Developing a Hazard Profile of The Kashmir Valley Through Historical Data Analysis For The Period 1900-2020

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Abstract

Disasters not only cause high mortality and suffering, but thwart developmental activities and damage local economies in process of formation. A part of the NW Himalayas, the Kashmir Valley is very distinct with respect to its location, topography, climate, socioeconomic structure, and strategic geopolitical nature owing to which it has witnessed a multitude of disasters ranging from local incidents of rockfalls to catastrophic earthquakes, and has often paid heavily in terms of loss of life and property. However, the information on most of the events is either partially reported or exaggerated or sometimes not recorded at all and largely scattered. Availability of organized and reliable record of past hazards and disasters is essential for tackling the risks and mitigating the future disasters. In this context, the present study attempts to address the lack of data availability by focusing on developing a dependable hazard and disaster catalogue of the Kashmir Valley by investigating into the existing literature and the available secondary data sources. A record of natural hazards and disasters most prevalent in the valley viz., earthquakes, floods, landslides and snow avalanches, has been compiled for the time period 1900 to 2020 by making use of various secondary sources, comprising of 1854 events with a range of triggers and impacts reported in the valley, which provide an insight into the spatial and temporal (frequency and distribution) trends of different hazard types for the selected time-period. Developing a catalogue of events reported in the Kashmir Valley can help in building a hazard and disaster scenario which serves as a reliable information source and is of great value from the perspective of regional design, planning and policy responses to promote disaster risk reduction.

1. Introduction

Disasters appear in the news headlines almost every day. Most happen in remote places, with lesser human interaction or limited extent and impact, are forgotten easily, while others have compelling consequences and leave a mark in history. Disasters are an outcome of hazardous events which cross the threshold of human endurance capacity and bring about devastating consequences upon interaction with human existence (vulnerable populations) (UN-ISDR, 2004). Whereas a hazard is defined as a potentially damaging physical event, phenomenon, or human activity that may cause loss of life or injury, property damage, social and economic disruption, or environmental degradation (UNISDR, 2004).

Statistics show that the world has experienced an increasing impact of disasters in the past decades, the main cause of which is attributed to a higher frequency of extreme hazardous events (especially, hydro-meteorological events, mostly related to climate change) and to an increase in vulnerable population (as a result of enhanced exposure) (Westen, 2012; CRED Report, 2018, 2020). To reduce disaster losses more efforts should be put into Disaster Risk Management, primarily based on a comprehensive and detailed Risk Assessment. Hazard Identification and disaster profiling is an essential element and the first step of the entire process of evaluating risks (i.e., risk assessment) and of disaster management (Weston, 2004, 2013). Developing disaster scenarios through historical perspective represents a valid back analysis tool that offers useful insights to understand the occurrence and impacts of natural disasters, establish existing and potential hazards, the conditions within which a given hazard takes place, determine the degree of vulnerability and the capabilities of response of the society subjected to that hazard (Jahn and Wehling 1998; Ahmad et al., 2021). It is typically contextual to 'forensic investigation of disasters' to indicate the root causes and risk drivers (Burton, 2010; IRDR, 2015); or like the 'science of past disasters' (Riede, 2014); or similar to 'charting a historical trajectory of disasters' (Bankoff, 2007; Ahmad et al., 2021).

Cataloguing disaster data of different hazards has picked great pace at international, regional, and national scale in order to facilitate various activities of assessment, policy and decision making, mitigation and management of disasters, relief, rehabilitation, risk reduction, development and research (Oliver-Smith and Hoffman, 2002; Schenk, 2014; Riede, 2017; Oliver-Smith et al., 2017). National (Indian Statistical Institute, Kolkata; Vulnerability Atlas of India) and international databases (EM-DAT International; Munich RE NATHAN Database; Dartmouth Flood Observatory Database), regional (Asian Disaster Preparedness Centre (ADPC); Asian Disaster Reduction and Response Network (ADRRN)) and intergovernmental (SAARC—Disaster Knowledge Network) and international nongovernmental organizations and programs (UNDP's Global Risk Identification Program; CRED; UN Office for Coordination of Humanitarian Affairs), and national disaster agencies (NIDM) play a pivotal role in keeping a track of disaster events taking place worldwide (Gupta and Muralikrishna, 2010; National Research Council, 2012). These Datasets differ in coverage and data quality, have different filters, strengths, and limitations (Beckman, 2009; Gall et al., 2009), and despite some overlap, each offers different information and insights into disasters (Below et al., 2010; National Research Council, 2012).

Inventorying disasters and hazard profiling have been attempted in various research works which add substantially to the disaster database. Compiling and analysing data from existing research publications can be sought as a reliable means to provide insight into different natural disasters to which a specific area is subjected to (Kapur, 2010). Chronological archival records can promote an understanding of social and economic consequences of natural disasters to a place (Malamud, 2004; Prakash, 2011; Prakash and Kathait, 2014).

From the historical perspective Kashmir Valley has been vulnerable to multiple natural disasters and intermittently subjected to their consequent impacts which can be established from its rich archival data sources (Kelman et al., 2018; Ahmad, 2021). Historical events data have been utilized to study the patterns of seismicity and trends of earthquake occurrences in the Kashmir region (Ghaffar and Abbas, 2010; Anees and Bhat, 2016) and to illustrate hotspots for seismic activity (Sharma, Kumar and Ghangas, 2013). Reconstruction of chronology of floods in Kashmir Valley by employing historical hydrology has been attempted to overcome the deficiency of sufficient time-series database for better flood hazard assessment (Bhat et al., 2019). Historical natural hazards were profiled by Ahmad (2021) to have better insight into what vulnerable populations were subjected to under severe natural and deprived socio-economic conditions in Nineteenth Century Kashmir. An intersection of vulnerability to environmental hazards and to socio-political conflict to provide an overview of the disaster diplomacy of Jammu and Kashmir throughout history was studied by Kelman (2018) by compiling events of both environmental hazards and socio-political violence.

The valley of Kashmir is subjected to several natural hazards for example, earthquakes, floods, landslides, snow avalanches, droughts, wildfires, extreme temperatures, lightning and thunderstorms, snowstorms, hailstorms, etc., (SDMP, 2017; Patel et al., 2020). Henceforth, a case study on the recent past emphasizes the need to know how the valley of Kashmir has been impacted by natural hazards and disasters during the entire Twentieth Century and early

Twenty-first Century through historical review and to stress its utility in disaster preparedness (Reide, 2014, 2017; Ahmad, 2021). Therefore, the present study attempts to develop a hazard and disaster profile of the Kashmir Valley focusing on the four most prominent natural hazards viz., earthquakes, floods, landslides, and snow avalanches.

2. Study Area

Kashmir, a separate geographical entity, is an oval shaped valley, and one of the mesoregions of erstwhile Jammu and Kashmir, located in the North-Western Himalayas, spanning over 15,984 km^2 (Ganjoo, 2014). The region is one of the most unfortunate portions across the globe where natural disasters and political unrest have greatly challenged the progressive development (Shah, 2018). Its physiography typically consists of mountain ranges on all three sides– Zanskar (~ 6000m amsl) and Pir Panjal (~5000m amsl) on Northeast and South-Southeast, respectively, contrary to which the valley floor drops to a minimum elevation of ~1570 m amsl (as shown in the Fig. 1). The geological past suggests that it was formed when Indian tectonic plate collided with the Eurasian plate during the Eocene epoch, which lead to the development of some intermontane basins and a prehistoric lake, by the uplift of mountains between the present Indian and Pakistan Administered Kashmir which over geological time, silted in and the alluvium from the mountains became the fertile soil of the valley floor, which itself is a peculiar combination of depositional and erosional features (Gansser, 1964; Bhat, 1987; Alam et al., 2015). A characteristic feature of valley floor is the presence of trunk river Jhelum which stretches over almost the entire length of the valley, originating at its southern end, near Verinag and flowing in a north-west direction receiving numerous tributaries before entering Wular Lake (Albinia, 2010). In general, the valley is spread over three major physiographic divisions i.e., mountains, karewa uplands (Plio-Pliestocene deposits), and floodplains. The altitude and climate of the region favour plenty of precipitation both in the form of rains and snow and thus, snow bearing peaks and glaciers are a dominant feature of the mountainous stretches (Ahmad et al., 2016). Every thousand feet of elevation brings some new phase of topography, climate, and vegetation (Lawrence, 1967). As the tectonics is still actively shaping the topography, geology, geomorphology, and climate of the region, the occurrence of hazards like, earthquakes, landslides, floods, snow avalanches, etc. in the area is potentially unavoidable. More than 5.5 million people reside in areas prone to multiple risks and are posed by various geophysical hazards. The presence of active faults, the river drainage network, physiology, topography, lithology, geomorphology, climate, and demography all make the region vulnerable to different types of hazards and pose potential threat to the population of the valley (Shah, 2018).

3. Methods And Materials

3.1 Search strategy and data sources

The study has compiled a hazard and disaster events database of the Kashmir Valley to generate a profile focussing on four potentially most prevalent and majorly impacting hazards viz., earthquakes, floods, landslides, and snow avalanches, for the time-period 1900 to 2020, which includes charting information on disaster events in the form of various attributes (Table 1) (Lin and Wang, 2018; Kelman et al., 2018). Identifying and inventorying various hazard events can be performed through some defined means and sources which include analysing historical data, government records/documents, newspaper reports, research literature, primary field surveys and geological study of the region (Westen et al., 2002; Taylor et al., 2015; Sultana, 2020). For the present research we studied and incorporated information from mixed sources of data, which primarily include secondary data sources like national and international open access databases, portals and websites, government and non-government documents and reports, existing research literature, news reports, private and public online blogs, portals and websites, books, personal and travel accounts, etc. In general, we used a diverse range of data sources in collecting information on natural hazards and disasters to assess and establish their authenticity. Despite the scattered nature of information dispersed across numerous sources of varied types and credibility we have been able to condense 1854 events in time and their trends spanning over a century and more.

Table 1
Summary of variables collected for the database and their description

Category	Description of variable	Relevance to each hazard type
Date of occurrence	Year (for all events), month and date (wherever available)	It gives an idea of the distribution and occurrence of events throughout the time period. It may be used to estimate the increase or decrease in hazard/disaster events over time and also, which time (season) of the year is more likely to witness a particular hazard type like floods, snow avalanches and landslides.
Location	Geographic or spatial information as name of the place (village, block, sector, district, etc) or latitudes and longitudes.	It gives an idea of the place of occurrence/onset of any hazard event. For earthquakes epicentres were considered within or near Kashmir valley. While, for landslide and snow avalanches geographic coordinates were assigned based on the place of occurrence, and for floods, names of the area were used.
Places affected	Includes the places impacted by the event (villages, sectors, blocks, districts, etc)	It denotes the extent and spread of hazard/disaster. It includes places where ground shaking or any damage or casualty is witnessed in case of an earthquake or the extent of inundation during a flood or areas impacted by avalanches and landslides.
Cause/ triggering mechanism	It could either be an environmental or anthropogenic factor acting as trigger or a primary disaster leading to secondary events.	It helps determine the causes that make the area prone to any particular hazard.
Magnitude	It is one of the factors to measure the strength and size of a disaster event.	Magnitude recorded on the Richter scale for earthquake hazard type and water level for flood hazard type.
Casualties	Including fatalities and injuries	It reflects loss to human life and injury. It is one of the important determinants of the severity of a hazard or disaster event.
Associated impacts	Impacts other than casualties, including damage to property, economic losses, missing, trapped, dislocated and evacuated/rescued people, secondary disaster events, etc.	Not available for all the events.

3.2. Compiling procedure and data analysis techniques

The collected events for individual disaster types, with all the information pertaining to the six selected variables (Table 1), were systematically documented into tables using Excel in a chronological order starting from 1900 up to 2020. Any sort of repetition in the event entry or allied information were removed from the database by proofreading. The excel sheets were used to analyse temporal variability, frequency distribution (Section 4.1.3.), and impacts of the events in the form of casualties (Section 4.1.2.). Further analysis was done by making use of the ArcGIS software. The spatial information of each event was made specific by adding geographic coordinates for earthquakes, landslides and snow avalanches, and then plotted using an SRTM DEM and a district shape file of the Kashmir valley as a base map to generate spatial distribution maps. While, in case of floods spatial extent was represented by the spread of and inundation levels of the 2014 Kashmir floods. Further, thematic maps for district wise susceptibility of all four hazard types were generated from the spatial distribution maps based on the number of occurrences per district for earthquakes, landslides and snow avalanches and on total area (in square kilometres) inundated per district for floods. Events reported with substantial damage and loss were discussed in detail in the study to get a clear picture of the hazard and disaster scenario of the Kashmir Valley in the 120 years long time frame (1900-2020) (Section 4.1.1.).

4. Results And Discussion

4.1. Hazard and disaster profiling

A meticulous review of the consulted secondary archival data sources enabled us to discover a spectrum of hazardous events their spatial extent, magnitude, cause, and impact in Kashmir throughout the selected timeline. With the aid of an exhaustive research, comparative analysis, and data presented in the form of catalogues, graphs, and maps, an incisive insight into the disaster and hazard scenario across the valley of Kashmir in the entire twentieth century and early twenty-first century has been achieved. The period under review has experienced repeated natural hazard events of different types, several of which have turned into devastating disasters. In our analysis, basic trends concerning 1854 natural hazards witnessed by the Kashmir valley consisting of 1693 earthquakes, 39 floods, 65 landslides and 57 snow avalanches have been represented. Out of the total hazard events, 91.31% comprised of earthquakes, 2.10% floods, 3.50 landslides and 3.07 snow avalanches. Some of the entries in the table concern more than one phenomenon occurring concurrently, as cascading disasters amplifying the intensity (damage and loss) of the primary disasters, like the Kashmir Basin flood of 1900 which was succeeded by a Cholera epidemic killing 4225 people; the magnitude 7.8 earthquake of 4th April, 1905 (having epicentre in Kangra Valley, H.P.) that triggered landslides and caused large number of casualties and damage to buildings and hillside aqueduct networks; the flood of 1957 (August-September) which almost submerged the entire valley causing colossal damage to crops that in turn led to a famine; the September flood of 1992 which took place in the NW border districts of Kashmir and parts of PoK, was unprecedented in terms of fury and most devastating in terms of casualties, caused land sliding as an associated secondary disaster; 19th February, 2005 Waltengu snow avalanche triggered multiple landslides across the affected area adding to the damage and loss; 8th October, 2005 largest instrumented earthquake with epicenter in Muzzafarabad, PoK (Mw 7.6) lead to extensive land sliding causing large scale damage and loss in N-W border districts; 2006 (August-September) floods in J&K lead to associated disasters in the form of land and mud slides; 24th January, 2012 snow avalanche in Kupwara triggered landslides; 2nd September, 2014 floods land and mud slides; 26th July, 2015 cloud burst triggered landslides along the Baltal route to Amarnath; 20th March, 2017 flooding in Chadoora, Budgam induced mud slides; 6th April, 2017 snow avalanches along higher reaches in Kashmir and Ladakh caused landslides; and 14th January, 2020 snow avalanches in Ganderbal and Kupwara triggered land sliding events but no damage and loss was witnessed.

Table 2
Annual Distribution of the total number of events from 1900 to 2020 (E= Earthquakes, F=Floods, L=Landslides and SA=Snow Avalanches)

Year	E	F	L	SA	Year	E	F	L	SA	Year	E	F	L	SA	Year	E	F	L	SA	Year	E	F	L	S
1900	-	01	-	-	**1924**	02	–	-	-	**1948**	01	-	-	-	**1972**	22	01	-	-	**1996**	52	01	-	-
1901	-	-	-	-	**1925**	01	-	-	-	**1949**	01	-	-	-	**1973**	18	01	-	-	**1997**	20	01	-	[illegible]
1902	01	01	-	-	**1926**	02	-	-	-	**1950**	08	01	-	-	**1974**	19	-	-	-	**1998**	34	-	-	[illegible]
1903	-	01	-	-	**1927**	05	-	-	-	**1951**	03	-	-	-	**1975**	35	01	-	-	**1999**	31	-	-	-
1904	-	-	-	-	**1928**	03	01	-	-	**1952**	03	-	-	-	**1976**	121	01	-	-	**2000**	49	-	-	-
1905	01	01	01	-	**1929**	02	-	-	-	**1953**	04	-	-	-	**1977**	16	-	-	-	**2001**	42	-	-	-
1906	01	-	-	-	**1930**	03	-	-	-	**1954**	01	01	-	-	**1978**	14	-	-	-	**2002**	49	-	-	-
1907	-	-	-	-	**1931**	01	01	-	-	**1955**	04	-	-	-	**1979**	16	-	-	-	**2003**	36	-	-	-
1908	-	-	-	-	**1932**	-	-	-	-	**1956**	03	-	-	-	**1980**	18	-	-	-	**2004**	43	-	-	-
1909	-	01	-	-	**1933**	03	-	-	-	**1957**	-	-	-	-	**1981**	21	01	-	-	**2005**	69	-	02	-
1910	01	-	-	-	**1934**	01	-	-	-	**1958**	-	-	-	-	**1982**	16	-	-	-	**2006**	57	02	01	-
1911	-	-	-	-	**1935**	01	-	-	-	**1959**	01	01	-	-	**1983**	09	-	-	-	**2007**	47	-	03	-
1912	-	01	-	-	**1936**	01	-	-	-	**1960**	01	01	-	-	**1984**	18	-	-	-	**2008**	43	-	06	[illegible]
1913	-	-	-	-	**1937**	03	-	-	-	**1961**	05	-	-	-	**1985**	18	01	-	-	**2009**	27	-	10	[illegible]
1914	01	-	-	-	**1938**	02	-	-	-	**1962**	04	-	-	-	**1986**	21	01	-	01	**2010**	23	01	16	[illegible]
1915	-	-	-	-	**1939**	-	-	-	-	**1963**	06	-	-	-	**1987**	16	07	-	-	**2011**	25	-	03	[illegible]
1916	01	-	-	-	**1940**	-	-	-	-	**1964**	27	01	-	-	**1988**	17	-	-	-	**2012**	52	-	01	[illegible]
1917	02	-	-	-	**1941**	01	-	-	-	**1965**	13	01	-	-	**1989**	09	-	-	-	**2013**	47	-	-	[illegible]
1918	-	-	-	-	**1942**	01	-	-	-	**1966**	6	01	-	-	**199**	25	-	-	-	**2014**	39	01	05	[illegible]
1919	01	-	-	-	**1943**	01	-	-	-	**1967**	09	-	-	-	**1991**	23	-	-	-	**2015**	34	03	02	-
1920	-	-	-	-	**1944**	-	-	-	-	**1968**	10	-	-	-	**1992**	43	01	01	-	**2016**	28	-	01	[illegible]
1921	01	-	-	-	**1945**	02	-	-	-	**1969**	03	01	-	-	**1993**	20	01	-	-	**2017**	39	01	02	[illegible]
1922	-	-	-	-	**1946**	03	-	-	-	**1970**	07	-	-	-	**1994**	17	-	-	01	**2018**	24	01	07	[illegible]
1923	01	-	-	-	**1947**	01	-	-	-	**1971**	07	-	-	-	**1995**	29	01	-	-	**2019**	38	01	-	[illegible]
-	-	-	-	-	**-**	-	-	-	-	**-**	-	-	-	-	**-**	-	-	-	-	**2020**	77	-	04	[illegible]

4.1.1. Extreme events and their impacts

The study discusses in detail disaster events witnessed within the timeline for which damage and loss have been reported in the form of fatalities, injuries, loss of cattle, damage to structures and crops, population affected, and other associated impacts. These comprise 121 events out of the total 1854, including 7 earthquakes, 17 floods, 49 landslides and 47 snow avalanches, which constitute 5.78%, 14.04%, 40.49% and 38.84% of the total severe events, respectively. This shows that even though the total number of earthquake events (1693) is very high only a small number (7) of these events actually turn into disasters i.e., 0.41% of the total occurrences. In case of floods out of the total 39 events 17 have turned into disasters which is about 43.58% of the total occurrences. Whereas, for landslide hazard, 49 events i.e., 75.38% of the total 65 occurrences and for snow avalanches, 47 events i.e., 82.45% of the total 57 occurrences show impacts. Although, a larger portion of the total landslide and snow avalanche events have impacts recorded but the magnitude of these impacts is far lesser than that of both earthquakes and floods individually, as can be established from the tables discussed in the following sections. This could be because landslides and snow avalanches are small scale and localized events with limited extent and impact as compared to earthquakes and floods thus, proving an inverse relationship between the magnitude and frequency of the hazard events. Standing true for the generalization, that the magnitude of a natural hazard event varies in its frequency of occurrence over time in an inverse power relationship (Jackson, 2013).

Earthquakes

History shows earthquakes don't occur randomly but follow a general pattern and are distributed along geological faults across the globe (Bolt, 2003). The NEIC (National Earthquake Information Centre) locates about 20,000 earthquakes in the world each year and approximately 55 per day. According to records (since 1900), 16 major earthquakes are expected in a year, 15 in the magnitude 7 range and 1 magnitude 8.0 or greater (Bolt, 2003; USGS, 2020) which have been responsible for millions of deaths and an incalculable amount of damage to property over centuries. India has a long history of disastrous earthquakes, majorly documented from 1800's (Iyenger et al., 1999) and about 59% of its total land area is prone to seismic hazards (BMTPC, 2006; MHA Report, 2015). The Himalayas originated due to continental collision between the Indian and the Eurasian plates (Searle et al., 1987, Le Fort, 1989, Searle, 1991, Thakur, 1992, 1998) and this orogenic process continues till date, as is indicated by significant small to moderate earthquakes and neo-tectonic movements along several thrusts and faults located in the region (Valdiya, 1998, 2001; Bilham, 2001). A major risk lies for more than 50 million people living near the seismically active Himalayan region (Bilham, 2001). The Himalayan zone is divided into three seismic gaps – Kashmir gap, Central gap and Assam gap. The Jammu and Kashmir, Himachal Pradesh and Uttarakhand fall under Kashmir gap which is the highest earthquake prone zone (Gupta, 2012; Sharma, 2013).

Jammu and Kashmir, the western most extension of the Himalayan Mountain range in India, lies atop a web of active geological faults and thrusts on the boundary of the two colliding tectonic plates (Gavillot, et al., 2016; Shah, 2016), many of which have and are capable of producing earthquakes of magnitude 8.0 or greater (Seeber and Armbruster 1981; Ni and Barazangi 1984; Thakur and Kumar 2002; Kayal, 2007). As a result of active participation of some faults in the ongoing collisional deformity the region shows active seismicity through small to moderate magnitude earthquakes at a continuous rate and occasionally large magnitude ones (Burbank and Johnson, 1983; Ambraseys and Bilham, 2000; Yin, 2006; Shah, 2018). According to seismic zonation map of India, the entire region has been classified as very high damage risk zone V (MSK IX or more) and high damage risk zone IV (MSK-VIII) (BIS Map, 2002; SDMP, 2017; Mahajan et al., 2010).

A major portion of the districts in Jammu and Kashmir fall under seismic zone V. Kathua, Leh, Ladakh and Tribal Territory districts lie in Zone IV, the districts Anantnag, Budgam, Bandipora, Baramulla, Ganderbal, Kishtwar, Kulgam, Kupwara, Pulwama, Ramban, Shopian and Srinagar occupy seismic V zone and the remaining under seismic IV zone (SDMP, 2017). Kashmir region is very important in relation to seismic activity in the Great Himalayas. Earthquakes in the Himalaya, in general, and in Kashmir, in particular, pose serious challenges. Historical records of the past centuries show that several big earthquakes have destroyed parts of the Himalayan settlements (and many earthquakes have possibly gone unrecorded). The history of earthquakes dates back to 1505 in this region (Ghaffar and Abbas, 2010) and the record of the past decades shows that the Kashmir region has been hit at least by one earthquake of magnitude 5 or larger every year or two (Sorkhabi, 2006). Among the most notable earthquake occurrences of the region are the N-W Kashmir earthquake of 2005 (Mw 7.6); 2002 Astore, PoK (Mw 6.4), Pattan earthquake of 1974 (Mw 7.4), Kangra earthquake of 1905 (Mw 7.8), 1885 (Magnitude 7.5), 1842 (Magnitude 7.5), 1555 (magnitude more than 8), 1505 (Magnitude 7.6) etc., (Sharma, 2013).

Earthquakes, if strong enough, are extensive events, with far-reaching impacts which cannot be contained by political and geographical boundaries, therefore, earthquakes with epicentres in and around the valley have been considered for this study while events with their epicentres within the Valley numbered 58 for the selected timeline (e.g., 1963 and 1967). In the present study of 120 years, the region witnessed intensive seismic activity where earthquakes were felt across the entire valley (Table 2), including 1693 events of magnitude 2.0 to 8.0, out of which 34 were strong earthquakes with magnitude greater than Mw 6.0 and 7 events have been reported with severe impacts (Table 3). The highest magnitude episode recorded for the time period is the earthquake of 4th April, 1905 with its epicentre in Kangra Valley, Himachal Pradesh and magnitude Mw 8.0. The record also shows some incidents of magnitude 7 and above viz., 1974 Pattan earthquake with 7.4 magnitude, 1975/19/01 Kinnaur District, HP (M 7.0), 19th January, 1996 Aksai Chin (M 7.1), 8th October, 2005 Muzzafarbad, Pakistan (M 7.6) and 26th October, 2015 Hindukush Mountain region, Afghanistan (M 7.5).

Table 3
Major earthquake events located in and around Jammu & Kashmir for which damage and loss were reported.

Date of occurrence		Location			Places affected	Magnitude (Mw)	Casualties		Associated impacts
Year	DD/MM	Place of occurrence	Long	Lat			Fatalities	Injuries	
1905	04/04	Kangra Valley	76.16	34.04	J&K and Himachal Pradesh. Shocks felt in Leh, Kargil, Drass and Muzafarabad	8.0	20,000	-	53,000 domestic animals killed. 100,000 buildings damaged. Damage to hillside aqueducts networks.
1963	02/09	Budgam, Kashmir	74.64	33.93	Budgam, Kashmir	5.2	100	-	-
1975	19/01	Kinnaur District	78.43	32.45	J&K and Himachal Pradesh	7.0	47	-	-
1981	12/09	Gilgit Wazarat (Pakistan occupied Kashmir).	73.59	35.69	Shocks were felt in Srinagar (J&K, India) and in Peshawar and Rawalpindi (Pakistan)	6.3	220	2500	Unconfirmed reports of surface faulting.
2002	20/11	Astore Valley, Pakistan occupied Kashmir	74.60	35.00	Astore Valley, Pakistan occupied Kashmir	6.3	23	-	Damage to property.
2005	08/10	Muzzafarabad Kashmir-Kohistan,	73.58	34.53	Indo-Pak Border Region. Strongly felt in much of Pakistan, North-India, East-Afghanistan. Tremors felt as far as Delhi and Punjab in India.	7.6	80,000 1350 (J&K)	70,000 6266 (J&K)	Largest instrumented in the area. 4 million homeless. Secondary disasters: landslides, fires. 32, 000 buildings completely or partially damaged, blocked roads. Series of hundreds of aftershocks. [Homeless=150000; Affected=156622 (J&K)]
2015	26/10	Hindukush mountain region of Afghanistan.	78.15E	37.45	Afghanistan, India and Pakistan. Tremors felt in J&K, Delhi, Lucknow and parts of Pakistan, Afghanistan and China.	7.5	399; 4 (J&K)	2536; 20 (J&K)	Damage to property. Cracks appeared in most multi-storied buildings. (53 houses damaged in J&K.)

Floods

Floods with natural and anthropogenic triggers are among the most common and devastating natural disasters and the leading cause of deaths, responsible for 6.8 million deaths in the 20th Century worldwide, impacting about two-thirds of the total population affected by natural disasters (1991-2000) (UNISDR, 2001, 2015; Doocey, et al., 2013; CRED Report, 2018, 2020). In agreement with the global pattern, the disasters with the largest human impact in Asia were floods during the year 2015 (Guha-Sapir et al., 2015). The occurrences and impacts of flooding are expected to rise due to increase in population, unscientific development and climate change (Tanoue et al., 2016; Bhat et al., 2019). 12% of the total land area of India faces the threat of flooding (MHA Report, 2015).

Kashmir, a highly populated, Himalayan intermontane basin flanked by mountains, drained by major rivers such as Jhelum, Chenab, and Indus, and mainly divided into three physiographic units: floodplains, karewas and mountains, (SDMP, 2017), is prone to floods, widely established through historical records. The structure of the Valley, hydrographic features and drainage characteristics of its river systems viz., bowl shape (elongated trough), variation in altitudes with consequent reduced lag time and sudden peak flows in rivers along low-lying areas during heavy rainfalls make the region specifically prone to floods and congenial for inundation (Bhat et al., 2019). Pertinently, most of the population and socio-economic activity is hosted by the area prone to floods and is one of the major urban centres of the region, Srinagar, where the number of wetlands that act as natural sponges, have come down severely, resulting in frequent flooding (Gupta, 2014; Meraj, 2015; Bhat et al., 2017, 2019). In terms of impact, frequency and economic loss, floods are the largest of all the natural hazards to which the Kashmir Valley is prone (Bhat et al., 2017).

Historical reports reveal that flooding is a recurrent phenomenon and owing to River Jhelum, the valley has witnessed a series of floods, dating back to 635 A.D., many among which were disastrous with widespread socio-economic and environmental impacts (Lawrence, 1895; Uppal, 1956; Bhat et al., 2017). Research indicates two major reasons responsible for the flood vulnerability in the Kashmir valley – inadequate carrying capacity of the River Jhelum from Sangam (Anantnag) to Khandanyar (Baramulla) and naturally flat topography of the Jhelum Basin (Meraj, 2015; Bhat et al., 2017).

Maximum topography of the valley is precipitous, exposing low-lying areas to frequent inundation especially during extended hours of precipitation (seasonally) however, some intensifying factors such as enormous population growth and the resultant expansion of human settlements, ill-planned urban sprawl, modification of floodplain, including, encroachment of waterways, landfilling, and road/railway construction in the floodplain, changes in river morphology and reduced water holding capacity of rivers, erosion and subsequent alluvial deposition in water bodies leading to degradation and extinction of wetlands and waterways have amplified the existing flood risk (Alam et al., 2018; Meraj, 2015). It has also been observed that as a result of climate variability, the frequency of floods in Kashmir Valley is likely to increase in future (Bhat et al., 2019).

Although, most of the flood events in Kashmir have meteorological origin, historical records bear instances where flooding has been associated to a primary disaster event like floods triggered by damming of the Jhelum caused by landslides or earthquake-triggered landslides and dam failures (856 AD and 635 AD) (Kalhana, 1149; Chaudora, 1620; Khanyari, 1857; Khoihami, 1885; Stein, 1891; Bamzai, 1962; Ahmad & Bano, 1984; Bilham and Bali, 2014; Meraj, 2015).

A total of 17 severe flood incidents which show a substantial impact on society were compiled in detail (Table 4). For certain events no figures were available to record impacts but the severity of the situation was described as “the entire valley being completely submerged in water” or “resembling a vast lake” (1903 and 1957) which gives us the idea that major portions of the valley are susceptible to floods and how wide spread can flooding be in Kashmir. Few notable flood events of the recent past recorded in the study were 1903, 1950, 1957, 1959, 1963, 1992, 1994, 1996, 2004, 2006, and 2014 (Raza et al., 1978; Koul, 1993; Meraj et al., 2015; Kumar, 2016; Bhatt et al., 2017; Rather et al., 2017; Alam et al., 2018).

Table 4
Major flood events witnessed by the Kashmir Valley for which damage and loss were reported

Date of occurrence		Location/Area affected	Cause/ trigger	Casualties		Magnitude (water levels)	Associated impacts
Year	DD/MM			Fatalities	Injuries		
1900	-	Kashmir Basin	Continuous rains caused floods.	-	-	Water level was 9 feet lower at Munshibagh than previous flood (1893- R.L. 5197.0).	Breaches in right bank above Sherghari. Succeeded by cholera killing 4,225 people
1903	23 July	Srinagar City, Kashmir valley	5" of rainfall recorded between 11-17 July and 8" between 21-23 July.	Large number of deaths	-	River rose to max R.L. 5200.37 on 24 July (three points higher than 1893 flood).	Whole valley converted to one great expanse of water. 7,000 dwellings marooned in city. 83 villages affected; 26 villages lost entire kharif harvest. 421 houses completely destroyed.
1905	-	Kashmir Valley	-	6	-	-	74 villages affected, heavy loss to government records. Extensive loss to crops.
1909	-	Kashmir Valley	-	-	-	-	Disastrous for crops. Total estimated loss: Rs. 98,393.
1912	May	Kashmir Valley	-	21	-	-	Spill channel minimized extent of damage. Many bridges from Baramulla to Chakoti (across LoC) were washed away.
1928	-	Kashmir Valley	-	76	-	-	Total 1,750 houses partially damaged and 282 houses fully damaged. Loss of 2,228 domestic animals. Agricultural sector affected badly.
1950	01-17 Sep	Jhelum Basin, J&K	-	100	-	Water of Jhelum was flowing at 10-15 feet over the banks in Srinagar.	More than 15,000 houses collapsed or heavily damaged. River bank breached at multiple places posing threat to civil lines of city. About 70 miles of the area of valley was under water.
1957	Aug-Sep	Kashmir Valley	Natural Hydrological Flood	92	-	Highest water level ever recorded (till that time) in state (roughly 90,000 cusecs to 1,20,000 cusecs) at Sangam.	Almost submerged entire valley. Jhelum overflowed right bank in uptown Srinagar, submerging low-lying areas. Colossal damage to crops and property. Led to famine. 600 villages inundated. Estimated damage: 4.2 crores.
1959	July	Kashmir Valley	Natural Hydrological Flood. Four days of incessant rains in valley.	104	-	Flood water level touched 30.25 feet on July 5 in Jhelum. Jhelum was assumed to be 80,000 to 1,00,000 cusecs.	Damage to public utility services: 20 million; damage to crops: 15.6 million.
1973	6–10 Aug	J&K	-	70 (50 in Jammu and 20 in Kashmir)	-	-	Flooded 40 villages impacting 20% of population. Damages amounted to Rs. 12.18 crore.
1992	September	N-W border districts Kashmir	Recording highest rainfall (of that time)	200 (IoK) 2000 (PoK)	-	-	Unprecedented in terms of fury and most devastating in terms of casualties. Over 60,000 people were affected in several NW border districts. Parts of POK bore the brunt. Secondary disaster: landslides

Date of occurrence		Location/Area affected	Cause/ trigger	Casualties		Magnitude (water levels)	Associated impacts
Year	DD/MM			Fatalities	Injuries		
1996	23, Aug	Kashmir Valley 29600 Km2 (Dis. Mag. Value).	Natural Hydrological Flood	23	226	-	Homeless:70,000; Affected: 70,000. Water level in Jhelum not as high as earlier floods but water didn't recede for long period after rains stopped causing heavy damage to houses. In Srinagar city and outskirts, about 10,000 houses were flooded for over a fortnight.
2006	24 Jul-22 Aug	Jhelum-Chenab basins, J&K Provinces Lat/Long: 34.61-73.20	Natural Hydrological Flood; Riverine flood; Monsoonal rains	15	800	-	Affected: 800;
2006	31 Aug-11 Sep	J&K Provinces; Jhelum, Sutlej, Lidder, Chenab, Tavi basins	Natural Hydrological Flood; Flash Flood; Monsoonal rains;	19	-	-	Homeless:15000 Affected:15000 Secondary disasters: Slides (land, mud, snow, rock).
2014	02 Sep	Kashmir region, India-Pakistan Worst affected districts: Srinagar, Anantnag, Baramulla, Pulwama, Ganderbal, Kulgam, Budgam, Rajouri, Poonch and Reasi.	Natural Hydrological Flood; Riverine flood, Monsoonal Rains Caused by torrential rainfall.	557 (277 India, 280 Pakistan) (190 Jammu, 78 Kashmir)	–	-	Affected:275000; Homeless: 275000; Damage:16000000. 60 major and minor roads were cut off and 30 bridges washed away, hampering relief and rescue. 80,000 people evacuated. 390 villages in Kashmir completely submerged. 1225 villages affected partially and 1000 villages affected in Jammu. Secondary Disasters: Slides (land, mud, snow, rock)
2015	25 July	Amarnath, Pahalgam, South Kashmir	Flash floods; Cloudburst	2	9	-	Yatra suspended, tents washed away. Secondary disaster: land and mud slides
2015	04 Sep	Various parts of the Kashmir Valley	-	55	25	-	862 cattle killed, and 12565 structures damaged. 211 camps set up to house 2907 evacuated families.
2017	20-31 March	Chadoora village Budgam district; Jhelum river basin; Lat/Long: 33.1767-76.41; Disaster magnitude value: 70288 Km2.	Natural Hydrological Flood; Flash flood; Heavy rains	44 16 in mudslides	25	-	Homeless: 2097; Affected: 2122; Damage: 76000 Secondary disasters: Slides (land, mud, snow, rock). Deaths in mudslides and house collapse. Hundreds moved to safety. Flood alert issued. Schools closed. Relief camps set up.

Some major flood events have been of regional scale spreading across international borders like flooding in the years 1912, 1992 and 2014. The Kashmir Flood of September, 2014 has been declared the highest magnitude flood recorded instrumentally on Jhelum with a discharge of 72585 cusecs (recorded by the Department of Irrigation and Flood control) and inundated maximum part of the floodplain, resulting in colossal loss of life and property but could still not reach the highest flood levels (HFLs) as documented for events of years 1144, 1360, 1462, 1747, 1903 and 1929 (Alam et al., 2018). However, the event recorded with the maximum number of casualties i.e., 200 deaths in IoK and 2000 deaths in PoK, was the 1992 flood. Floods, as we can make out from the data, have shown some episodes of domino effect by being a cause to secondary disasters, like, epidemics, landslides, famines, etc., (Table 4) viz., 1900 (Cholera epidemic), 1893, 1929,1957 (famines) and 1992, 2006, 2014, 2017 (landslides) (Mehran, 2015).

Consequently, the Valley was affected in a very passive way, exhausting the stores and destroying the assets of the dwelling population (Ahmad et al., 2021) in the past century, through impacts like deaths and injuries (1950, 1957, 1959, 1973, 1992, 2014, 2015), long periods of inundation (1957, 1996, 2014), marooned settlements and entire villages (1973), partial or total damage to infrastructure and washing away of structures (1912, 1928, 1950, 1959, 2014), devastating crops and agricultural sector (1903,1909, 1928, 1959), loss of domestic animals and cattle (1928, 2015), causing health (1900) and food insecurities (1957), and damage and loss of government records (1905).

From the developed catalogue we establish the fact that flooding is a prominent recurring phenomenon of the Kashmir Valley and floods generally occur in the summer months (June to September) when heavy rain is followed by the bright sun, which melts the snow cover and occasionally in springtime (March, April and May).

Landslides

Landslides, more widespread than any other geological event, are localized in nature often with small to medium scale impacts, and can either occur as an individual primary disaster, as a result of a wide array of processes and therefore, be a geological, hydro-meteorological and an anthropogenic hazard, or happen to be an associated secondary disaster to some major disasters like earthquakes, floods, droughts, volcanic eruptions, etc. and thus, worsen their impacts (Chingkhei, et al., 2013; Parkash, 2011). It is apparent from prior research that in recent years the abundance, activity, frequency, socio-economic consequences of, and vulnerability to landslides have increased (Guzzetti, 2000; Gariano & Guzzetti, 2016; Haque et al., 2019) and landslides have been ranked as the 4th deadliest among natural disasters, after floods, storms, and earthquakes (Lacasse et al., 2005).

In India about 12.6% of the total land area is prone to landslides, consisting of the Himalayas and the Western Ghats, in which many slopes also fall in high seismically active zones, including Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and the entire North-East (NIDM, 2011; MHA, 2015). Located in the N-W Himalayas, a major portion of Kashmir is mountainous, the complex, young and continuously changing topography along with the prevalent climate and various anthropogenic drivers interfering in the fragile ecosystem make it vulnerable to landslide hazard (Shah et al., 2018; SDMP, 2017), varying in magnitude from soil creep to landslides and solifluction (mass movement) common in higher snow-covered ranges of the region.

Almost every year the region is affected by one or more major landslide events affecting the society in many ways like loss of life, damage to settlements, roads, means of communication, agricultural land, and floods. Heavy rainfall, cloudburst and consequent flash floods particularly in narrow river gorges are one of the main causes of major landslides in Kashmir (SDMP, 2017). Doda, Udhampur, Kathua, Kishtwar, Gulmarg, Dawar, Gurez, Tangdhar, Rajouri and Kargil are some areas of the erstwhile state highly prone to landslide hazard, also areas along major highways particularly Ramban, Panthal, Banihal, Qazigund (NH 44), and Baltal, Sonmarg, Zogila (NH 1) are vulnerable (Chingkhei et al., 2013).

The rugged topography of the region makes it highly susceptible to major landslides triggered by flash floods along narrow river gorges eventually jeopardizing the whole hill systems. The geologically young, unstable and fragile rocks of the region have witnessed an increase in vulnerability by manifolds in the recent past due to various unscientific developmental activities like deforestation, road cutting, settlement construction and terracing, quarrying practices, indiscriminate encroachment on steep hill slopes, etc., increasing the frequency and intensity of landslides which is also evident from the events recorded from the data (Table 5 and Fig. 3(c)) (SDMP, 2017). The Jammu-Srinagar national highway gets blocked at number of places during the monsoon and winter seasons, due to landslides of which the Ramban-Banihal stretch has become one of the most affected portions (Chingkhei et al., 2013).

Table 5
Major Landslide events witnessed by the Kashmir Valley for which damage and loss were reported.

Date of occurrence		Location	Cause/ trigger	Casualties		Associated impacts
Year	DD/MM	Place of occurrence Long/ Lat		Fatalities	Injuries	
1905	04/04	J&K and HP	Earthquake induced	-	-	Damage to structures and network of hillside aqueducts feeding water to affected areas.
1992	Sept	NW border districts of valley Kupwara and Baramulla	Flood induced	-	-	Huge loss to life and property at the hands of floods and associated landslides
2005	19/02	Waltengu, kund and nar villages Kulgam and Anantnag	snow-avalanche induced	-	-	Large scale loss of life and damage to property, loss of connectivity and hindrance in rescue and relief
2005	08/10	Multiple locations of NW districts, J&k (Tangdhar, Uri) Kupwara and Baramulla	earthquake induced	-	-	Splitting of earth, landslides, rockfalls, complete and partial damage to roads, and hillside structures.
2007	25/06	Ganderbal and Srinagar	-	3	-	-
2007	17/12	Srinagar and Ganderbal	-	2	6	Temple, bridge and army bunker damaged
2008	09/01	Banihal-Ramban HW 44	-	-	-	200 vehicles stranded
2008	08/02	Ramban-Banihal HW 44	-	3	15	Vehicles stranded
2008	18/02	Uri Baramulla	-	1	1	-
2008	31/03	Qazigund Anantnag	-	2	1	-
2008	26/10	Srinagar	-	2	-	32 cattle lost
2008	20/11	Gurez Bandipora	-	6	-	-
2009	06/02	Srinagar	-	4	4	-
2009	17/06	Amarnath Anantnag	-	1	-	4000 pilgrims stranded
2009	29/07	Srinagar-Ladakh HW 1 and Baltal road Ganderbal	-	3-4	-	Pilgrims buried, tourism affected
2009	29/07	Kupwara	-	3 pilgrims	-	Tourism affected
2009	02/08	Amarnath Anantnag	-	2	-	-
2009	12/12	Keran Sector Kupwara	-	1 BRO porter	-	-
2009	17/06	Gurez, Bandipora	-	1	-	-
2009	17/06	Railpathri, Baltal base camp Ganderbal	-	1 porter	1	-
2010	09/01	Kupwara District	-	4	-	-
2010	08/02	Uri, near LoC Baramulla	-	1	7	5 Houses collapsed, cattle affected (7 cows, 30 goats killed)
2010	08/02	Uri, Gharkote Baramulla	-	-	1 army man	Shooting stones
2010	10/02	Gulmarg Baramulla	-	3	-	-
2010	22/02	Chairvani village, Ganderbal, Srinagar	-	6	6	-
2010	22/02	Uri Baramulla	-	1	6	-
2010	20/04	Zojila HW 1	Heavy rains	-	-	-
2010	28/04	Ganderbal, Srinagar	-	1	-	Srinagar-Leh highway closed
2010	28/04	Srg-Leh HW 1	-	1 BRO laborer	-	Highway closed

Date of occurrence		Location Place of occurrence Long/ Lat	Cause/ trigger	Casualties		Associated impacts
Year	DD/MM			Fatalities	Injuries	
2010	20/05	Srinagar	-	1	-	-
2010	04/06	Baramulla	-	-	1	-
2010	06/06	Uri Baramulla	-	6	-	Traffic disrupted for several days
2010	10/10	Uri Baramulla	-	1	7	-
2010	23/10	Uri Baramulla	-	3 (Army men)	-	Hampered traffic movement
2011	04/03	Uri Baramulla	-	1	-	4 houses damaged
2011	18/04	Phimram, Shangus Anantnag	-	5 family members	1	-
2011	09/12	Gurez Bandipora	-	3	-	8 shops and 10 kiosks destroyed, dozen vehicles damaged
2014	02/09	Multiple sites in J&K	Flood induced	-	-	Colossal damage to life and property. Blocked river channels and caused flash floods, aggravated flood situation.
2014	12/03	Kulgam district	Avalanche induced	13	-	houses collapsed
2014	12/03	Balsaran Danaukandimarg village, Kulgam district	-	4	-	-
2014	12/03	Qazigund (Anantnag), Kulgam	-	1	-	House collapsed
2014	12/03	Shopian district	-	1	-	House collapsed
2015	06/03	Sunergund, Awantipora, Pulwama, Anantnag	-	1	-	-
2017	20/03	Chadoora, Budgam	flood induced and heavy rains	16	-	mudslides and house collapse
2018	05/01	Sadna pass, Kupwara	-	10	-	Avalanche and landslides hit camp
2018	18/01	Happat Koal, Happat nar Anantnag	-	1 Swedish skier	-	-
2018	31/03	Ladden Chadoora Budgam	-	16	-	Traffic disrupted for more than 10 days
2018	04/07	Railpathri and Brarimarg Ganderbal	-	10 (4 pilgrims)	-	Amarnath yatra was suspended
2020	11/06	Salar Pahalgham, Anantnag District	-	1	-	-

Table 6 Major Snow avalanches witnessed by the Kashmir Valley for which damage and loss were reported.

Date of occurrence		Location	Casualties		Associated impacts
Year	DD/MM	Place of occurrence	Fatalities	Injuries/ missing/rescued	
1986	January	Zojila, Srg-Leh National HW	60	-	-
1994	February	Jawahar tunnel, Banihal HW	98	-	Passengers trapped and perished on both sides of the tunnel
1997	28/03	Monang Post, Uri Baramulla	4 soldiers	-	A patrol party of 4 was swept and later bodies recovered
1998	25/02	Mou Mangat, Banihal HW	11 civilians	-	House buried located far from the main village
2005	10/02	Kund and Waltengu Nar villages, Qazigund Anantnag Kulgam	175	60 civilians rescued	Hundreds trapped
2008	10/01	Uri Baramulla	15	-	-
2008	08/02	Qazigund Anantnag	3	15 injured	500 trucks stranded
2008	08/02	Jammu -Srinagar HW	25	-	-
2008	08/02	Ramban-Banihal, HW	3	-	400-500 trucks stranded
2008	18/02	Uri Baramulla	1	-	-
2009	13/01	Kashmir valley	2	-	-
2009	06/02	Kupwara	4	-	-
2009	06/02	Srinagar	4	-	-
2009	14/04	Kupwara	7	-	-
2010	09/01	Kupwara	4	-	-
2010	08/02	Gulmarg Baramulla	17 Soldiers	17 soldiers injured	-
2010	09/02	Kupwara	2	-	-
2010	10/02	Gulmarg Baramulla	3	-	-
2011	12/02	Phiram Shangus, Anantnag	2	1 injured	-
2012	24/01	Kupwara	7 (army and BSF)	-	Associated slides
2012	23/02	Ganderbal & Bandipora	16 Army personnel	Many injured	-
2012	24/02	Gurez Bandipora	13 army personnel	-	-
2012	21/03	Gurez Bandipora	2	3 people rescued. 1 person missing.	Civilian vehicle caught in the avalanche.
2013	23/12	Gurez Bandipora	2	-	-
2014	13/03	Batalik	3 soldiers	2 rescued	-
2016	14/03	Kupwara	10	73 civilians rescued.	People stranded in vehicles.
2017	25/01	Gurez Bandipora	24 (4 civilians; 20 soldiers)	-	Series of 3 avalanches. Army camp and patrol party was hit.
2017	25/01	Sonmarg Ganderbal	4 civilians	-	-
2017	26/01	Gurez Bandipora	10 soldiers	-	-
2017	26/01	Sonmarg Ganderbal		4 soldiers injured	-
2017	28/01	Machil, Kupwara		5 soldiers rescued	-
2017	06/04	J&k, higher reaches of Kashmir and Ladakh. Batalik, Kargil, Kupwara, Kokernag, (Anantnag) Rajori, etc.	9 (6 civilians, 3 army men)	-	Avalanches, minor flooding, landslides, rise in water levels in Jhelum and tributaries.
2017	13/12	Gurez (Bandipora) & Naugam, (Kupwara)	5 soldiers	-	Trapped after snow track caved in.

2018	06/01	Sadhna top, Tangdhar Sector (C-T), karnah, Kupwara (khooni nallah)	11 (civilians)	-	2 avalanches. Vehicle hit by avalanche.
2018	25/01	Sonmarg (Ganderbal), Gurez (Bandipora) & Kupwara	6 (5 civilians, 1 army major)	4 soldiers missing, 6 soldiers rescued alive	Camp hit, House collapsed, family of four died.
2018	26/01	Bandipora	11 (7 soldiers, 4 civilians)	Several missing	A camp and patrol party got hit.
2018	02/02	Kupwara	2 soldiers	1 injured	Avalanche struck army post
2018	16/02	Gulmarg Baramulla	5(tourists- 1 international, 4 national)	-	-
2018	24/02	Guchibal Behak, Kupwara	3 civilians	2 missing	-
2018	01/03	Tulail Bandipora		1 injured	-
2018	09/09	Kolahoi	2 local trekkers	-	-
2019	04/12	Tangdhar Kupwara	3 soldiers	-	Army post hit
2019	04/12	Dawar, Gurez, Bandipora	1	1 injured	Foot patrol of army was hit
2020	14/01	Kulan, Sonmarg Ganderbal	5	-	Several houses damaged when village was hit by avalanche
2020	14/01	Machil sector, Kupwara	4 soldiers	5 trapped	Army post hit
2020	14/01	Naugam sector, along LoC Kupwara	1 soldier	6 rescued alive	-
2020	18/11	Roshan post, Tangdhar Kupwara	1	2 injured	-

For landslide hazard out of the total 65 events collected, 49 events with substantial damage and loss were discussed in detail (Table 5). The events with highest number of deaths in the databset are the landslide event of 20th March, 2007 Chdoora budgam and 31st March, 2018 Ladden, Chadoora, Budgam with a death toll of 16 persons each. Land sliding can have varied triggers, heavy rains appear to be the most frequent cause of landslides and therefore, many a times landslides coincide with floods and flash floods (1992, 20th April, 20th March, 2007 and 2010, 2nd September, 2014), earthquakes (4th April, 1905, 8th October, 2005) and snow avalanches (19th February, 2005 and 12th March, 2014) are also a common cause for land sliding. Landslides frequently lead to road blockade, disrupted traffic movement (of people and goods) as can be seen from the data, along with other impacts like deaths and injuries, loss of cattle, damage to hillside settlements, infrastructures, roads and bridges causing loss of connectivity, hamper pilgrimage activities, accidents and damage to vehicles, affect tourism, and daming of rivers causing flash floods. National hihgway is the main link of the valley to the rest of the country which gets blocked ever so frequently during rainy and winter seasons leaving the valley without accessibility for days at a strech having impacts like shortage in supplies, availability of goods, inflation, hampered movement of people, etc (Prakash, 2011). From the data we can establish a pattern in the seasonal variability of landslide occurrences, with maximum number of events (9 each) in the months of February and March, which account for 34.04% of the total occurrences, and minimum (1 each) in May and November, rest occassional slides occur throughout the year. 53.19% of the total land sliding activity occures in the months of January, February, March and April, but a substantial number of occurrences have also been recorded for the month of June, which accounts for 14.89% of the total incidents recorded.

Snow Avalanches

An endemic feature of snow-covered mountain ranges (Spencer, 2011; Bruno, 2013), avalanches are both widespread and one among the most destructive natural hazards (Keylock, 1997), causing fewer casualties globally, on an average several hundred people per year (Birkeland, 2021), than many other natural hazards, but overall fatalities have been on the rise over the past several decades (Bruno, 2013). The overwhelming expansion of tourism and increasing popularity of winter sports and climate warming has escalated the number of people exposed to avalanches by influencing the behaviour, uncertainty and increasing frequency of snow avalanches (Martin et al., 2001; Bruno, 2013; Castebrunet et al., 2014).

The Himalayas (Indian Himalayas) are highly vulnerable to snow avalanches (Sethi, 2000; Ganju, 2002; Mc Clung, 2016) and with increased communication to isolated mountain villages, the number of incidents and casualties recorded has enhanced substantially in the last few decades (Sethi, 2000). Snow-covered regions of Jammu and Kashmir, Himachal Pradesh, Uttaranchal and Western Uttar Pradesh are significantly susceptible (Sethi, 2000; Ganju, 2002) while eastern states witness occasional incidents. In erstwhile, Jammu and Kashmir higher reaches of Kashmir division (Kashmir valley, Gurez valleys, Kargil and Ladakh), areas of Jammu region (Doda, Ramban, Udhampur, Reasi, Kishtwar, Banihal), some of the major roads (long stretches of national highway connecting J&K to the rest of the country, from Ladakh through Srinagar to Jammu, Mughal Road, etc.) (Kelman, 2018; RMSI Report, 2018) and famous pilgrim centres (Amarnath, Phalgham and Baltal, and Vaishnu Devi, Katra) (Sethi, 2000) are highly vulnerable to snow avalanches (SDMP, 2017).

J&K, as compared to the other vulnerable regions of the country has taken the major brunt of avalanche accidents in the past (Ganju, 2002) with both civilians and the army being severely impacted as can be established from the recorded events (Gusain et al., 2018). Table 6 discusses 47 incidents in detail most of which have been recorded for the period 2000-2020. An evident increase in the number of avalanche occurrences and subsequent casualties can be seen in the past three decades which can be primarily attributed to insufficient knowledge about the terrain, lack of forecasting mechanism, and ill-equipped adventures taken-up by army as well civilians like construction of roads, enhancement in tourism and increased patrolling activity in the region post 1990's (Ganju, 2002). Snow avalanches have substantial adverse impact on human activity (Keylock, 1997) threatening human life directly by causing death or injury, or by detaining them and indirectly by obstructing the overall development, disrupting ecosystems, damaging built structures and landscapes in mountainous regions (Ganju, 2002; Choubin, 2019).

A considerable portion of the total fatalities seem to occur when people are in movement, as opposed to when they are static (like in their houses, barns etc.,), and majority of the accidents take place during snowfall or immediately after cessation of snow storm, as can also be confirmed from the reported events in this study (Table 6) (Sethi, 2000; Ganju et al., 2002). The incident showing highest number of casualties is the avalanche of 10th February, 2005 in Kund and Waltengu Nar Villages killing a total of 175 people while 60 were rescued alive. The record shows a few more severe incidents with large number of casualties like 1986 Zojila (60 deaths), 1994 Jawahar Tunnel (98 deaths), 8th February, 2008 Jammu-Srinagar National HW (25 deaths), 8th February, 2010 Gulmarg (17 deaths and 17 injuries), and 25th January, 2017 Gurez (24 deaths). Recorded casualties show a greater number of army personnel than civilians which is due to the proximity of the region to the international border that mostly stretches across avalanche-prone snow-covered slopes, therefore, the presence of army posts along the LoC makes them highly susceptible to snow avalanches (Gusain et al., 2018). The data reveals that areas like Tangdhar, Drass, Gurez, Keran, Machhal, Gulmarg, Naugam and Banihal are highly avalanche prone sites in the valley (Table 6) (Kelman, 2018; Gusain et al., 2018).

The major roads of the region, winding up on some of the prominent passes on the Pir Panjal and the Greater Himalayan Range, are often closed due to landslides and avalanches during the winter and early spring seasons, with a number of casualties every year, frequent suspension of vehicular movement and confinement of pedestrian movement to only village level for long periods creating various socio-economic problems, but with no systematic compilation of incidents or casualties (Kelman, 2018). The important road axes susceptible to avalanche activity include: Jammu-Srinagar, Naugam-Kaiyan, Chowkibal-Tangdhar, Srinagar-Leh and Bandipora-Gurez. Tangdhar is one of the regions studied well for avalanches and many researchers have reported various prediction techniques for this road axis in the past (Gusain et al., 2018).

The avalanche activity for major portions of mountain areas of Kashmir is most pronounced in the months of January to March, but may stretch over the months of November to April (Sethi, 2000), while in the high alpine areas the avalanche season continues all year-round (9th September, Kolahoi) (Ganju, 2002). In Kashmir 72.34% of the total avalanches occur in January and February followed by the months of March and April accounting for about 17.02% of the total.

4.1.2. Casualties

Casualties form one of the most important aspects to study the intensity and extent of impact caused by a particular disaster event. A casualty can be any person who becomes a victim to an adverse impact caused by any hazardous event, which may include persons killed, injured, trapped, missing, evacuated, or rescued. However, the present study only includes two forms of casualties viz., fatalities and injuries. The trend shows that maximum number of reported casualties are related to earthquakes (30,530 i.e., 90.94%), followed by floods (2,194 i.e., 6.53%), snow avalanches (642 i.e., 1.91%) and least for landslides (204 i.e., 0.60%). Although many of the events have a regional and cross border extent, only the casualties reported for the area under focus i.e., the Kashmir Valley, whereever provided, were considered for analysis. The total number of severe events shows an inverse relation to the total casualties reported, for example only 7 severe earthquake events were reported for the entire timeline for which the count of casualties far surpasses that caused by any other hazard type, whereas a total of 49 landslide events were of the magnitude to cause substantial damage and loss, for which the total count of casualties stands the least among all the four hazard types.

4.1.3. Temporal variability and distribution

The temporal variation and frequency (annual and decadal events distribution) of hazard and disaster events of all four types for the time period 1900 to 2020 (Fig. 3 and Fig. 4) shows a general increasing trend in the last few decades depicted by a sharp rise in the graph line between 1980 to 2020, establishing the fact that the number of disaster events recorded has considerably increased in the past few decades. This indicates that the frequency of hazard and disaster occurrences, due to various natural (climate change and global warming, geological endogenic and exogenic processes) and anthropogenic factors has increased to a great extent. Another factor responsible for the rise in recorded incidents possibly could be the enhanced and improved recording and reporting of disaster events globally and nationally in recent times. Also, due to dramatic population growth and rapid urban expansion, overburdening of regions takes place which forces people to move to and settle in unsafe conditions and vulnerable areas, increasing the chance of human interaction with these potential hazards and therefore, elevate the levels of exposure to which populations and societies are subjected to, thus, consequently increasing the number and frequency of these adverse events.

In case of earthquakes, although, major events are well recorded throughout the timeline, small to medium scale incidents, which need technological intervention to be detected find more reliable and frequent reporting post 1960s which can be backed up by the gradual but evident increase in the number of events recorded per year (Table 2 and Fig. 3a). The history of instrumental monitoring of earthquakes in India dates back to 1898 when the first seismological observatory of the country was established in Calcutta after the great Shillong plateau earthquake of 1897. Other similar occurrences like 1905 in Kangra Valley, necessitated the strengthening of the national seismological network with 1960s marking a landmark in history of seismic monitoring when the WWSSN (World Wide Standardized Seismic Network) stations started functioning globally, post which the number of reported earthquake events shows a drastic increase (Table 2 and Fig. 3a). For the given timeline of 120 years (1900-2020) the highest number of earthquake events i.e., 121 were recorded in the year 1976. The dataset reveals that there is a strong earthquake (magnitude 6.0 and above) every few years, in and around the Kashmir region, with occasional episodes of continued occurrences without any gap like 1963, 1964, 1965 and 1972, 1973, 1974 and 1975. Sometimes more than one strong earthquake seems to have jolted the region in a single year (1950, 1975, 1990, 2005 and 2015). Earthquakes with magnitude lesser than 6 occur more frequently all the year-round.

Flood events on the other hand show the most consistent trend of occurrence throughout the timeline, with occasional periods of no flood occurrences. Although, a slight increase can be detected through the slope of the trend line in the graph 2000-2020, indicating more than one flooding event in the same year (Fig. 3, b). Floods, in general, show a repeated pattern through the 20th century arriving at regular intervals (Table 2 and Fig. 3b) and during the years

1900 to 1965, the valley experienced about 15 major floods (Razdan, 2014). 3 flood events in a single year 2015 were the highest number of flood events recorded for any year. Detection of a flood event is more evident through the rise in water levels, which are easier to measure and record, and therefore, are available for most of the times when water levels have crossed the flood mark, dating back to 635 A.D.

Landslide and snow avalanche events are localized events and have limited spread. From the graph we can make out a comparatively less consistent trend of occurrence and frequency throughout the timeline, which hints at a dramatic increase in landslide and snow avalanche incidents in the recent past which could be attributed to, firstly, increase in exposure of populations to these hazards through tourism and adventurous activities, communication to and settling in remote susceptible areas, increased movement of traffic in these areas, and also, large scale patrolling activity post-1990s, and secondly, better reporting and recording of these events, which was found almost negligible for the twentieth century except for incidents with greater human impact and those along the national highway, (Ganju, 2002) and the increasing trend can be seen continuing in the 21st Century (Table 2 and Fig. 3c, 3d). A total number of 16 landslide events in a single year 2010 were the highest recorded and for snow avalanches the highest number of events recorded in a single year were 13. Looking at the dataset we infer that on an average 2 to 3 low to moderate intensity avalanche events occur in a year. Also, some very high impact events with a large number of casualties keep repeating once in few years (Table 5 and 6).

4.1.4. Spatial distribution

The spatial distribution of the selected four hazard types was represented through maps developed in ArcGis. For earthquake hazard only the events with epicentres lying within the Kashmir Valley were plotted using the geographic coordinates provided in the secondary sources consulted, similarly, the landslides and snow avalanches reported within the area of interest were plotted by making use of the latitudinal-longitudinal information collected for the reported events, but for flood hazard spatial distribution was represented through the extent of inundation experienced by the Valley in the Kashmir Flood of September, 2014 (declared as the highest magnitude flood recorded instrumentally on Jhelum by the Department of Irrigation and Flood control), in order to give an idea about the area of Kashmir Valley which may be at risk of inundation during a Flood event of similar magnitude.

The entire valley is about equally prone to earthquake hazard with a somewhat homogenous distribution of earthquake incidents in and around the region, which coincides with its zonation into high to very high seismic intensity zones (zones IV and V) (Fig. 5a). For flood hazard, however, flood plains and low-lying areas, on both sides of the Jhelum River, across the length of the entire valley, are under the threat of inundation (Fig. 5b). Analysis of recent available data suggests that the left bank of the Jhelum is more vulnerable to inundation than the right bank (Ram 1895,1928; Bhat, 2019). As for the landslides and snow avalanches, incidents are limited to higher reaches, unstable slopes, with pockets of high, moderate and low frequencies throughout the mountainous stretches of the Valley (Fig. 5c and Fig. 5d), especially along the roadways running through these hilly terrains.

The plot distribution and inundation extent data were further used to generate susceptibility maps of all four hazard types for the districts of the Kashmir Valley (Fig. 6) based on the concentration of events in each district for earthquakes, landslides and avalanches and for floods the extent of area inundated in each district, as factors for classification of the districts as less to more vulnerable to specific hazards. This gives us a general idea about the proneness of the districts towards different hazards, from which we can make out that all the districts are susceptible to two or more of the selected hazard types.

Based on the choropleth/thematic maps (Fig. 6), maximum concentration of earthquake incidents is seen in the district Kupwara, whereas, Shopian shows the lowest concentration (Fig. 6a). For flood hazard, districts with maximum flooded area appear to be Baramulla and Bandipora whereas, Kupwara and Shopian show least area affected (Fig. 6b). There can be seen pockets of concentration depicting landslide incidents, located predominantly in the mountainous terrain running along the periphery of the valley (Fig. 5c and d). In figure 6c, it is evident that districts Baramulla and Anantnag have witnessed the maximum number of landslide events in the time period and therefore, exhibit the highest susceptibility, while the districts with the least susceptibility are Pulwama and Shopian. For snow avalanches, the events are spread over the snow-covered ranges of the valley, especially towards the north and northeast (Fig. 5d). In some spots, locations of high-concentration of avalanche events coincide with those of the landslide events. Among the districts, Kupwara shows the highest susceptibility towards snow avalanches, whereas, Budgam, Pulwama and Shopian show the least susceptibility towards avalanche hazards (Fig. 6d).

5. Data Uncertainty And Limitations

Disaster data has been found to be scattered and broken, showing intermittent and discontinuous coverage in the major portion of the 20th Century. While large impactful events find a place into literature through one way or the other most of the small-scale incidents go unreported. In the later part of the 20th Century disaster events can be seen recorded more continuously with more accurate details, which continues in the 21st Century, attributed to improved technology for detection, reporting and disseminating information. There has been no specific literature dealing with what can be generally termed as disaster data base in the historical perspective in the former part of the timeline but things have begun to change ever since the inception of databases like CRED-EM-DAT, Munich RE, ADRC, IDNDR, etc. Consequently, information about natural events and resulting processes were littered in the vast corpses of literature making them difficult to assemble.

Ambiguity and unreliability are produced by relying upon online digital sources in the process of data accumulation for extended periods as these usually get deactivated or removed from the web after a certain period of time. Similarly, digital newspaper archives are also only available for 5-8 years which poses a challenge to data collection retrospectively. Additionally, websites which work as supplementary resources to global and regional hazard databases are mostly region and country specific, especially to developed nations (Sultana, 2020). Also, databases have specific criteria which limit the recording of all disaster events specifically to those which fulfil these particulars, e.g., EM-DAT. As a result, many events don't make it to such databases and thereby, forming a corrupt picture of the hazard or disaster scenario and making data collection a challenge.

Some hurdles arise when it comes to characterizing disaster events. Generally, information can fluctuate widely regarding frequency, magnitude, impacts, exact location (latitude-longitude), etc. which results in several biases and overlaps. Like in case of earthquakes, the epicentres or the magnitudes showed variation from one source to another. Similarly, figures relating to damage and loss can also be erroneous, example death of someone injured in the main event a few days after the event. Sometimes, the events with minimal consequences go unreported which results in inaccurate figures of total disaster episodes. An over or under estimation is encountered when news of multiple events occurring on the same date at same or different locations are reported as a single event. Therefore, in terms of impacts and other specifications, multiple sources were consulted for a single episode and the data from best reported and more reliable source was selected in that case.

In some cases, casualties and economic losses pertaining to a single hazard type may be higher than what is commonly documented (Schuster, 1996, 2001; Guzzetti et al., 1999; Anderson et al., 2011). There is widespread recognition that the overall consequence of landslides and avalanches is usually underestimated (Kjekstad & Highland, 2009; Petley, 2012). Data is not systematically reported or readily available (Petley, 2005, 2010; Corominas et al., 2014) unlike other natural disasters. Casualties are often recorded under the label of triggering events, which are usually larger events such as flood, hurricanes, or tropical storms, earthquake, etc. (UNDP, 2004; Froude & Petley, 2018). Also, in most of the cases, exact reporting is hindered by the comparative smaller scale on which they occur, lack of close observation, short span of occurrence and that too at specific, remote locations and during specific seasons, which limit their impacts and is unrecognized in most natural disaster's registers (Holcombe & Anderson, 2010). All this may cause flawed estimations pertaining to the hazard impact and susceptibility.

In these records, for landslides and snow avalanches it was seen that data pertaining to army accidents is more or less complete as compared to that of the civilian data, which has often gone unreported, therefore giving a false idea of the actual hazard susceptibility.

6. Conclusion

The aspect of utmost importance for preparing a mitigation plan is to understand the hazards facing a community. Understanding the various hazard risks and their subsequent consequences is of prime concern while mitigating the adverse effects of potential hazard events. A hazard profile is an account and analysis of different types of hazards specific to a place/community. It is performed for each natural hazard and based off certain criteria such as frequency, location, duration, speed of onset, and impacts. A hazard profile enables decision makers to compare the physical aspects that all hazards share. By comparing the characteristics of hazard events, they are able to identify and prioritize the hazards for mitigation, risk reduction, policy and decision making, and funding.

From the above discussion, we assert that the valley of Kashmir is subjected to a threat of multiple hazards that have the potential to turn into devastating disaster events and jeopardize the lives of millions residing in this area. The analysis finds out that the frequency of disaster events has drastically increased over the past few decades, enhancing the threat of natural hazards to which the population and society of Kashmir are subjected to. The results reveal that these four natural hazards individually, can have devastating impacts and also, a catastrophic event may take form if multiple hazards overlap or cascade after one another. Therefore, it becomes essential to gauge this impending threat, mitigate the risks and prepare for the worst through sustainable Disaster Risk Reduction which the present study aims to facilitate by developing a multi-hazard profile of Kashmir based on the disaster database compiled. The disaster catalogues prepared in the study can prove of great help for various stakeholders and policymakers, to assess the local risk and hazard scenario of the valley, in order to be incorporated in planning, to reduce disaster risk and subsequently create sustainable environments.

Information availability and ease of access to data regarding the events were found to vary with the type of hazard, like in the case of earthquakes, data was readily available in national and international databases as well as on open access portals and websites, because of improved recording technologies and dissemination platforms. Similarly, for floods, a good amount of data was found from various existing research studies, especially, due to a boon in flood research post-2014 Kashmir floods. On the contrary, for landslides and snow avalanches, it was encountered that data recording, reporting and access was limited due to various factors. Both landslide and snow avalanche events have not received as much recognition as is the case with floods and earthquakes.

The data for earthquake incidents, their magnitudes and for flood incidents, the experienced water levels and damage and loss for either of the two types, have been more or less recorded and have found place in literature either through official record or historical literature as both events can have colossal adverse impacts and spread over a vast expanse, which is not the case with landslides and snow avalanches. The fact that events data of landslides and snow avalanches, for major portion of the selected timeline is missing from the consulted data sources could draw a misleading picture of the hazard and disaster scenario of the Kashmir valley, making the valley appear little to not vulnerable to these hazards, which is very contradictory to the actual scenario.

Declarations

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8. Conflict of Interests/ Disclosure Statement

The authors declare that there is no conflict of financial or personal interests or beliefs that could affect the objectivity of the research.

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Figures

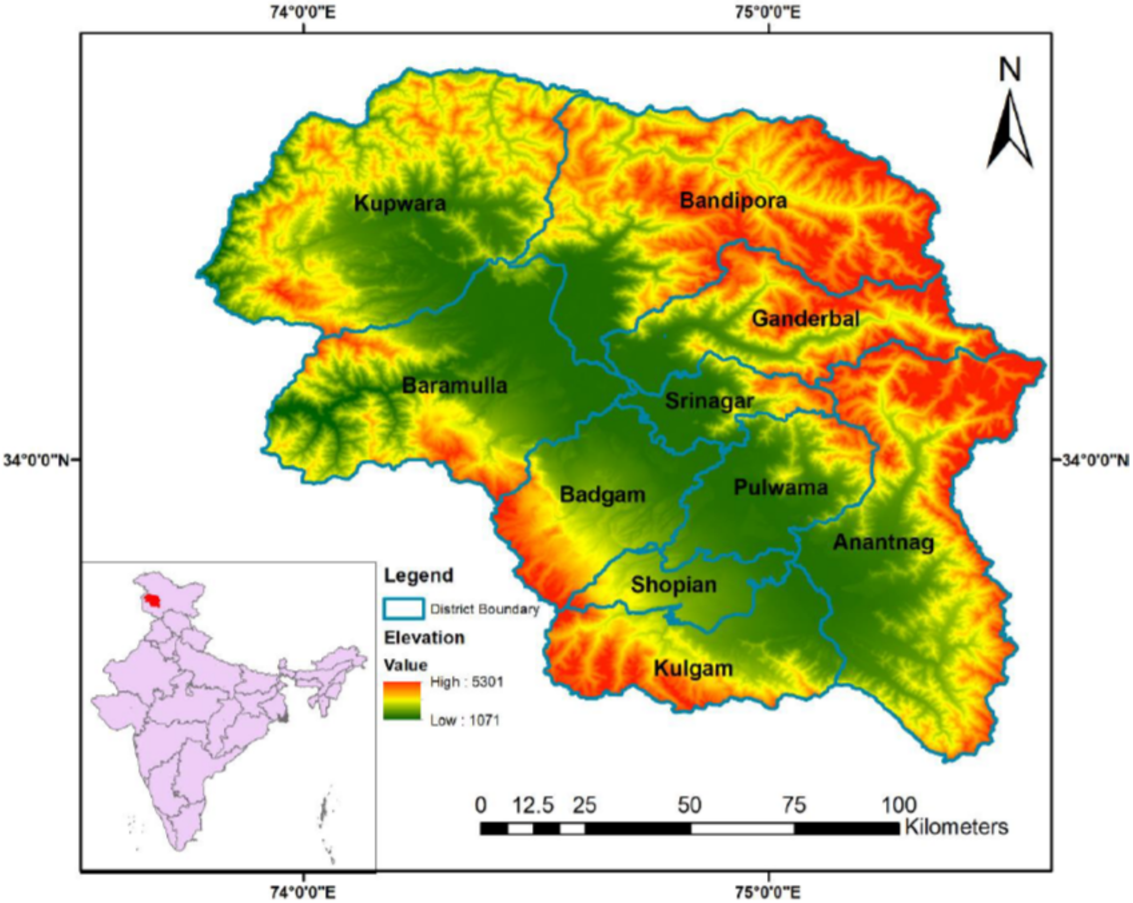

Figure 1

<p>Location map of the study area</p>

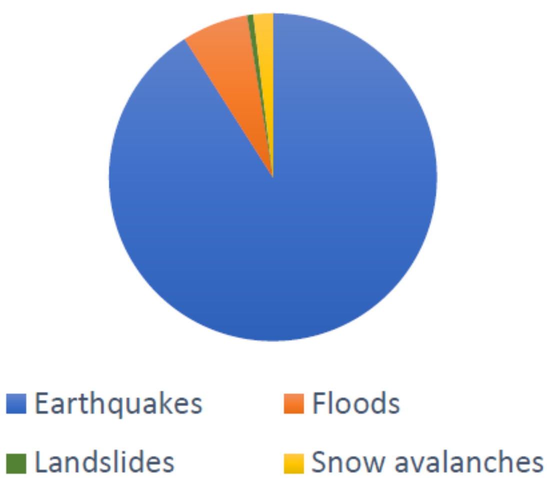

Figure 2

<p>Casualties (fatalities and injuries) caused by each hazard type</p><p>
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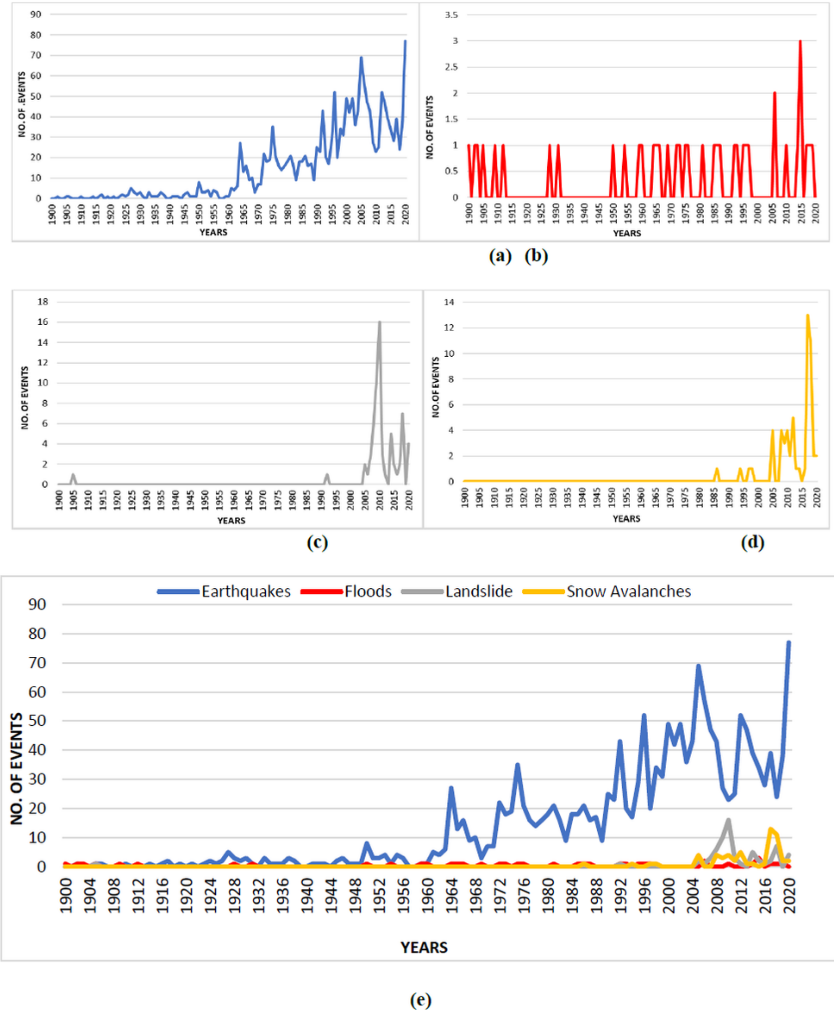

Figure 3

<p>Temporal variability and frequency trends of each hazard type for the time-period 1900-2020 (a) Earthquakes (b) Floods (c) Landslides (d) Snow Avalanches and (e) Comparative analysis of all four hazard types</p><p>
</p>

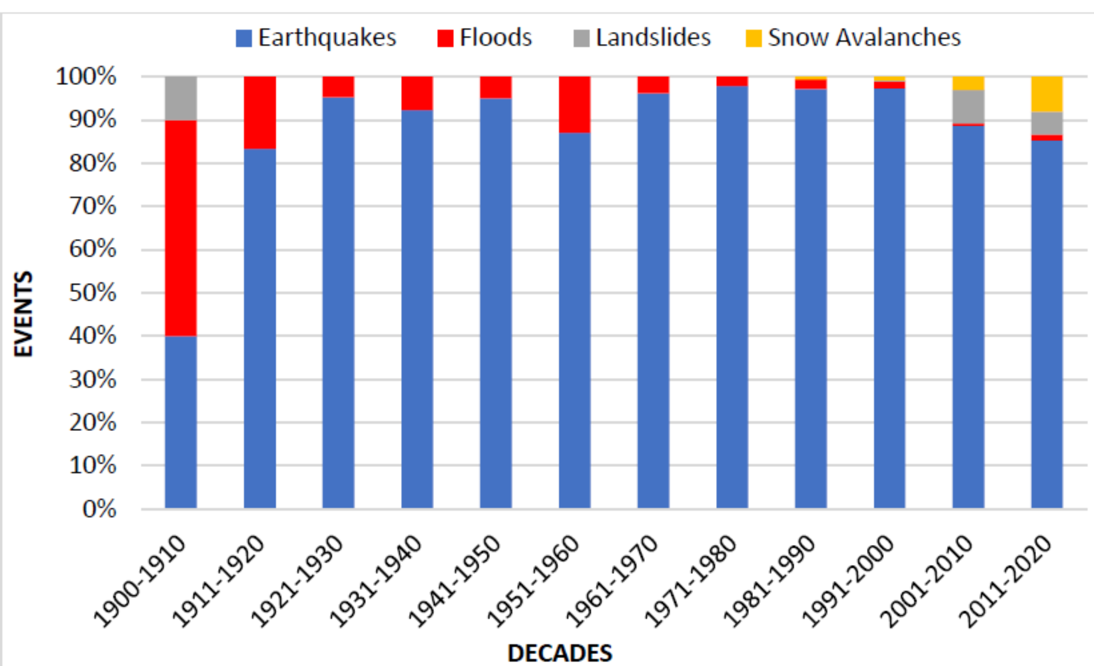

Figure 4

<p>Comparative analysis of Decadal trend of all four hazard types</p>

Figure 5

<p>Spatial distribution of hazards in the Valley (a) Earthquakes with epicentres within the Valley (b) Spatial extent of the 2014 flood (c) Landslide events and (d) Snow avalanche events</p><p>
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Figure 6

<p>Thematic maps for district-wise susceptibility of Kashmir Valley to hazards (a) Earthquakes (b) Floods (c) Landslides and (d) Snow avalanches</p><p>
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Supplementary Files

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