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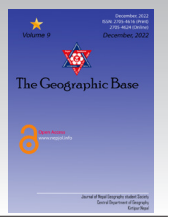

Impact of Climate Induced Disaster in Sindhupalchowk District

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Abstract

This study attempt to analyze the impact of climate induced disaster on human, private housing, government building, and economy in Sindhupalchowk district based on the information available on Nepal Disaster Risk Reduction Portal from 1971 to 2022. The disaster caused by climate change can be classified as hydrological, climatological, meteorological, or both. Hydrological disasters are controlled by hydrological processes, such as floods, droughts, and avalanches; climatological disasters are concerned with hazards related to extreme temperatures, such as heat waves, cold waves, and wildfires; and meteorological disasters represent storms of all types, such as snowstorms, thunderstorms, hurricanes, and tornadoes. This article is based on literature review that includes district disaster preparedness and response plan (DPRP) and different articles related to disaster and climate induced disaster. DRR portal of MoHA and Disinventar are the major secondary source of information. Sindhuplchowk district is one of the disaster-prone districts of Nepal. Landslide, flood and

thunderbolt are the major disasters of Sindhupalchowk district. Climate induced disaster affected 100,903 families; 4,467 persons have lost their lives, 2,778 to have been injured, 314 missing. It has found that among all disaster 53% death toll by climate induced disaster and 47% death happens due to the non-climate induced disaster. Damage and losses due to the disaster were amounted to an estimated 72,565,001 Nepalese rupees. The findings of this study can help local, national, and international policies and decision-making in order to lessen the risks associated with these disasters and foster resilient communities.

Introduction

Every sudden, unanticipated, or extreme catastrophe is referred to as a disaster, regardless of the number of victims, the size of the region, the nation, or the entire world (Proag, 2014). A disaster can be described as an unexpected and devastating incident that severely interferes with the normal operations of a community or society, resulting in significant human, material, economic, or environmental damages that go beyond the community or society's capacity to manage with its own resources (IFRC, 2022). A disaster is an event that causes significant harm, such as injuries, loss of life, and social and economic disruption, and which goes beyond the ability of the affected individuals and the environment to cope (Kamara et al., 2018). The aim of this research is to offer policy makers timely information on the significance of analyzing the effects of disasters and how it can be integrated into economic planning.

The disasters can be broadly categorized into two types, natural and human caused (IFRC, 2018). The natural disaster has five classifications around the world (CRED & UNISDR, 2018) which include: i. geophysical disasters such as earthquakes, volcanic activity, tsunamis, and landslides, ii. hydrological disasters like floods, droughts, and avalanches, iii. climatological disasters which involve extreme temperature hazards like heat waves, cold waves, and wildfires, iv. meteorological disasters such as snowstorms, thunderstorms, hurricanes, and tornadoes, and v. biological disasters including epidemics and insect/animal plagues. Among five kind of disaster, three categories namely hydrological, climatological, and meteorological are confined in climate induced disaster (CRED & UNISDR, 2018). Landslides caused by heavy precipitation are very likely to occur in Nepal's hilly and mountainous regions. These landslides are more common now as a result of the extreme hydro-meteorological conditions brought on by climate change (Wijaya et al., 2023). In opposition to natural disasters, human-induced disasters involve several types of events, including armed

conflicts and wars, famine, ethnic clashes and population displacement, industrial and transportation accidents, pollution-induced environmental degradation, as well as anthropogenic intentional threats such as terrorism or weapons of mass destruction (Chen et al., 2018 & IFRC, 2018).

With the growing severity and frequency of climate-triggered disasters, which encompass the effects of hydrological, meteorological, and climatological factors, cities across the globe have faced a stern test of their ability to remain resilient (Haggag et al., 2021). Disasters from 2000 to 2012 impacted more than 2.9 billion people across the world, and the documented damages resulting from these disasters had a total cost of $1.7 trillion (Nestler & Jackma, 2014). Additionally, these catastrophes cause an estimated 60,000 lives annually and are predicted to add an additional 250,000 deaths annually by 2020 and 2030 (Haggag et al., 2021). Around 570 cities and 800 million people worldwide would be under danger from storm surges and increasing sea levels by 2050 (Muggah, 2019). Sea level rise has resulted in chronic flooding in more than 90 coastal cities in the USA alone over the past ten years (Muggah, 2019). Aside from the anticipated mortality, negative health effects are anticipated to cost $2 to $4 billion yearly by (WHO, 2018).

Nepal is exposed to various types of natural disaster such as earthquake, flood, landslide, and debris flows mainly because of steep topography, on-going mountain building processes, highly fractured rocks, diverse climate and intense precipitation. In addition, the impact of climate change has further provoked the spheres of natural hazards as the extreme climatic events like short-lived heavy rainfall, localized intense precipitation, and overlong drought. Such variation in weather denotes that there is increasing trend of climate change impact in Nepal (Bhattarai, 2012). Landslides and drought are main climate induced disaster in Lesser Himalayan zone. Similarly, the Siwalik zone is extremely affected by landslides, debris flows, and rill erosion whereas the Tarai region is more prone to flood hazards along with sediment deposition at some places and riverbank cutting at other places (Devkota & Bhattarai, 2011). Rugged topography, weak geological formations, active seismic conditions, occasional glacier lake outburst, concentrated monsoon rains and unscientific land utilization are some of the major reasons for water-induced disaster (DWIDP, 2013). Commonly, during the monsoon floods and landslides are a natural phenomenon in Nepal. Nepal has more than 6,000 rivers and rivulets, with a total of 45,000 km in length that backing irrigated agriculture and other livelihoods. On the other hand, it causes

devastation in valleys and in the Tarai when they overflow (Dixit, 2010).

In the past 10 years, it is believed to have lost an average about 211 lives annually (DRR Portal, 2022). The scale of vulnerability from water induced disasters has increased in recent years. The increasingly long drought periods have affected rainfed farmers and rural women. The scale of landslide and drought has increased due to climatic variability and anthropogenic activities, such as rural road construction in the mountain and forest degradation in the Siwaliks and mountain region (Tiwari & Rayamajhi, 2018). Over the past few years, Nepal has been affected by several factors, including rapidly retreating glaciers (average retreat of more than 30 m/year), rapid temperature rise (>0.06OC), erratic rainfall patterns, and an increase in the frequency of extreme events like floods and drought-like conditions. Since the majority of Nepal's major rivers are glacier-fed, continual changes in glacier reserves, snowfall, and natural disasters will have a significant impact on the country's primary supplies of water and hydropower (Karki et al., 2010).

Natural disasters can affect Nepalese citizens, their property, and the country's infrastructure because of the country's fragile mountainous and flood-prone terrain, low levels of awareness, high rates of illiteracy, poverty, political unrest, rapid and unplanned urbanization, and insufficient institutional and legal frameworks for disaster risk management. Geological instability, extreme topography, and climatic change all contribute to the deterioration of the situation (ICIMOD, 2007). The effects of various climate-related disasters, including floods, droughts, high winds, and landslides, on various economic sectors, including the agricultural, industrial, and service sectors, as well as various economic sub-sectors and time periods (Weerasekara et al., 2021). The Himalayas have warmed significantly more than the world as a whole (0.74°C) over the past century (Du et al., 2004 & IPCC, 2007). Research on temperature trends in Nepal between 1971 and 1994 showed that temperatures experienced a consistent increase, with an average annual warming rate of 0.06°C, which fluctuated regionally and seasonally (Shrestha et al., 1999).

Table 1 illustrate the major climate change outcome risk according to geologic and ecologic unit in Nepal (Devkota, & Bhattarai, 2011).

Table 1. Major climate change outcome risks in different geologic zones of Nepal Himalaya

Geologic unit	Ecologic units	Major climate change outcome risk
Tarai Siwalik Zone	Tarai-Churia Range (includes also Dun Valleys)	Debris flows, forest fire, vector, riverbank cutting, floods, drought, waterborne diseases, degradation of ecosystems.
Lesser Himalayan Zone	Middle Mountain (includes also Mahabharat Range and Midlands)	Drought, drying out of springs, wildlife migration, prevalence of insect and diseases in agriculture, landslides.
Higher Himalayan Zone Tibetan Tethys Himalayan Zone	High Mountain (includes snow peaks)	Rapid glacial melting, glacial lake outburst flood (GLOF), drying out of springs, wildlife habit degradation, shifting of snow line, landslide and ecosystem degradation

The objective of this study is assessing the impacts of climate change in Sindhupalchowk district. This involves studying the effects of climate-induced disasters on human communities, economy and infrastructure particularly houses. By studying the impacts of climate-induced disasters aim to provide information and insights that can help guide disaster response and recovery efforts, including providing support for those who have been affected and promoting sustainable recovery efforts. Advance our understanding of climate-induced disasters and to inform effective responses to these challenges.

Sindhupalchowk district is highly vulnerable to a range of climate-induced disasters, including flash floods, landslides, and glacial lake outburst floods (GLOFs) (Delalay et al., 2018). Despite these ongoing threats, the full extent of the impacts of these disasters in the district is not well understood. This study aims to fill this gap by assessing the impacts of climate-induced disasters in Sindhupalchowk, with a focus on the social, economic, and environmental dimensions of these events.

Methods and Materials

Study area

Sindhupalchowk district is located in Bagmati province of Nepal. Sindhupalchowk district spreads 27° 27" north to 28° 13" north latitude and 85° 27" east to 80°06" east longitude (DPRP, 2078). Sindhupalchowk district is situated between China and Dolakha district to the east, and between Kathmandu and Nuwakot district to the west. To the north, it is surrounded by China and Rasuwa district, and to the south, by Kavrepalanchowk and

Ramechhap districts. The district, with an area of 2,542 km2 (District profile, 2067) is divided into 4 constituents, 9 rural municipality, 3 municipality and 103 wards. The 2542 sqkm land area is distributed among different categories with 776 sqkm of forest, 737 sqkm of agriculture, 323 sqkm of bushes, 47 sqkm of mountain areas, and 118 sqkm of pasture land. Other categories include 3 sqkm of landslide, 26 sqkm of sandy area, 456 sqkm of fallow land, 2 sqkm of water, and 54 hectares of other areas.

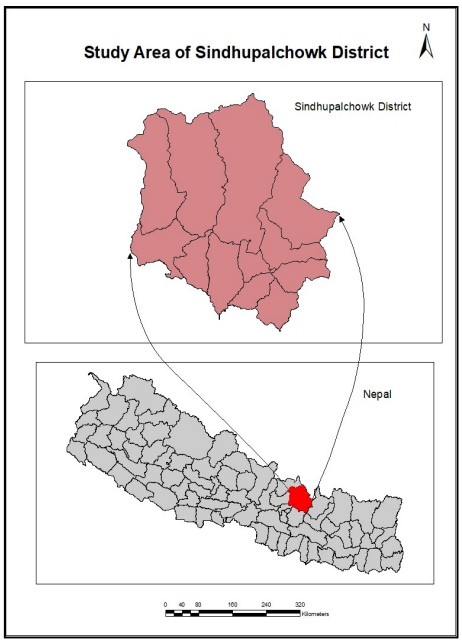

Figure 1. Location of the study area

The altitudinal range of the district is from 850 masl to 7080 masl. It has three types of climates: tropical in low-lying areas up to 1000 meters, sub-tropical between 1000 to 2000 meters, and temperate at elevations above 2000 meters. The annual precipitation is 2500 mm, and temperatures range from 7.5°C to 32°C (Shrestha et al., 2017). Rainfall is 3604.3 ml, with 80% of it falling during the monsoon season, (Nepal Tourism Board, 2008). The total population of this district is 262,852 individuals (CBS, 2021). There are a total of 69,751 households in the district. The population density of the district is 113 per square kilometer. The literacy rate is 59.59% in Sindhupalchowk district. Sindhupalchowk district has been extended 49.38 KM east west and 53.06 KM north south in average. One fourth of the total land of the district covers by Langtang National Park. Sindhupalchowk district also shares some of the part of Shivapuri National Park. Bhotekosi, Sunkosi, Indrawati, Balefi, Melamchi, Sindhukhola, Handikhola, Bhyadikhola and Mahadevkhola are the major rivers of district (District Profile, 2067). This is one of the climates induced disaster prone district of Nepal. Sindhupalchowk district is stricken by various disaster every year.

Data source

This article is based on extensive review of different types of literature regarding disaster, climate and climate induced disaster. The DRR portal of Ministry of Home Affair, Nepal and Disinventar are the major secondary source of information. In addition, district disaster preparedness and response plan (DPRP) of Sindhupalchowk districts provides the information on district level hazard ranking and affected wards by climate induced disaster. The data from the

DRR portal of Ministry of Home Affair has analyzed available from 1971 to 2022. Collected data of DRR portal has categorized in to climate induced disaster and non-climate induced disaster. Landslide, flood, thunderbolt, storm, forest fire, hail storm, heavy rainfall, cold wave, snow storm, and drought confined within climate induced disaster. Human loss, injure, missing, affected family, private house and government building damages, estimated economic loss are calculated both by climate induced and non-climate induced disaster. Comparison of both climate induced and non-climate induced disaster has been embraced on analysis section.

Results and Discussion

Hazard ranking

The district of Sindhupalchowk in Nepal is identified as a vulnerable area for disasters triggered by climate change, with a higher probability of experiencing multiple disasters (DPRP, 2078).

Table 1: Hazard ranking in Sindhupalchowk district

SN	Hazard	Rank
1	Landslide	1
2	Flood	2
3	Thunderbolt	3
4	Fire	4
5	Wild life attack	5
6	Hailstone	6
7	Epidemic	7

Source: DPRP, Sindhupalchowk, 2076

Out of seven hazards, four namely landslide, flood, thunderbolt and hailstone are climate induced disaster. Landslide, flood, thunderbolt and hailstone are on first, second, third and sixth position respectively in hazard ranking. On the other hand, Sindhupalckowk districts was highly affected by Gorkha earthquake, 2015 in terms of loss and damage. Out of 14 affected districts, most death, injuring and missing of people occurred in Sindhupalchowk. Similarly, it was in top rank in terms of physical damage such as house, building, school, road, hydropower damage (DRR Portal, 2022). Even there was highly affected by earthquake, District Disaster Preparedness and Response Plan has not listed earthquake as a hazard. Earthquake is not predictable disaster in terms of time, scale, location (Bilham, 2010) so it is always in top rank even not listed in hazard ranking.

Climate induced disaster affected municipalities and wards

All three municipalities and nine rural municipalities are on the risk of climate induced disaster. A total of 67 wards from all municipalities and rural municipalities are highly and 24 wards are moderately susceptible for landslide disaster. Similarly, a total of 31 wards of three municipalities and eight rural municipalities are highly and 16 wards moderately affected by flood in Sindhupalchowk district. It seems that Lishankhu Pakhar rural municipality is not affected by flood disaster (Tiwari, & Rayamajhi, 2018). In addition, thunderbolt disaster highly affects 31 wards of three municipalities and seven rural municipalities.

Table 2: Climate induced disaster affected municipality and number of wards.

Local government	Population	Affected number of wards								
		Landslide			Flood			Thunderbolt		
		H	M	L	H	M	L	H	M	L
Chautara Sangachowkgadhi M.	46,501	4	6	3	4	2	8	3	3	8
Melamchi M.	45,343	6	4	3	7	3	2	4	2	7
Barabise M.	26,535	9			7	1	1	4		5
Tripurasundari R.M.	15,062	3	3		3		3		1	
Bhotekoshi R.M.	17,156	3	3	1	1	2	4	3		
Sunkoshi R.M.	16,713	3	3	1	1	2	4	3		
Balefi R.M.	18,909	7	1		5		3	2	2	4
Helambu R.M.	17,671	7			4	3		3	1	3
Panchapokhari Thangpal R.M.	10,693	7			5	2	1			
Jugal R.M.	19,223	7			5		2	3		4
Lisankhu Pakhar R.M.	15,143	4	2	1				2	6	
Indrawati R.M.	28,517	7	2	4	5	1	6	4	2	6
Total	277,466	67	24	13	30	16	20	31	8	25

Source: DPRP, Sindhupalchowk, (2076 B.S.)
Note: M-Municipality, RM-Rural Municipality, H-High, M-Medium, L-Low

Impact of climate induced disaster on human

Sindhupalchowk district shares a huge number of human losses as a result of several natural and man-made calamities. Table no. 3 illustrates that the human loss by climate induced disaster during 51 years from 1971 to 2022 June. There are 3,940 deaths from Non-climate induced disasters, but only 527 of those deaths were caused by climate induced disaster in Sindhupalchowk district. Out of 527 deaths only landslide causes 410. Similarly, thunderbolt, flood, storm, forest fire, heavy rainfall cold wave and snow storm has 57, 43, 8, 3, 4, 1, 1 death respectively. Hail storm and drought has not any effect on human particularly death, missing and injuring. Flood is the second devastative disaster based on the number of deaths, missing, injuring and affected family. With the reference to affected family, landslide is the most devastative disaster which affected 9,128 family. Similarly, hailstorm, flood, storm and thunderbolt are major disaster that affected family. It can be seen that climate induced disaster is more catastrophic than non-climatic disaster.

Table 3. Impact of climate induced disaster on human

Types	Disaster	Death	Missing People	Injured People	Affected Family
	Landslide	410	184	159	9,128
Climate induced disaster	Thunderbolt	57	0	207	243
	Flood	43	108	18	4,497
	Storm	8	4	9	906
	Forest Fire	3	0	0	0
	Hailstorm	0	0	0	4,609
	Heavy Rainfall	4	0	1	12
	Cold Wave	1	0	0	0
	Snowstorm	1	0	0	0
	Drought	0	0	0	0
	Total	527	296	394	19,395
Non-climate induced disaster	Accident, Epidemic, Earthquake, Structure Collapse, Fire	3,940	22	2,383	81,512
Grant Total		4,467	318	2,777	100,907

Source: DRR Portal, MoHA, (2022)

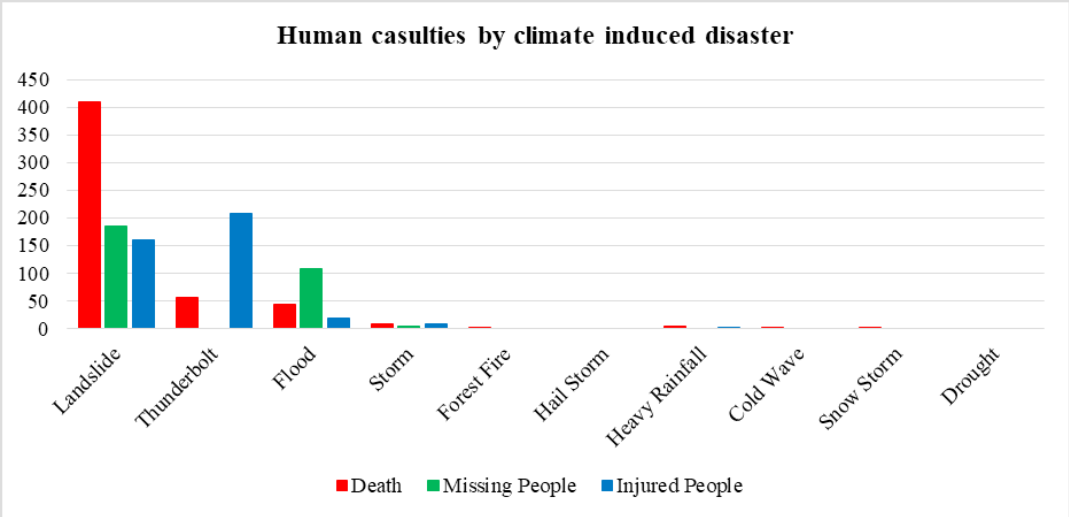

Figure 2. Human casualties by climate induced disaster

The diagram shows that thunderbolt has highest impact on injured people. Drought has not any kind of affect among death, missing and injuring people. The figure clearly shoes that the number of deaths by climate induced disaster is less than non-climate induced disaster. Climate induced disaster shares 11.79 percentage and non-climate induced disaster shares 80.20 percentage. A huge number of death toll brought by Gorkha Earthquake 2015. Only the earthquake shares 3,572 death which raised the number of deaths in non-climate induced disaster. Otherwise, the death of people by non-climate induced disaster would decrease.

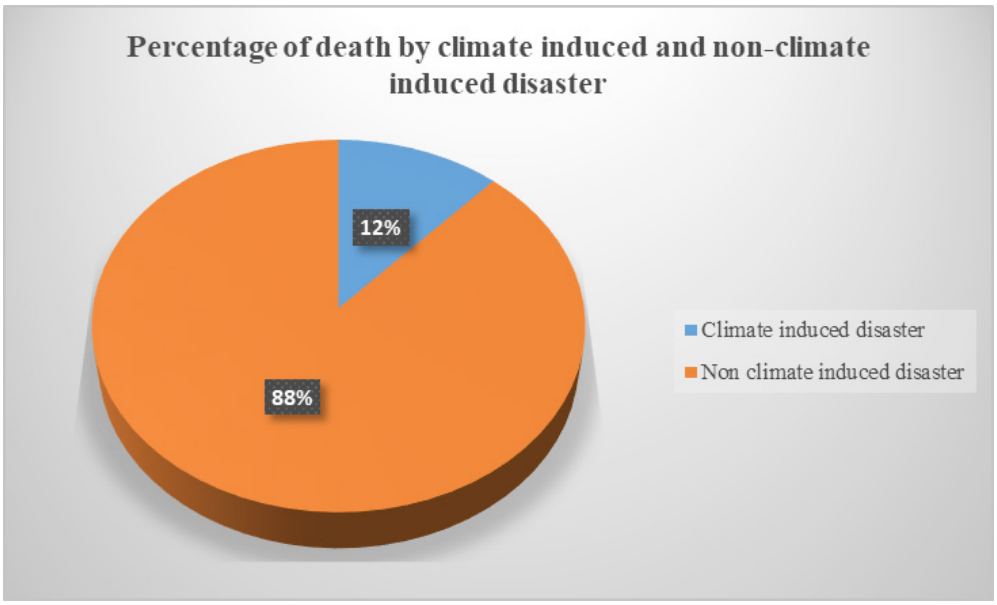

Figure 3. Percentage of death by climate and non-climate induced disaster

Impact on housing

Housing is a major factor in determining a person's level of stability in life (Kotani et al., 2020). After disasters destroy their houses, people frequently have to spend a lot of time in temporary accommodation, which makes it difficult for them to properly maintain their quality of living. The most frequent disasters in Sindhupalchowk district are landslides, floods, epidemics, fires, earthquakes, and other hydro-meteorological disasters such as heavy rain, thunderstorms, hailstorms, and windstorms. These disasters cause significant human and economic losses, including damage to housing and infrastructure (Shrestha, 2019).

Table 4 shows that out of total 92,151 fully damaged private household, climate induced disaster only covers 1,150 and non-climate induced disaster covers 91,001 households. Only the Gorkha Earthquake 2015 covers 89,884 household damaged (MoHA, 2022).

Table 4. Impact of climate induced disaster on housing

Types	Disaster	Total damaged private house	Partial damaged private house	Total damaged government buildings	Partial damaged government buildings
Climate induced	Flood	586	147	2	0
	Landslide	549	107	0	0
	Thunderbolt	11	25	0	0
	Heavy Rainfall	3	1	0	0
	Cold Wave	0	0	0	0
	Snow Storm	0	0	0	0
	Storm	1	32	0	0
	Drought	0	0	0	0
	Forest Fire	0	0	0	0
	Hail Storm	0	5	0	0
	Total	1150	317	2	0
Non-climate induced	Accident, Epidemic, Earthquake, Structure Collapse, Fire	91,001	3,272	710	37
	Total	92,151	3,589	712	37

Source: DRR Portal, MoHA, (2022)

There are total 3,589 partially damage private household, out of which climate induced disaster covers only 317 and non-climate induced disaster include 3,272. The number of non-climate induced disaster is high due the earthquake of 2015 that covers 2,751 households. There are two government building fully damaged by climate induced disaster where 710 households are damaged by non- climate induced disaster. Here the number of damaged private and government buildings are more than climate induced disaster due to the Gorkha Earthquake 2015.

Almost 99% private and government house are reconstructed in Sindhupalchowk district. The rebuilding process in developing countries is frequently delayed by a lack of capacity and high demand for certain skills (Hallegatte & Dumas, 2009).

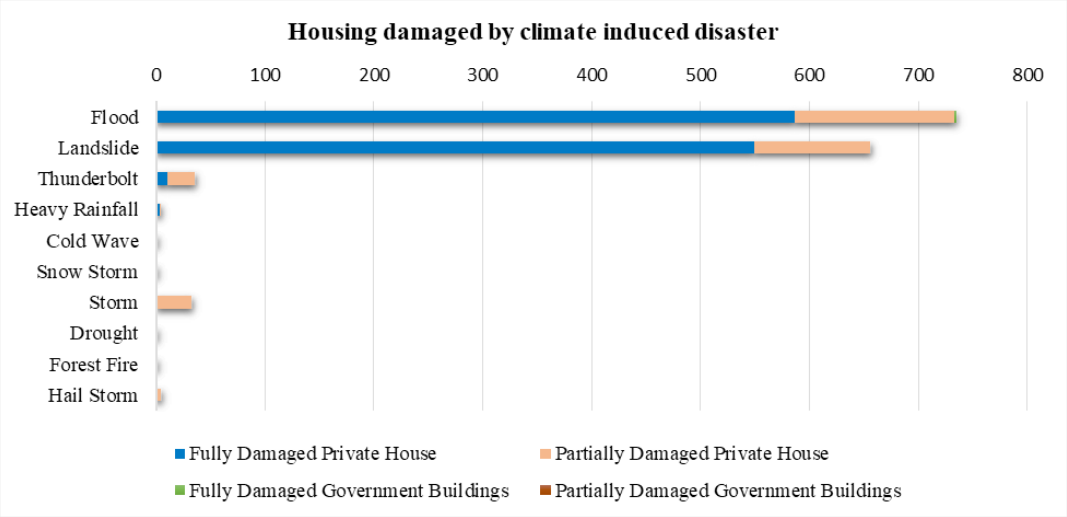

Figure 4. Housing damaged by climate induced disaster

Figure 4 illustrates the housing damaged only by climate induced disaster in Sindhupalchowk district. In comparison between climate and non-climate induced disaster, climate induced disaster has very few impacts on housing damage. Among the various types of climate induced disaster, flood which shares 586, has huge impact on housing in Sindhupalchowk district. Landslide is the second impactful disaster on housing that covers 549 household damage. The third is thunderbolt that affected 11 households. Cold wave, snow storm, drought and forest fire has not any kind of damage on housing. Similarly, only two government buildings fully damaged by flood in Sindhupalchowk. Thus, a total of 1,150 private houses are fully damaged, 317 private houses partially damaged, 2 government buildings are fully damaged and none of the government buildings are partially damaged by climate induced disaster in Sindhupalchowk district.

Economic loss

The both types of disaster losses the property equivalent 159 million rupees. Out of that a total of 73 million shares by climate induced disaster and 86 million losses by non-climate induced disaster. Among climate induced disaster, only flood disaster resulted 38 million rupees losses. Flood is following by landslide disaster which shares 32 million rupees losses. Thunderbolt is the third rank which shares 2 million economic losses. Cold wave, snow storm, forest fire, drought has not any record of economic loss (DRR portal, 2022). It might have the higher amount of economic loss but due to the lack of proper record, there is not much amount of economic loss as should have.

A total of 818 cattle has lost by disaster in Sindhupalchowk district. Climate induced disaster losses 804 cattle and non-climate induced disaster contributed 14 cattle loss. Out of 818 only floods shared 746 cattle loss. Table 5 illustrates the economic loss by climate induced disaster and non-climate induced disaster in Sindhupalchowk district between 1971- 2022 AD.

Table 5. Economic loss by disaster

Types	Disaster	Estimated Loss	Cattles Loss
Climate induced	Flood	37,901,001	746
	Landslide	32,484,000	45
	Heavy Rainfall	25,000	0
	Cold Wave		0
	Snow Storm		0
	Storm	415,000	1
	Drought		0
	Forest Fire		0
	Thunderbolt	1,740,000	12
	Total	72,565,001	804
Non-Climate induced	Accident, Epidemic, Earthquake, Structure Collapse, Fire	86,303,000	14
	Grand total	158,868,001	818

Source: DRR Portal, MoHA, (2022)

"Economic losses, poverty, and disasters" (2018) is a United Nations report that shows a 151 percent exponential rise in direct economic losses caused by climate-related disasters globally over the last two decades. Between 1998 and 2017, nations affected by disasters suffered direct economic losses of US$2,908 billion, of which US$2,245 billion or 77% were caused by climate-related disasters, according to a research study. The paper further highlights that external shocks and disasters can significantly harm the macroeconomic stability, growth, poverty, and debt sustainability of less developed countries. Moreover, it emphasizes that low-income countries that depend more on agriculture suffer more negative effects overall and are at higher risk from climate-related disasters than developed nations (Weerasekara et al., 2021). Flood is advantageous and disadvantageous for rice production and the rubber industry. It is widely accepted that floods have a good effect on cereal crops like rice and maize, especially in flood plains where agricultural productivity is often highest. Stern (2006) listed a number of characteristics of climate change, including melting glaciers, disruption of the monsoon cycle, flooding, drought, and cyclones,

which could cause a significant loss of GDP for developing countries relative to developed countries if the climate is not stabilized through mitigation (Bista, 2020).

Key problems in Nepal include the damaging effects of climate change and its associated disasters on households, which result in huge costs. It is further complex in the case of poor and marginal households, which includes small farmers and farmers without any land (Bista, 2020). Vietnam has the potential of becoming more vulnerable in the future if socioeconomic development is unsuccessful due to the large proportion of climate-induced disasters (as opposed to geophysical disasters) (Rubin, 2014).

Conclusion

Sindhuplchowk district is one of the climate-induced disaster-prone districts of Nepal. Landslide, flood and thunderbolt are the major disaster of Sindhupalchowk district. Climate induced disaster affected 100,903 family; 4,467 persons were reported to have lost their lives, 2,778 to have been injured, 314 missing. It has found that among all disaster 53% death toll by climate induced disaster and 47% death happens due to the non-climate induced disaster. Damage and losses were amounted to an estimated 72,565,001 Nepalese rupees (DRR portal, MoHA, 2022). The aim of this research is to offer policy makers timely information on the significance of analyzing the effects of disasters and how it can be integrated into economic planning.

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