range of many countries, warning alerts are imminent in avalanche danger employing a five-level danger scale [16]. They found that their data were inherently incomplete got results referring to a lower limit, and consider using other similarly comprehensive data sets. Thakuri et al., (2020) studied an avalanche in the high mountain of Nepal [17]. They underlined avalanche as well as glacial hazards and reflect the condition of a mountain in Nepal. In this article, the nature is to understand the various avalanche data and casualty of Nepal present in snow covering area of Nepal and in different highest mountains of Asia. It helps us to compare various avalanche fatality of US, Colorado and European country with Nepal which helps us to reduce the damage and human loss from avalanche.

2 Methodology and instrumentation

The data is collected from United National Disaster Risk Reduction (UNDRR) from 1971 to 2021 that includes all the disasters available in the world and the Nepal disaster risk reduction portal; Government of Nepal (<http://drportal.gov.np>) from 2012 to 2022. The data is also collected from min-

istry of home affairs (MoHA) compared with united national disaster risk reduction. The data include death, missing, and injured people along with economic loss of all affected areas out of 77 districts of Nepal from 1971 to 2022. The collected data were analyzed using graphical design was done by aeronautical reconnaissance coverage geographic information system (ArcGIS) software tools. Statistical package for social science (SPSS) is one of the statistical analyzed packages used to calculate sampled data. Geographic information system (GIS) is the software used to visualize, analyze and explore geographically referenced information. This software is used to map the different data and used to map the avalanche data district-wise of all the disasters compared with the avalanche. Study Area: Nepal is an Asian country that lies between India and China having 147,516 km² in the surface area. It has been characterized into three major regions namely terai,

hill, and Himalayan. The altitude varies from 59 m above sea level to 8848.86 m; the height of Mount Everest, within the range of 160 Km. The whole region of the Nepal as well as other Himalayan region are study area.

3 Results and Discussion

3.1 Analysis of disaster of Nepal and avalanche fatality rate of highest mountain peak of Asia

There are several natural hazards such as avalanche, earthquake, landslide, flood, etc. in the study area. Due to this disaster, there are so many people lost their life, injured and missing. The data observed and recorded from 1971 to 2022, is shown in the table 1 in which the number of death people, injured and missing people with the estimated loss due to different disaster in Nepal.

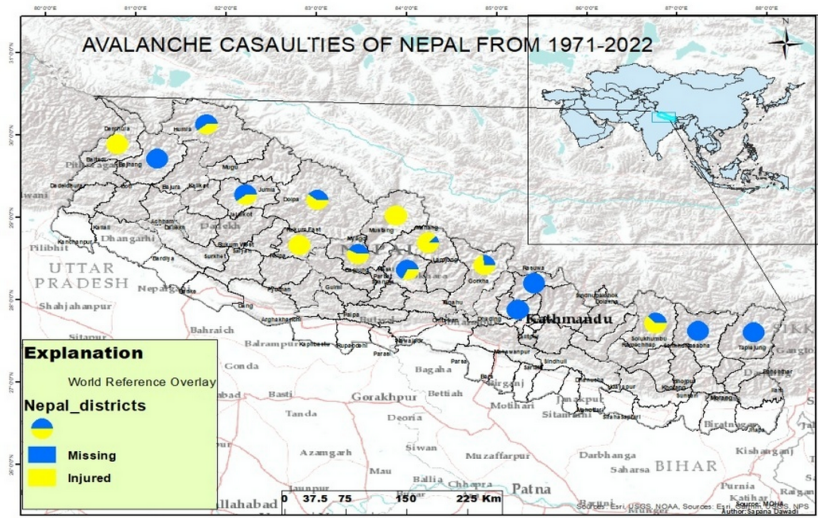


Figure 1: Avalanche causality of Nepal from 1971-2022.

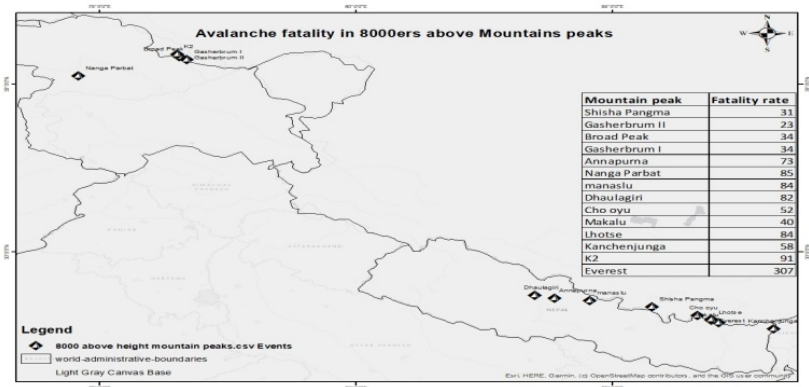


Figure 2: Avalanche fatality in 8000ers above high mountain peak, Source:www.earthobservatory.nasa.gov.

Table 1: The data of deaths, injured and missing people caused by several hazards in the Nepal during 1971-01-01 to 2022-06-30.

S.N.	Name of incidents	Number of death people	Number of missing people	Number of injured people
1	Animal incidents	138	0	638
2	Snake bite	85	0	60
3	Flash flod	43	32	0
4	Accident	1675	286	646
5	Panic	89	0	121
6	Explosion	36	0	99
7	Strong wind	184	0	497
8	Forest fire	74	7	48
9	Snow storm	98	31	45
10	Heat wave	45	0	20
11	Plague	11	0	0
12	Hail storm	65	0	104
13	Structure collapse	417	8	668
14	Breaking tuin	0	2	0
15	Bridge collapse	2	1	12
16	Air crash	56	0	38
17	Avalanche	281	65	138
18	Cold wave	870	0	83
19	Boat capsize	334	586	181
20	High altitude	80	0	22
21	Heavy rainfall	186	4	285
22	Wind storm	84	1	1449
23	Hailstone	0	0	0
24	Epidemic	7684	0	32709
25	Storm	90	8	303
26	Thunderbolt	1718	0	4485
27	Fire	1304	0	2964
28	Landslide	3520	660	2068
29	Flood	2089	702	622
30	Earthquake	8969	195	22311
31	Other	201	20	268
	Total	30428	2608	70884

Table 2: Fatality number, fatality rate and deaths to total number due to avalanche on the 8000 m peaks during the period of 1922 to august 2022, respectively.

District	Average population (millions)	Fatalities		Number of missing people	Number of injured people	Fatalities density (per km ²)
Panchthar	0.191	2	12	0	0	0.00161
Solukhumbu	0.105	76	1	15	25	0.00051
Taplejung	0.127	13	7	3	0	0.00357
Dhading	0.33	2	12	0	0	0.0010
Makwanpur	0.42	1	13	0	0	0.0004
Nuwakot	0.27	1	13	4	0	0.00008
Rasuwa	0.04	13	7	1	0	0.00841
Gorkha	0.27	20	4	7	18	0.0055
Kaski	0.49	18	5	12	6	0.0089
Shankhuwasabha	1.58	2	12	1	0	0.00057
Manang	0.006	59	2	1	7	0.02600
Mustang	0.01	16	6	0	26	0.00447
Myagdi	0.11	6	10	3	4	0.00261
Rukum East	0.05	0	14	0	1	0
Dolpa	0.03	32	3	2	3	0.00405
Humla	0.05	7	9	6	4	0.00159
Jumla	0.10	9	8	9	6	0.00316
Rukum West	0.15	1	13	0	0	0.00034
Bajhang	0.19	0	14	7	0	0
Darchula	0.13	3	11	0	35	0.00129

Table 3: The data of deaths, injured and missing people caused by several hazards in the Nepal during 1971-01-01 to 2022-06-30 Source(www.8000ers.com; www.earthobservatory.nasa.gov/8000meterpeaks; www.Wikipedia/wiki/list_of_deaths_on_eighthousanders.com).

S.N.	Peak(altitude)	Height(m)	Fatality number	Avalanche Fatality rate (%)	Total number of Death
1	Everest(Nepal-Tibet)	8848	10	26.77	83
2	K2(Pakistan-China)	8611	95	16.84	16
3	Kanchenjunga(Nepal-India)	8586	54	9.25	5
4	Lhotse(Nepal)	8516	32	40.62	13
5	Makalu(Nepal-Tibet)	8463	40	7.5	3
6	Cho Oyu(Nepal-Tibet)	8201	52	17.30	9
7	Dhaulagiri(Nepal)	8167	82	51.21	42
8	Manaslu (Nepal)	8163	89	44.94	40
9	Nanga Parbat(Pakistan)	8125	82	40.24	33
10	Annapurna(Nepal)	8091	73	54.79	40
11	Gasherbrum I (Pakistan-China)	8068	34	26.47	9
12	Broad peak(Pakistan)	8047	37	13.51	
13	Gasherbrum II(Pakistan-China)	8035	24	16.67	4
14	Shisha Pangma (Tibet)	8013	31	35.48	11

Table 4: Avalanche occurred in Nepal Himalaya and human casualties due to avalanche for the year 1990 to 2022.

S. N.	Year	Location	No. of death people
1	1990	Mount Everest	6
2	1991	Mount Everest	8
3	1992	Khumbu	2
4	1994	Mount Everest	2
5	1995	Khumbu region, near Mt.Kanchanjunga base camp	48
6	1996	Mount Everest	9
7	1997	Mount Everest	19
8	1998	Mount Everest	6
9	1999	Mount Everest; Chunchet	
6 10	2005	French expedition base camp	21
11	2006	Khumbu icefall at Mount Everest	3
12	2007	Mount Everest	6
13	2009	Khumbu icefall	2
14	2010	Mount Baruntse	2
15	2012	Manaslu peak	9
16	2013	Mount Everest	8
17	2014	Annapurna and Dhaulagiri	59
18	2015	Mount Everest	23
19	2017	Dolpa	1
20	2018	Dhaulagiri	9
21	2019	Dhading	8

Table 5: Total numbers of annual fatalities with 5 year average of US, Colorado and European countries.

year	Fatalities in		
	United States	Colorado	European
1950-1960	38	13	854
1960- 1970	53	21	627
1970 – 1980	120	27	1158
1980 -1990	143	51	1177
1990 - 2000	220	62	1015
2000 -2010	279	52	990
2010 -2020	256	61	938
2020 –	60	18	182
Total	1169	305	6941

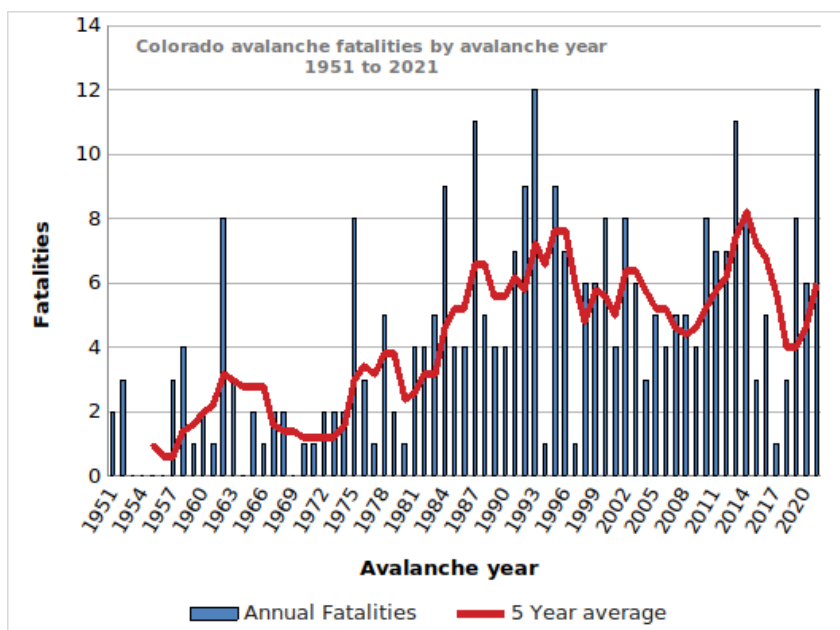


Figure 3: US avalanche fatalities data in combination chart.

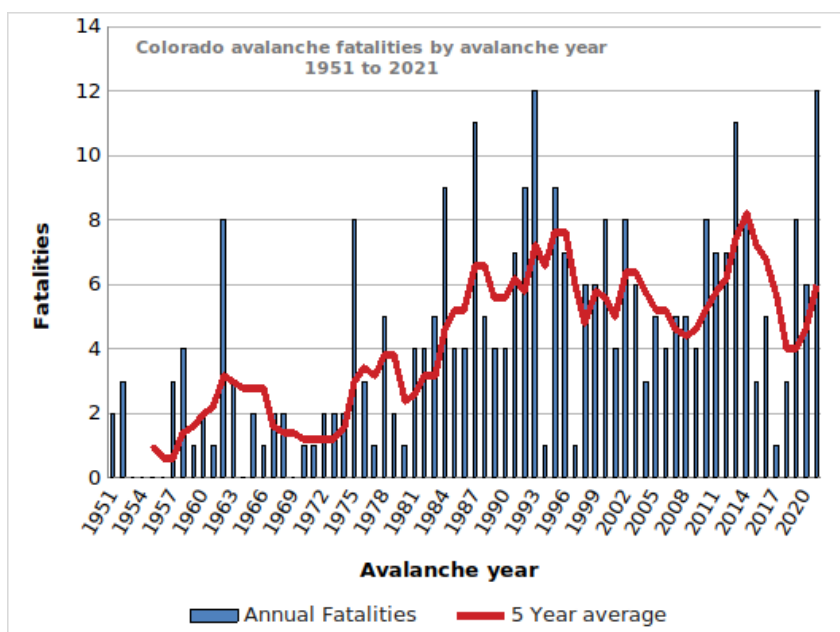


Figure 4: Colorado avalanche fatalities data in combination chart.

Nepal is affected by different disaster as shown in table 1. The earthquake, epidemic, landslide, flood, thunderbolt, accident, fire, cold wave, avalanche, boat capsized, are the main disaster during the time of fifty-two years. Nepal is mostly harmed by earthquake which was totally damaged in 2015 Gorkha epicenter earthquake. In this earthquake 8969 lost their life and so many were injured with many loss of property. Similarly, 7684 people lost their life due to epidemic, 3520 due to landslide, 2089 due to flood, 1718 due to thunder-bolt light-

ning, 281 due to avalanche during the mentioned period. Nepal had been facing economic problems from the natural disaster which created lots of losses the property. Not only the loss of human life, animals, but also many physical properties. Among 77 district of Nepal, only 20 districts area affected from avalanche. The total number of fatalities was divided by the total number of population is the fatality density as per millions to obtain fatality rate per million for each district of Nepal as shown in table 2. The total population of Nepal was ob-

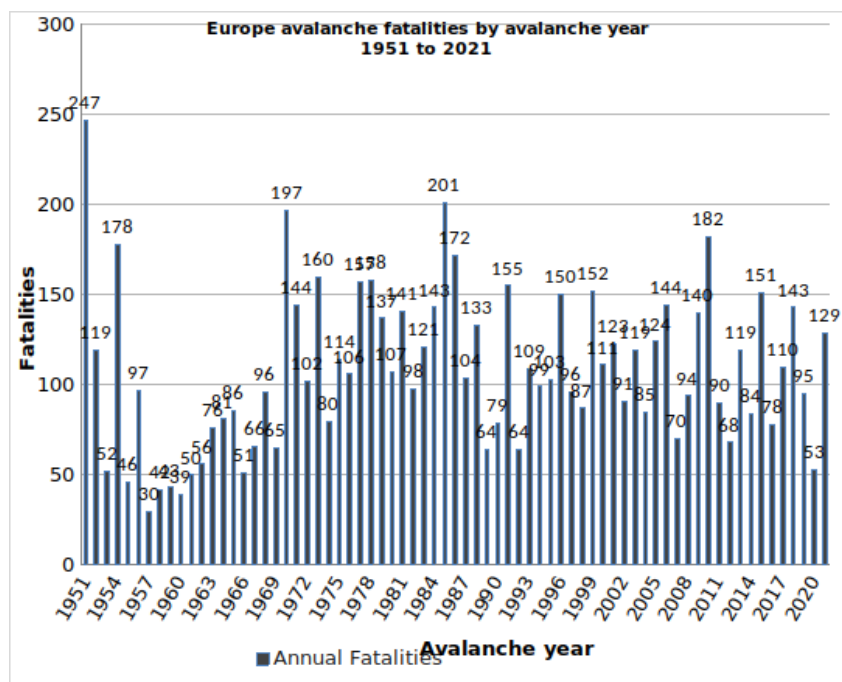


Figure 5: Europe avalanche fatalities data in bar graph.

tained from the Nepal census 2021 and the data of fatalities, missing, and injured people in different district occurred from avalanche during the period of 52 years.

In the table 2, we mentioned districts, average populations of these districts, fatalities numbers with ranks and fatality density per area (km²). There are only 20 district's data among 77 districts because no loss of lives and properties in this area caused due to avalanche. The fatality density on this table is calculated by dividing fatality number by area (per square kilometer) where the highest one is 0.00051 of district Solukhumbu and lowest are Bajhang, Rukum east and Lamjung. The highest fatality occurred, 76 in Solukhumbu district followed by Manang with 58.4. fatalities and Dolpa as a third ranked has 32 deaths due to avalanche. Himalaya lies in Nepal are mostly triggered by avalanche. The highest peak Mount Everest having height 8848.86 meter have two base camps. Many tourists or mountaineers come there to climb the peak and they can be affected mostly. The figure 1 represents the injured and missing people from avalanche effect. In this pie diagram, the size of the circle represents the affected area which is highest in Solukhumbu, then Manang, Dolpa and so on. Hence, in the Himalayan part avalanche condition is more than in hilly and terai region. In the Himalayan area, it is covered by snow and mountain peaks so avalanche triggering area is more. In the world, northern hemisphere is covered by snow and ice. In table 3, there is the data of avalanche fatality with different incident event recorded by

European avalanche warning services from 2020 to 2022. Fatality number of 14 mountain peaks due to avalanche up to august 2021 is shown in table 3. The data consist of documented cases and summary data from the websites of (www.8000ers.com) for the information of 8000 m peaks since 1979. The proliferation of expedition containing the database cannot be comprehensively represented over the past 30 years and has grown rapidly since 1990. The data were stratified according to type of accidents, climate change and so on. The table is the lists of avalanche fatality with its characteristics and risks occurred in this sets of peaks. These peaks are very challenging having highest risks to reach the summits. The high mountain of Asia having 8000 m peaks are the best recorded for fatal accidents. The table 3 suggests that the highest peaks of central Himalayas exhibit very high risk area of avalanche for climbers. The highest number of fatality was happened in peak mount Everest and the lowest number in Shisha Pangma in comparison to world's peaks but in the context of Nepal, the highest mountain in the world. Mount Everest which have height 8848.86 m have highest number of fatality and successful ascents per death and the lowest one is in the peak Makalu having deaths of 40 people. K2 peak located in Pakistan to China and Nanga Parbat located in Pakistan are the second and third in rank for fatality number 91 and 85 respectively. There are four peaks which have the same number of fatality case due to avalanche. Broad Peak located in Pakistan and Gasherbrum I located in Pakistan to China are

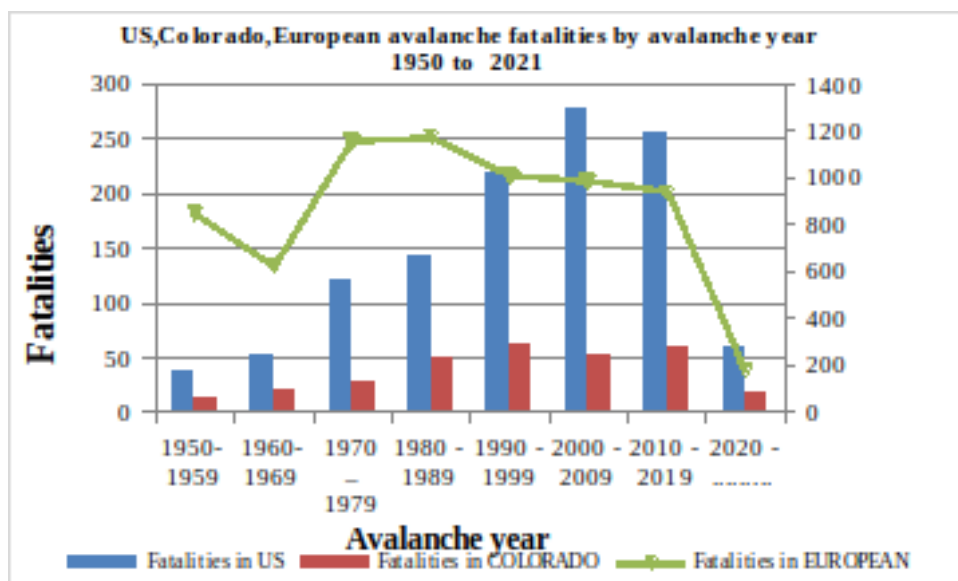


Figure 6: US, Colorado and European avalanche fatalities data in combination chart.

two peaks which have the same number of fatality 34, similarly, peak Manaslu and Lhotse both from Nepal felt same number of fatalities 84. In Shisha Pangma, the deaths appear from a mix of routes having fairly simple snow climbs prone for the formation of avalanche. The most deadly disaster in the history in Mt. Everest was from avalanche. There are eight mountain peaks which touch the outline of Nepal and four peaks are near and at Pakistan area. Avalanche data occurred in Nepal Himalayan is been listed in table 4. Here is the description of avalanche statistical data based on different literature, article, MOHA, on different location occurred on different ice land area and snow area. The years 1995, 1997, 2005, 2014 and 2015 have the top deaths rate respectively 48, 19, 21, 59 and 23 caused due to avalanche. The most affected area for the avalanche is Mount Everest where every year certain people died from avalanche. The area is also most triggering place where tourist has been killed in an avalanche as well as snow storm. The description of these all fatality rate in the 8000ers mountain peaks is virtually shown in figure 2. The most affected region from avalanche is in Mount Everest.

3.2 Comparing the avalanche data of US, Colorado and Europe

In the table 5, the total number of dead people from avalanche in Europe country is listed. The data is from 1951 to 2021 in which 5 year average fatalities of US, Colorado and European countries are also illustrated. The Europe continent contains 16 country. The data is taken from European avalanche warning services. The bar diagram and line graph of US avalanche fatalities is shown in figure 3, Col-

orado fatalities is shown in figure 4, and European avalanche fatalities is shown in figure 5 during the years of 1951 to 2021. The data is collected from Colorado avalanche information center and European avalanche warning service from 1951 to 2021. Bar diagram represent here in year wise avalanche and the red line denote the five year fatalities in the respective figures. Here, in US annual fatality rate from 1951 to 2022 is 1169. In the table 5 total annual fatality rate of Colorado is 305. The five year average annual fatality rate of avalanche from 1951 to 2021 is 284.6. It is shown that most affected area from avalanche is European continent. There are sixteen countries in a European continent. Mostly there is highest number of the European country is covered by snow which is most affected for avalanche. All the annual fatality rate of different years is represented in the given figure. Total number of fatalities with incident event from January 2020 to April 2022 occurred in European country** recorded by European avalanche warning services. The fatality rate is going on increasing from the data which indicates that the avalanche problem going on the danger level. Here the fatality rate of three countries is shown i.e. US, Colorado and European of fatality is shown in table 5. The table described about avalanche problem in different year with forecasted regional danger level. Here comparing the fatality rate of three countries which is shown in Figure 6, i.e. US, Colorado and European.

4 Conclusion

The avalanche is less studied in Nepal, on comparing to other disasters even its fatality rate is

high. Especially, people suffered from avalanche in the mountainous area and its dwellers area. The avalanche activity also depends on elevation of Mountain. There is an estimated loss of lives through disaster in different region of Nepal. The total deaths, missing and injured people due to avalanche is found to almost 100. The fatality rate due to avalanche activity in the Himalayan region varies from place to place. The solukhumbu is the most affected area due to avalanche, covered from snow due to high altitude. Mt. Everest, Dhaulagiri, Annapurna, Manaslu, have higher mortality rate than Kanchenjunga, Lotse, Cho-yu, and Makalu. The death rate is high in Nepal than other due to avalanche. European countries are most harmed and hampered than United States and Colorado. Switzerland is mostly effected among the different countries of Europe.

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