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Review

A Review of Spatial Variations of Multiple Natural Hazards and Risk Management Strategies in Pakistan

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Abstract: Natural hazards are dynamic and unpredictable events that are a continuous threat to global socio-economic development. Humans' reactions to these catastrophes are influenced by their proximity to the hazards and their ability to anticipate, resist, cope with, and recover from their consequences. Due to climatic changes, the risk of multiple natural hazards is expected to increase in several regions of Pakistan. There is a pressing need to understand the spatial discrepancies of natural hazards due to climate change and identifying the regions that require special measures to increase resilience, achieve adaptation, and sustainable development goals. This paper synthesizes the related literature to understand spatial variations of natural hazards due to climate changes across Pakistan. The Emergency Events Database (EM-DAT), National Aeronautics and Space Administration Global Landslide Catalog (NASA-GLC), National Disaster Management Authority (NDMA), and Pakistan Meteorological Department (PMD) are utilized to analyze spatial discrepancies and vulnerabilities to natural hazards. This study unveils that Pakistan's current risk analysis and management strategies seem to be obsolete compared to global trends. Because of spatial variations of hazards, most research work on hazard risk assessments and risk management focuses on a single hazard, neglecting the co-occurrence impact of different natural hazards. Very limited studies are included in comprehensive multi-hazard risk strategies. Therefore, in Pakistan, risk management would require integrated multi-hazard risk assessment approaches to detect, analyze, measure, and evaluate various natural hazards, their effects, and interconnections. Moreover, the Pakistan governmental institutes dealing with natural hazards should focus on pre-disaster mitigation and resilience techniques instead of investing only in post-disaster relief activities.

Keywords: natural hazards; spatial variations; climate change; multi-hazards; risk-assessments; Pakistan

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1. Introduction

Climate change and increasingly extreme weather events have caused a surge in natural hazards in Pakistan. Major hazards such as inland floods, storms, earthquakes, landslides, droughts, cyclones, and tsunamis [1] cause harm to people and a country's economy. The effect of disasters differs significantly from country to country and is primarily determined by a community's physical and socio-economic strength. The economic losses caused by extreme events have been reported to be higher in developed countries [2,3] than in developing countries, but the opposite is true for human casualty figures. In recent years, Pakistan is facing a substantial rise in the frequency and severity of weather events and earthquakes. This has a detrimental effect on underprivileged communities, including the men and women living in them. According to the German Watch Report 2019 [4], Pakistan is constantly affected by catastrophes. It ranks among the most affected countries due to natural hazards concerning human deaths, with around 512 fatalities annually between 1998 and 2020 [5]. On 4 January 2010, a massive mound of rocks crashed down the hill at Attabad, a town in Gilgit-Baltistan, north Pakistan [6]. The massive landslide buried parts of the town and the adjacent village of Sarat in the confined strip of land of the Hunza River. This landslide event did not appear suddenly [7]. The slope had been showing signs of developing fissures for years. While this was bad enough, it caused a second calamity due to the first. The debris produced a huge obstacle of a hundred meters high and one kilometer wide, blocking the Hunza River's passage [8] and covering up the Karakorum Highway (KKH). As a result, the entire territory upstream, the Gojal Tahsil, was isolated from Pakistan. Following that, a lake formed behind the obstacle, which kept expanding until August 2010. It had grown to about thirty kilometers long at that point [9]. One town was entirely flooded, while four others were partially flooded. Large portions of the KKH were flooded, causing major communication difficulties between the towns. Furthermore, hazards that originate outside of Pakistan's borders can affect Pakistan's society and economy. There is a need to develop new institutional frameworks [10–12] with the mission of developing multi-disaster risk management strategies. For better risk assessment and management planning, an integrated approach should be adopted by the researchers and scientific community, as set forth in multi-hazard early warning systems for disaster risk reduction reported by the World Meteorological Organization (WMO) [13]. Natural disasters, such as earthquakes and landslides, may strike without warning [14,15]. Droughts or famines are examples of slow-moving events [16]. A series of major disasters have hit Pakistan in recent years [17]. There is a pressing need for an increased understanding of spatial discrepancies in natural hazards due to climate change within a country and mapping regions that require resources to increase resilience and achieve adaptation and sustainable development goals.

The above discussion and head-to-head occurrences of natural hazards in the past decade in Pakistan emphasize the need of a review work to assess the previous research works and mitigation as well as adaption strategies to cope with the issues due to these natural hazards. Authors have been motivated to undertake work in this direction due to heavy human life and economic loses in Pakistan due to these natural hazards. Furthermore, highlighting the lack of knowledge and expertise in assessing risks due to natural hazards and their management techniques among the disaster management agencies in Pakistan has been considered valuable to recommend some fruitful directions for future research works. This review paper will synthesize the related literature to understand spatial variations in natural hazards due to climate change across Pakistan. Moreover, it will provide an overview of Pakistan's major natural hazards, their implications, and risk management strategies. Information gaps, i.e., research limitation areas, will be highlighted, particularly for multi-hazard risk assessment approaches. The findings and suggestions of this review article will hopefully help spatial planners, managers, and other policymakers in Pakistan to make productive decisions to mitigate the risks of natural hazards in a better way.

The research questions in this regard are as follows:

1. Is the current literature work about spatial variations of natural hazards in Pakistan fulfilling the criteria of global trends?
2. Are the current natural hazards mitigation and adaption strategies in Pakistan in line with global trends?
3. Does the current literature work consider the cascading impact of different natural hazards?
4. Are the current research works and hazards risk management techniques fulfilling the requirements to cope with the issues due to these natural hazards?
5. What would be the suitable research directions to deal with future scenarios of natural hazards in Pakistan?

2. Methodology

To explore the answers to the research question raised in the introduction section of this research work, past literature works spanning fifty (50) years (from 1970–2020) were gathered from various publishing sources. The explored literature is related to numerous natural hazards, including floods, drought, cyclones, earthquakes, landslides, heat waves, and glacial lake outburst floods in Pakistan. To understand the socio-economic impacts of natural hazards, we developed relationships for financial and human damages, risk analysis maps, and risk management strategies through the help of the explored data. The data's primary sources are scientific literature, and different databases include the Emergency Events Database (EM-DAT), National Aeronautics and Space Administration Global Landslide Catalog (NASA-GLC), the Pakistan Meteorological Department (PMD), the National Disaster Management Authority (NDMA), and the Provincial Disaster Management Authorities (PDMAz) of Pakistan. Risk analysis maps from explored data and risk management techniques are discussed after gathering data from these sources to comprehend the integrated behavior of the various natural hazards that occur in Pakistan. Figure 1 illustrates the methodology flowchart adapted to explore and review the literature. This was based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Initially, 160 articles were found, and after screening, only 60 articles were shortlisted and considered suitable for systematic review under the scope of this review article.

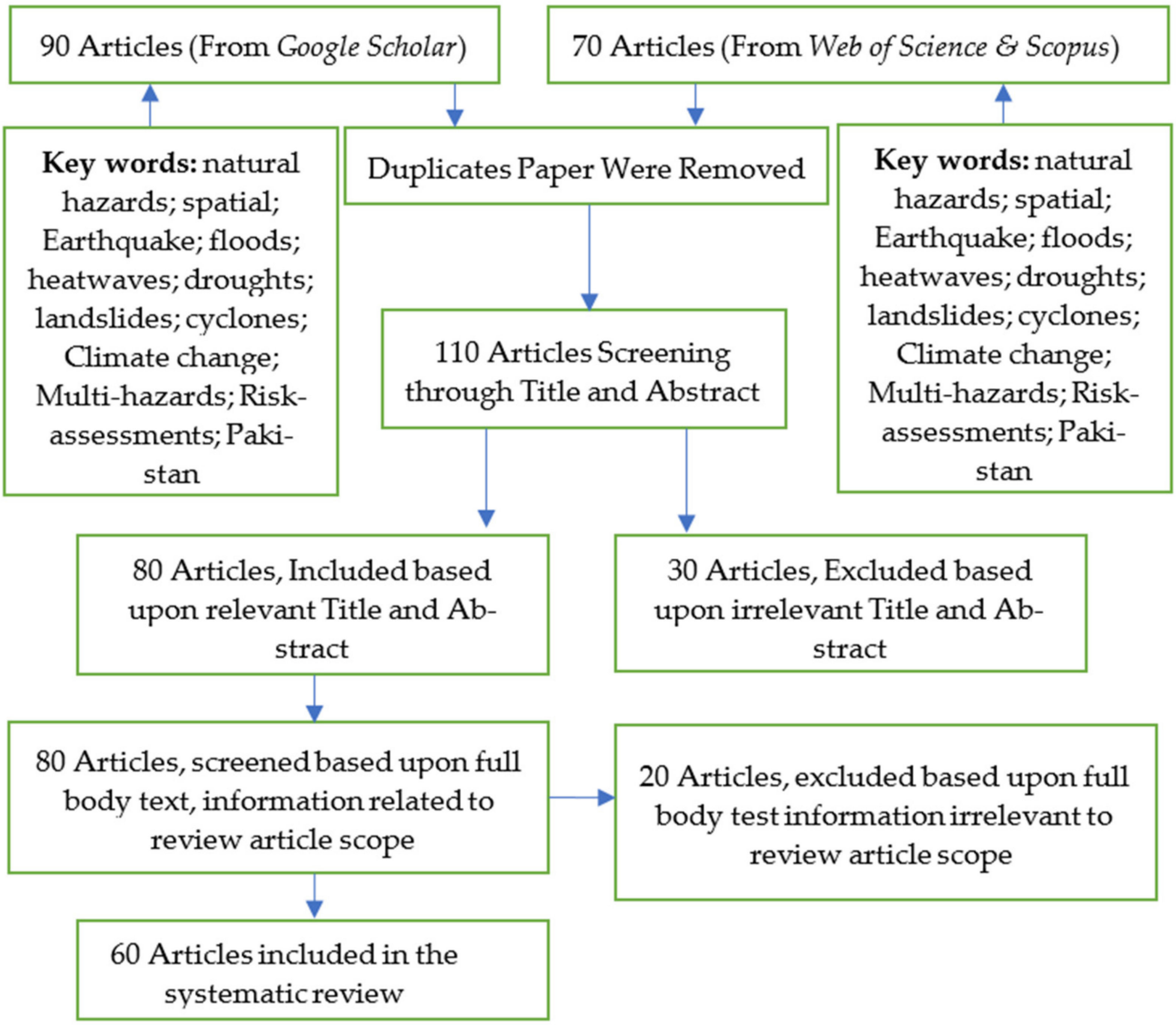

Figure 1. Search strategy for literature review.

In this article, we seek a deeper understanding of spatial variations of natural hazards in Pakistan. Firstly, we reviewed the scientific literature referred articles (Web of Science, Scopus, and Google Scholar) for all natural hazard risk assessment and management strategies individually. Secondly, we explored spatial variations in natural hazards from 1970–2020 using different databases (e.g., NDMA, PDMAs, PMD, EM-DAT, NASA-GLC, etc.). Thirdly, in the next sections, the spatiotemporal characteristics for major natural hazard that were developed are detailed. Finally, the data obtained from above-mentioned sources were synthesized to avoid any contrast in disaster events. Moreover, we discuss the current risk management strategies adopted in Pakistan in view of monitoring and mitigation measures for natural hazards. Consequently, the key findings and way forward are proposed for the policymakers of Pakistan. This review article is concluded by discussing future research challenges that may be faced by the community and several opportunities for addressing such challenges. Figure 2 demonstrates the overall methodology of this review article, including both the literature review and databases exploration.

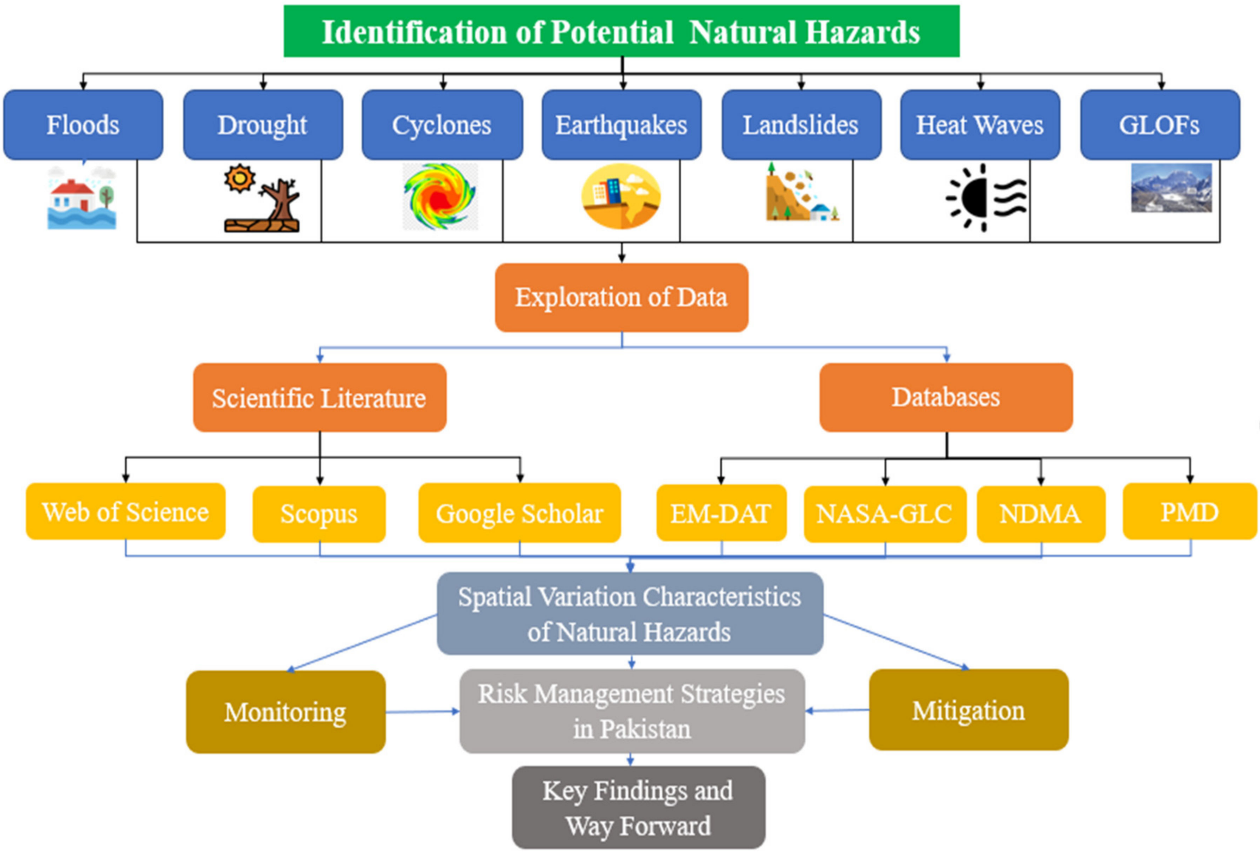

Figure 2. Methodology Flowchart.

Study Area

Pakistan has a total area of 770,875 km^2, and its geographical location and wide diversity in its topography make it strategically important within its neighboring countries. The three major topographical areas of the country are the northern mountainous ranges, the Indus River Plains, and the Baluchistan Plateau [18]. The Indus Plain, which runs from north to south across Pakistan, covers more than 60% of the region. Baluchistan and Khyber Pakhtunkhwa provinces are mountainous, and northern Pakistan has high peaks, such as K-2, the globe's second-largest peak, having a height of 8616 m. Pakistan comprises high-contrast regions with drastic temperature differences between seasons and locations. Pakistan is still primarily a dry land region, with 11 distinct climatic zones. Arid or semi-arid land makes up 80% of the land as prone to desertification; dry sub-humid land makes up 12%, and humid land makes up the remaining 8%. In January, temperatures in the plains vary from 4 °C to 15 °C, and in June and July, temperatures range from 30 °C to 45 °C [19]. Droughts are raging along the coast of Makran in the south. Jacobabad is one of the world's hottest cities, with temperatures regularly exceeding 50 °C. Pakistan is the world's sixth most populous country, with over 216 million people in 2019 [20,21]. Most of the population in southern Pakistan lives along the Indus River, with around one-third of the population living in cities. Karachi is Pakistan's most populated city.

Geographically, Pakistan stretches from 24° to 37° north latitude and 62° to 75° east longitude, as shown in Figure 3. Geographic location, elevation, and demographics [22] contribute to the country's severe vulnerability to climate change. Pakistan is situated on a steep incline, falling from nearly 8500 m to sea level in less than 2000 km.

Figure 3. Geographical Boundaries of Pakistan (Survey of Pakistan [23]).

3. Historic Damages Due to Natural Hazards

Various severe natural hazard incidents have struck Pakistan in recent decades. Floods, avalanches, landslides, heat waves, earthquakes, and droughts are among the 191 events (Figure 4a) mentioned in the international disaster database [24] between 1970 and 2020. In total, these events have impacted more than 96.77 million people (Figure 4b) in Pakistan and caused nearly USD 28.45 billion in damage. Flash floods cause the greatest economic loss, accounting for about 36%; riverine floods contribute almost 34%, earthquakes contribute approximately 19%, and storms account for 6% of economic damage in Pakistan (Figure 4c). These disasters caused total fatalities of about 1 million (Figure 4d). Earthquakes took most people's lives, accounting for approximately 80% of all casualties. Figure 5 demonstrates the annual frequency of natural hazards, with riverine floods and droughts having the highest and lowest rates, respectively. The hazard's annual frequency describes the value of the occurrence of hazards per year. It is determined by dividing the total number of each hazard that occurred over the study period (50 years). Droughts have the lowest frequency of occurrence, having a value of 0.04, which describes two major droughts during the considered period of time from 1950–2020. Furthermore, the maximum value of flash floods, i.e., 0.84, shows that there were 42 floods. This annual frequency of natural hazards is assessed on the basis of the data available on the EM-DAT database.

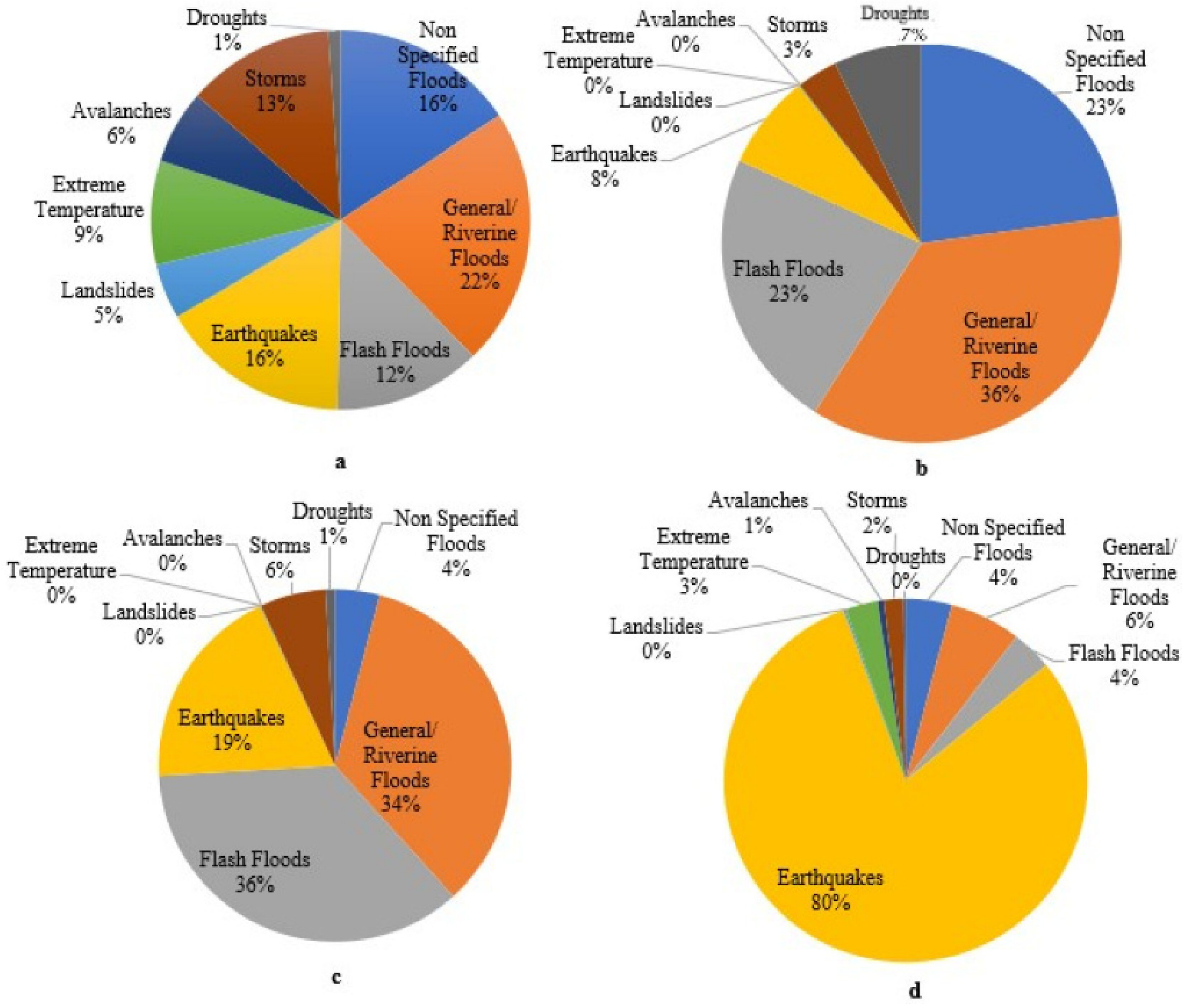

Figure 4. (**a**) Proportion of hazards number b/w 1970–2020 (total 191 events); (**b**) proportion of affected population by hazard type, 1970–2020 (total for 96.77 million people); (**c**) proportion of economic damages by hazard type, 1970–2020 (total of USD 28.45 billion); (**d**) proportion of fatalities by hazard type, 1970–2020 (total no. of fatalities: 99,367) (modified based on EM-DAT, 2021).

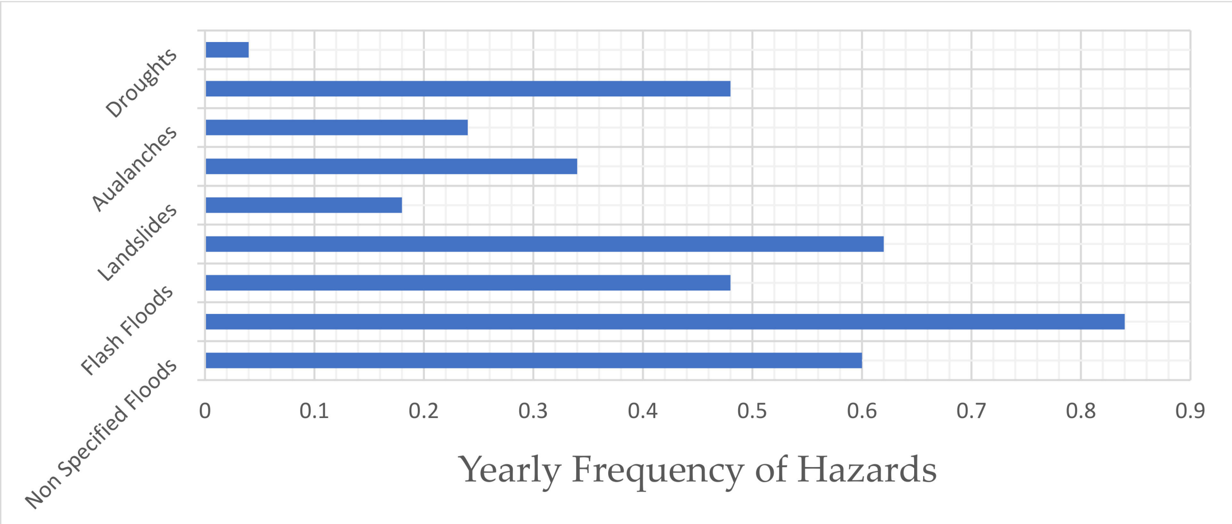

Figure 5. Yearly frequency of hazards, 1970–2020. Source: Authors based on EM-DAT, 2020 (Accessed on 19 May 2021).

Monsoon rains in 1950 wiped out approximately 2900 people around the country [25]. The River Ravi was flooded due to that monsoon season, and a number cities of Punjab Province and some parts of southern Sindh was severely damaged due to that natural hazard. Approximately 900,000 people were displaced due to the demolition of over 100,000 homes. The east Pakistan cyclone of 1970 [26,27] occurred on 12 November 1970, and the Bhola tropical cyclone hit east Pakistan (now Bangladesh). It was the worst tropical cyclone in history and one of the natural disasters that has wreaked havoc in modern times. The storm surge that engulfed much of the Ganges Delta's low-lying islands killed up to 500,000 people. A 6.2 Richter scale earthquake [28] struck the Hunza in the northern area of Pakistan and the Swat and Hazara districts of the North-West Frontier Province (now KPK) on 28 December 1974. A total of 5300 people were killed, 17,000 were injured, and 97,000 were forced to flee their homes. Rockfalls and landslides exacerbated the destruction. Most of the catastrophe took place in and around Pattan Village, about 160 km north of Islamabad. According to the national report, drought in 1998–2001 affected at least 1.2 million people in Baluchistan, and over 100 people died, mainly from dehydration. Hundreds of millions of animals died. The town of Nushki, near the Afghan border, was one of the worst-affected regions. The drought continued for more than ten months. A 7.6 Richter scale earthquake [29,30] struck Kashmir on the India–Pakistan boundary area and parts of north-western Pakistan on 8 October 2005. As per official estimates, at least 86,000 people lost their lives, and more than 3.3 million people [31] were displaced. The Neelum Valley, Bagh District, and Mansehra Division in Pakistan-administrated Kashmir were severely affected. As estimated, 380 lives were lost in Balochistan, 250 in Sindh, and 100 in Balochistan due to flash floods sparked by Cyclone Yemyin [32], which hit coastal areas in early July 2007. A total of 350,000 people was displaced, 1.5 million were impacted, and over two million animals were killed. A landslide in Attabad Village [33–35] in January 2010 in the Hunza-Nagar District in the country's far north killed 20 people and caused about 40 houses to slide into the Hunza River. The river was dammed by debris from the landslide [34], creating a massive lake that endangered downstream flood areas. By June, 20,000 people had been forced to flee their homes due to the formation of this lake. Thus far, 1600 people have died due to the 2010 floods [36,37], with over six million people afflicted. Pakistan requested foreign assistance to deal with the disaster. Despite massive relocation, the death toll is expected to increase as flooding spreads across Sindh's southern province, and the possibility of water-borne disease [38] outbreaks grows in many areas. Flooding caused by monsoon seasons brought severe damage to Pakistan in July 2015. According to the NDMA survey, 1.6 million people were affected. Pakistan has experienced the worst floods in its history as a result of the monsoon season. The Hindukush earthquake [39], which struck in October 2015, measured 8.1 on the Richter scale. As per the surveys report of NDMA, there were 272 fatalities, 2152 serious injuries, and 25,367 homes destroyed due to this earthquake. Table 1 describes the major disasters in Pakistan that happened between 1970 and 2020 in terms of deaths and economic damages.

Table 1. Most severe events with respect to economic loss and fatalities in Pakistan between 1970 and 2020.

Disaster	Date	Location	Fatalities	Est. Damage (Million USD)
Flash flood	27 July 2010	Almost all Pakistan and AJK	1985	9500
Riverine flood	August 2012	Punjab, Sindh, Baluchistan of Pakistan, and AJK	480	2500
Riverine flood	12 August 2011	Sindh Province of Pakistan	509	2500
Riverine flood	1 September 2009	Sialkot, Narowal, Lahore, Gujranwala, Mandi Bahauddin, Gujrat, Hafizabad, Jhelum, Jhang, Sargodha, Okara, and Attock Districts of Punjab Province, and AJK	255	2000
Storm (tropical cyclone)	26 June 2007	Balochistan, Sindh, and KPK Provinces	242	1620
Riverine flood	9 August 1992	Punjab Province of Pakistan and AJK	1334	1000
Flood	August 1973	Punjab, Sind	474	661.5
Flash flood	10 August 2007	Karachi Central, Karachi East, Karachi South, and Karachi West Districts (Sindh Province)	44	327
Drought	November 1999	Thar, Kohistan, Kachoo (Sindh Province), Lasbela, Kharan, Chaghi, Loralai, Zhob, Khuzdar, Kalat, Killa Saifullah, and Pshin Districts (Baluchistan Province)	143	247
Flash flood	22 July 2001	Islamabad, Rawalpindi District Punjab, and KPK provinces		246
Riverine flood	8 August 2008	Peshawar District KPK and Baluchistan Provinces	36	103
		Most severe events in respect to Fatalities		
Earthquake	8 October 2005	Northern areas of Pakistan and AJK	73,338	5200
Earthquake	28 December 1974	North Indus R. Valley, Balakot, and Patan	4700	32.55
Heat wave	12 June 2015	Sindh, Punjab Provinces of Pakistan	1229	
Flood	2 March 1998	Kech Valley, Baluchistan Province of Pakistan	1000	
Strom	14 November 1993	Keti Bandar, Hyderabad Sindh, Pakistan	609	
Riverine Flood	19 July 1995	Punjab, Sindh, Baluchistan, and KPK	600	376.25
Heat wave	01 June 1991	Jacobabab, Nawabsma, and Hyderabad (Sind Province)	523	
Riverine flood	2 February 2005	Different Districts of Baluchistan, KPK, and AJK	520	300
Flash flood	22 July 1995	Swat, Azad Kasmir, Dadu, Khuzdar, Dera Ismail Khan, Rawalpindi, and Khal Magsi	451	
Earthquake	24 September 2013	Awaran, Chagai, Gwadar, Kech, Khuzdar, Panjgur, and Districts of Baluchistan Province	399	100
Riverine flood	11 July 1994	Murree, Risalpur, Karachi, Pashawar, Lahore, Sialkot, Multan, Bahawalpur, Quetta, Rawalpindi, and Islamabad	316	92
Earthquake	31 January 1991	Malakand, Chitral, and Peshawar area	300	10

Source: Authors based on EM-DAT 2020 (Accessed on 19 May 2021).

4. Spatial Variations of Natural Hazards in Pakistan

Pakistan is exposed to a wide range of natural and manmade hazards. The wide range of natural hazards that Pakistan faces is due to the geological, topographic, and meteorological diversity of the country [40–42]. Natural disasters may occur on a variety of geographical and temporal dimensions. These occurrences vary greatly, ranging from a few seconds to several months [10]. Landslides, avalanches, and earthquake impacts are short occurrences that last only seconds to minutes. Other occurrences continue longer, ranging from a few hours to many days, such as heavy rain, flash floods, winter storms, debris flow, and earthquake. Cold and heat waves are long-term occurrences that can last anywhere from a few days to a few months [43]. The Indus Plain, which runs from north to south through Pakistan, covers more than 60% of the nation. The provinces of Baluchistan and Khyber Pakhtunkhwa are mountainous. Baluchistan is categorized as a semi-desert environment, with irrigated rice and wheat crops only present in the Indus Valley and lowlands and some northern woods. Pakistan is made up of high-contrast regions with drastic temperature differences across seasons and locations. Table 2 describes the natural hazards with their suspected prone regions with their spatial and temporal scale variations in Pakistan, given as below.

Table 2. Spatial-temporal characteristics of critical natural hazards in Pakistan (Data source: NDMA, PMD, PDMAs, SPARCO, and L. Rafiq and T. Blaschke 2012).

Natural Hazards	Hazard-Prone Region in Pakistan	Spatial Scale	Temporal Scale	Forecasting
Floods	Almost all of Pakistan and AJK	Several 10 km to several 1000 km	Few days to several months	Possible
Landslides	Northern areas, parts of the KPK province of Pakistan and AJK	Several 10 m to several 1000 m	Few minutes to hours and days	Not possible
Earthquakes	Himalayas and Karakorum ranges and parts of Hindu Kush in the north of Pakistan and AJK	Up to 500 km	Few seconds to minutes; aftershocks: several days	Not possible
Storms	Balochistan, Sindh, and KPK Provinces	Width of the wind field up to >1000 km	Few hours to several days	Possible
Droughts	All over Pakistan, especially in urban areas except some areas of Balochistan	Width of the droughts field up to >1000 km	Few days to several months	Possible
Extreme Temperature	All over Pakistan, especially in urban areas	Up to several 1000 km	Few days to several months	Possible

4.1. Floods

Pakistan is one of the top ten nations globally for frequent and severe global climate events such as floods, cyclones, heavy rains, excessive heat, etc. Pakistan is one of South Asia's most flood-prone countries. Pakistan is among the five South Asian countries with the most significant yearly average number of flood-affected individuals. For many years, the average world temperature has risen due to rise in atmospheric carbon dioxide and other greenhouse gas concentrations [44,45]. It has increased by 0.6 degrees Celsius during the previous century and is expected to rise by another 1.0 to 4.0 degrees Celsius through the end of the present century. Floods in several regions of Pakistan during the rainy season are the most recent severe climatic occurrences to affect Pakistan [46]. Since 2010, Pakistan has witnessed flooding virtually every year, resulting in massive losses of life and property. Climate change is also threatening the country's water security. Increasing temperatures in the country's mountainous ranges were expected to cause glacier melting, impacting the Indus River system's flows [47]. Floods occur virtually every year, destroying large areas of land and standing crops and affecting and displacing millions of people. It has been the country's most common natural danger since its founding in 1947. Flooding has become more common over the last few years as a result of global warming and fast climate change. Pakistan has seen several catastrophic flood disasters since its inception. The severity of flood hazards at the district level in Pakistan between 1970 and 2020 is shown in Figure 6. Figure 6 shows that southern part of Sindh and Punjab and some districts of KPK and Kashmir are very highly affected by the floods. This map was made on the basis of the occurrences of flood events in the past 50 years from 1970–2020. In addition, the districts of Washuk and Kharan of Baluchistan, most of districts Gilgit Biltistan, and some districts of Punjab, Sindh are found to be highly affected to floods, and most of the districts of Baluchistan and Punjab and some of the districts of KPK and Sindh were less affected by the floods.

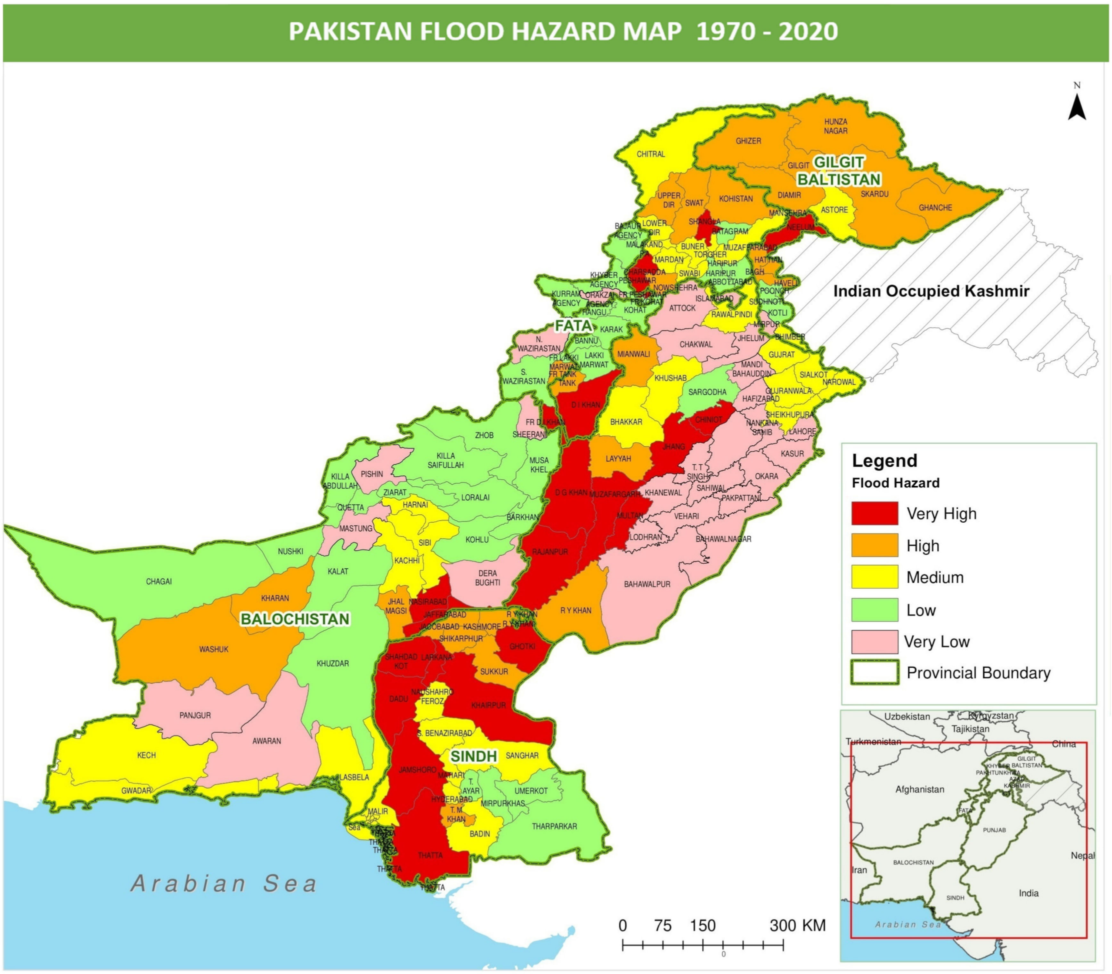

Figure 6. Pakistan Flood Hazard Map 1970–2020 showing intensity of flood at district level.

Riverine floods in the Indus River Basin, storm floods, glacial lake outburst floods (GLOFs) [48,49], and flash flooding linked with cyclone activity are the four primary types of floods that affect Pakistan regularly. Floods caused by rivers primarily occur in the Indus River Basin and inundate floodplains along major rivers (Indus, Jhelum, Chenab, Ravi, Sutlej, and Kabul). Such riverine floods are particularly severe in Punjab and Sindh Provinces, where they have recently inflicted exceptionally significant damages almost yearly. Agriculture is particularly affected in this area by damage to standing kharif crops. However, in certain situations, the flooded areas do not dry out in time, causing rabi crops planting to be hampered. Water spills do not return to the main river channel in the lower Indus River (Sindh province), which runs at a higher elevation than the neighboring plains. The 2010 floods, for example, were enormous, impacting virtually all of Pakistan. The damage was estimated to be worth USD 9.7 billion, as shown in Figure 7. Agriculture and cattle were severely affected, and the water also destroyed many homes and damaged roads and irrigation systems. According to Pakistani officials, more than 1700 people died as a result of this flooding, and more than 20 million people were affected [36,50,51]. The number of people displaced by the flooding outnumbered those displaced by the 2004 Indian Ocean tsunami, the 2005 Kashmir earthquake, and the 2010 Haiti earthquake combined. In Sindh Province alone, the 2011 floods impacted another 8.9 million people and damaged 1.5 million houses in 37,000 communities [52]. Flash floods are caused by highly localized connective rainfall or cloudbursts that occur in small- to medium-sized basins in hilly terrains and at the foot of mountains and hills. Such occurrences, which are common in Baluchistan, Khyber Pakhtunkhwa, and the northern provinces, can cause significant damage to crops and animals and substantially influence urban centers. The Nullah Lai, for example, overflowed and swamped surrounding buildings, bridges, and highways in July 2001 as a result of prolonged severe rains. According to government estimates, at least 10 individuals were killed, 800 homes were demolished, and 1069 homes were damaged in Islamabad. Twenty-six people died, and hundreds of houses were destroyed in Karachi in 2009. The overall damages attributable to significant flood occurrences in Pakistan total to more than USD 38.171 billion [53] during the last 67 years (1953 to 2020), with 50 percent of total direct losses occurring in the last decade after 2010. Figure 7 shows the districts that were affected by 2010 floods. Three provinces, namely Punjab, Sindh, and KPK, were severely affected by this flood. About 84 districts out 154 districts of Pakistan were affected due to this flood. Most of the districts around the River Sindh were severely affected by this flood.

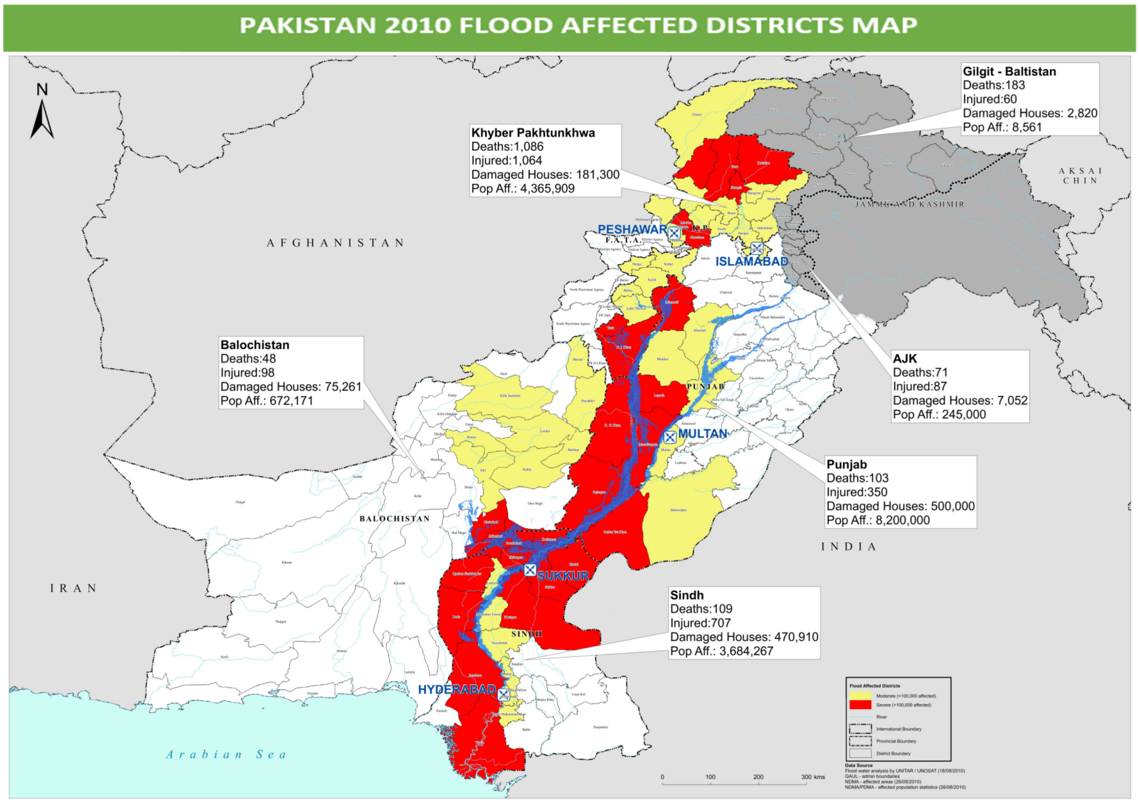

Figure 7. Map showing number of deaths, injuries, damaged homes, and affected population by province and region as of 30 August 2010. Source: 2010 Flood water analysis by OCHA [54].

4.2. Drought

Drought is one of the probable repercussions of global warming, resulting in a significant drop in water table levels and the drying up of wetlands. Pakistan is one of the nations predicted to be impacted the worst by global warming [55,56]. Drought has wreaked havoc on districts across Pakistan's southern and eastern regions. With low rainfall and severe temperature fluctuations, 60% of the country is categorized as semi-arid to dry, most notably in Baluchistan, Sindh, and the southern portion of Punjab. Arid areas receive less than 200 mm of rain per year, making them particularly sensitive to even minor changes in rainfall patterns or the over use of the limited water supply. The most vulnerable regions endure a two- or three-year drought in each decade. Climate change is susceptible in areas with no surface water and low or brackish groundwater. Drought is a complicated phenomenon that is intimately tied to its socio-economic environment [57,58]. It is generally associated with poverty and non-adaptive land, water, and agricultural activities, resulting in groundwater overexploitation, deforestation, and depletion of grazing areas.

Drought has a variety of acute and long-term consequences for the ecosystem of Pakistan's impacted areas. In most parts of Pakistan, agricultural production is heavily reliant on rainfall. Drought has been handled in most parts of Pakistan with the help of its vast and unique canal network. However, drought continues to be a problem in the places where there are no irrigation networks. Baluchistan Province, for example, is exceedingly arid, and there are no proper systems of canal networks to deal with this network. Almost half of Baluchistan receives less than 125 mm of rain per year, and the remaining areas receive little more than 250 mm of rain [59]. Droughts are also severe and common in the Thar Desert, which lies beyond the Sutlej and Indus Rivers' left-bank floodplains [60,61]. Droughts were so bad in 2000 and 2002 that people's livelihoods were devastated. In the Baluchistan and Sindh Provinces, over 3.3 million people were impacted, thousands of people were forced to move, and millions of cattle were destroyed [62,63]. According to one estimate, 15 million cattle died, resulting in USD 2.5 billion in economic damages. Because of the severe drought in 2001, the economic growth rate was lowered from an average of 6% to only 2.6 percent. Severe food and water shortages have been reported in the Tharparkar area of Pakistan's Sindh Province since the beginning of March 2014. Several children have allegedly died of starvation, prompting the regional administration to proclaim a state of emergency [64]. Rainfall was 30% below average between March 2013 and February 2014. However, other observers believe that the recent deaths are the consequence of a combination of causes, including chronic poverty aggravated by the drought and a disease epidemic that killed animals. Figure 8 map illustrates the situation of droughts in all districts of Pakistan. The drought situation map of Pakistan was developed based on the water-balance technique used to identify drought-prone districts. Any area receiving annual rainfall less than the mean annual rainfall for the study period of 1970–2020 is considered to be experiencing meteorological drought.

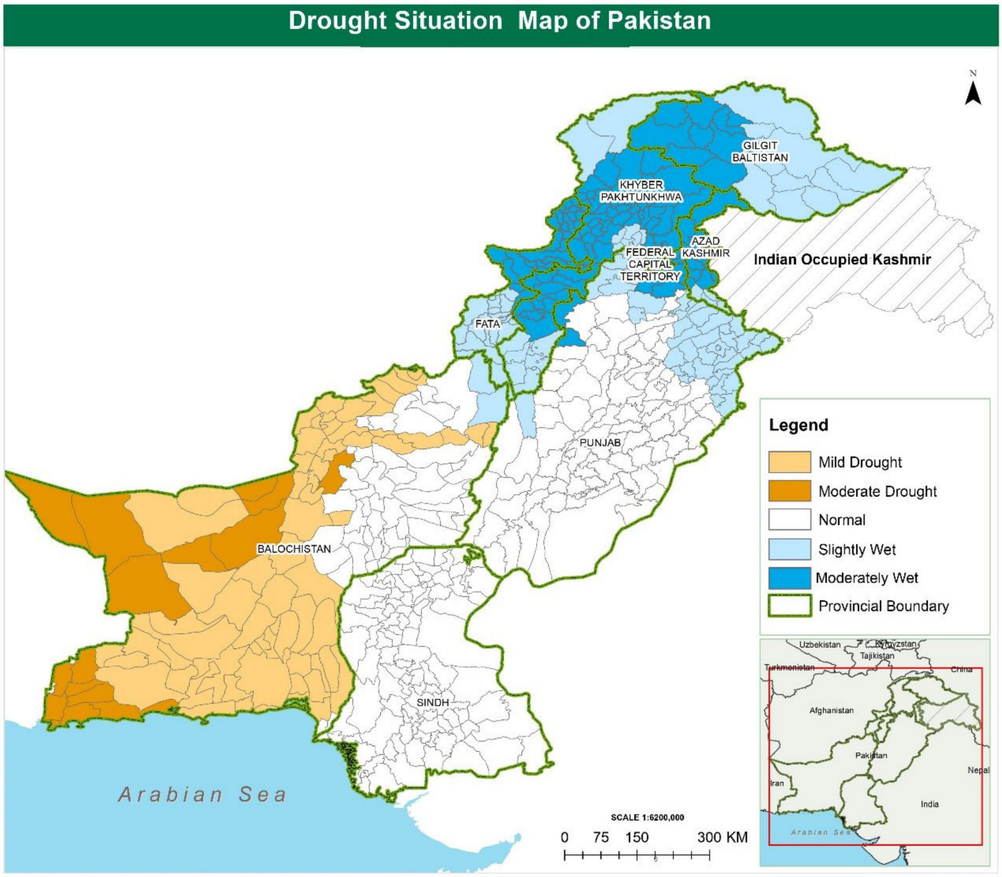

Figure 8. Illustration of the situation of droughts in all Pakistani districts.

4.3. Cyclones

There were 22 cyclones recorded in Pakistan Science from 1970–2020 [65]. While cyclones are common in the Arabian Sea, cyclones may cause severe damage to low-lying coastal areas. Typhoons primarily strike Sindh's coast rather than Baluchistan's. Cyclone 2A, a category three storm, wreaked havoc on the coastal regions of Badin and Thatta [66] in 1999, destroying 73 villages and displacing over 600,000 people. Property and agricultural disasters of up to USD 12.5 million have also been reported. According to the report of World Disaster [67], cyclones often batter Pakistan's 960 km long coastal strip, inflicting extensive death and property destruction, particularly in the coastal districts of Gawadar, Badin, and Thatta.

4.4. Earthquakes

Earthquakes occur when the ground slips along a fault plane, causing ground shaking. Friction at the margins of active tectonic plates causes them to become stuck, accumulating tensions along the edges [68]. Ground shaking caused by earthquakes is a major contributor to infrastructure damage and the occurrence of secondary hazards such as landslides, flooding, tsunami, fire, liquefaction, and ground deformation [69].

With active Himalayan mountains in the north, Hindu Kush mountain ranges in the northwest, and Suleiman mountain ranges in the southwest, Pakistan is one of the world's most seismically active areas [70,71]. The Indian tectonic plate, sub ducting beneath the Eurasian continent at a 31 mm/year pace, caused a high seismic hazard in Pakistan and the neighboring Indian and Afghan territories. The formation of the world's tallest mountain ranges, the Karakoram, Himalaya, and Hindu Kush mountain ranges, originated from the collision of the Indian and Eurasian plates [72]. The mountain ranges of the Hindu Kush, Karakorum, and Kohe-Suleiman are particularly susceptible, and the resultant destruction can be enormous due to poor building construction [73]. The most recent catastrophic earthquake occurred in 2005 [74]. Over 85,000 people died, 138,000 were wounded, and 3.3 million people were displaced as a result of the disaster [75]. Hospitals, schools, and emergency services such as the police and armed forces were also shut down. There was too little infrastructure, and communication was severely hampered [76]. Due to the low quality and limited seismic resistance of structures, small and frequent earthquakes also inflict significant damage. A 6.4 magnitude earthquake struck Quetta and the adjacent regions on 28 October 2008, killing 160 people and wounding 370 others in Baluchistan [77]. As a consequence of the earthquake, many homes were damaged. The quake's epicenter was 60 km northeast of Quetta. An earthquake of a magnitude of 7.2 struck Balochistan on 18 January 2011, killing numerous people and destroying 200 structures [78]. The quake was 50 km west of Dalbandin's epicenter. On 16 April 2013, a powerful earthquake of a magnitude of 7.7 struck Quetta, causing vibrations throughout Pakistan, Iran, India, and several Gulf nations [79]. The earthquake's epicenter was in Iran's Sarawan region, near the Pakistan–Iran border. According to reports, around 34 people were killed, 80 were wounded, and 10,000 homes were destroyed as a consequence of the quake. A 7.5 magnitude earthquake hit Pakistan's main cities on 25 October 2015, including the northern regions on Sunday, killing at least 200 people and injuring over 1000 more due to building collapses, landslides, and other quake-related events [80]. On 24 September 2019, a magnitude 5.8 earthquake struck Pakistan-administrated Kashmir and parts of Punjab Province [81], killing at least 37 people, including women and children, and wounding over 500 others, many of whom were severely injured. The quake hit Azad Jammu and Kashmir's Mirpur area in the south. Hundreds of homes were partly demolished, roads were damaged, and the region's hospitals were overwhelmed with casualties. Figure 9 illustrates a map of earthquake severity levels of all Pakistani districts. Most of the northern districts of Pakistan and north-western districts of Balochistan Province are vulnerable to earthquakes.

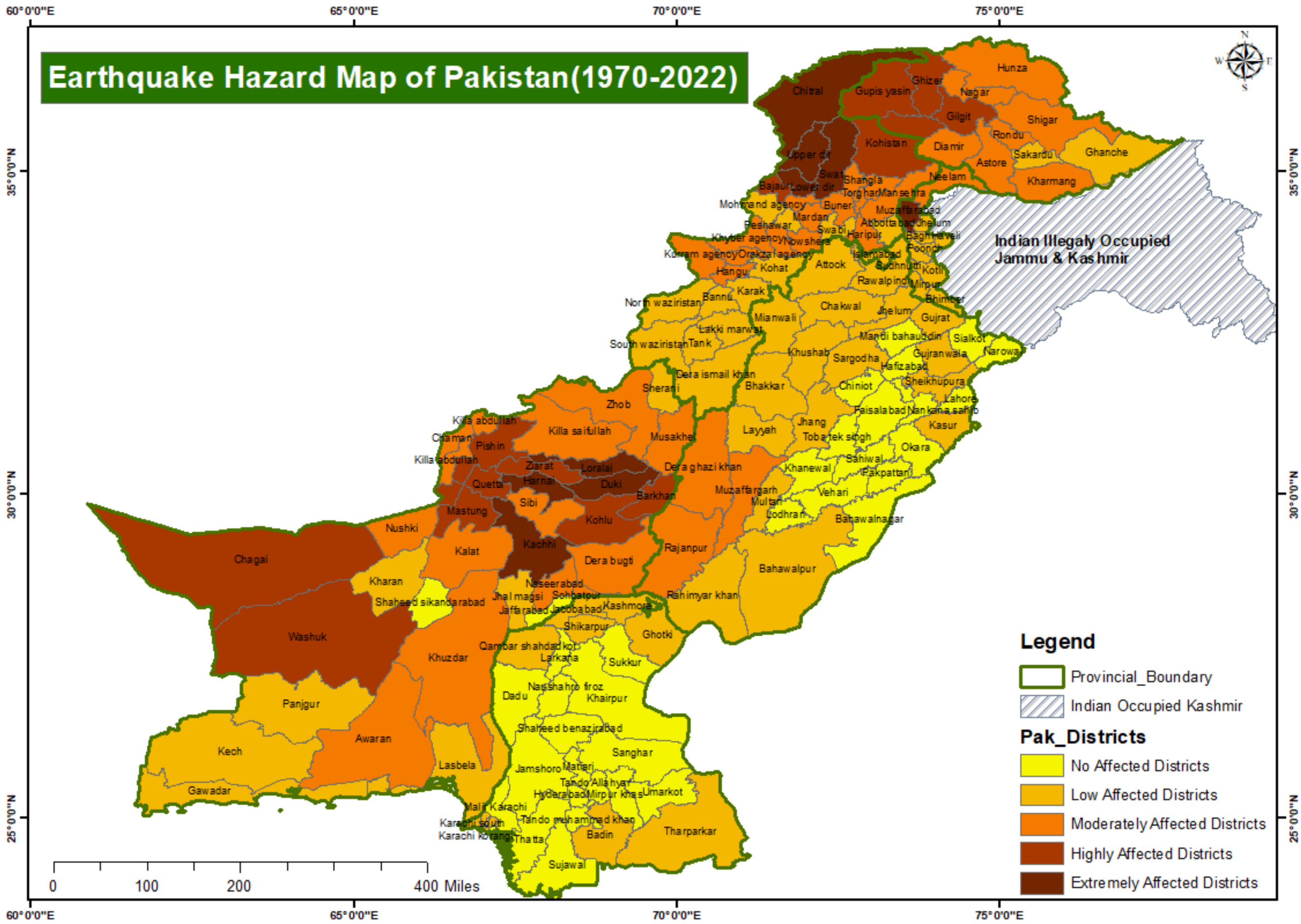

Figure 9. Pakistan Earthquake Hazard Map 1970–2020 showing the severity of earthquakes at district level.

4.5. Landslide

The term landslide has been used to describe the movement of earth material of varied sizes and origins for a long time. Landslides may vary from minor weather zone disturbances to the deep-rooted displacement of massive rock slab [82]. Their effect will be determined by their kind, depth of material, the pace of movement, environmental stressors, the volume of material invaded, and closeness to that slide, among other factors [83]. A large portion of the country is covered by steep and geomorphologically active mountains, apart from the huge alluvial Indus Basin, which is prone to periodic catastrophic floods and desertification (including waterlogging) [84]. In Pakistan, most landslides were discovered, recorded, and examined for analysis and statistical distribution. A huge landslide swept down the slopes of the isolated Hunza Valley in the Gilgit Baltistan region of northern Pakistan on 4 January 2010 [34,35]. Twenty people were killed, and twenty-six houses were destroyed when the town of Attabad was buried. The Hunza River was blocked by the landslide, and the newly created lake's quickly increasing waters endangered communities even below and above the reservoir [85].

Several studies and methods have been formulated to predict slope stability in terms of safety factors [86–90]. Landslides and mass wasting frequently occur in the country's hilly north and northwest. Landslides and slope collapses are frequent in Pakistan's mountainous regions, especially during the monsoon season [91]. These steep regions are densely populated, putting enormous strain on natural resources, especially land resources. In Pakistan, the Himalayan Region has the most slide-affected regions. In the steep regions of the north and northwest regions, deforestation has increased soil creep. Landslides occur along roads constructed in mountain terrains such as the Muree Hills, Pir Punjal, and the

Hindu Kush during the rainy season [92]. In Pakistan, no systematic and comprehensive research has been conducted to assess the issue's scope. Figure 10 depicts a map showing the severity of landslides in Pakistan at the district level. The authors appreciate the reviewer's remarks. The landslide zoning map is based on the number of occurrences of landslides in the past 50 years. The districts where landslides occur frequently are classified as severely vulnerable to landslides, while the districts where low landslides occur rarely are termed as less severe landslides. According to the map, the northern districts of Pakistan are highly vulnerable to the landslides.

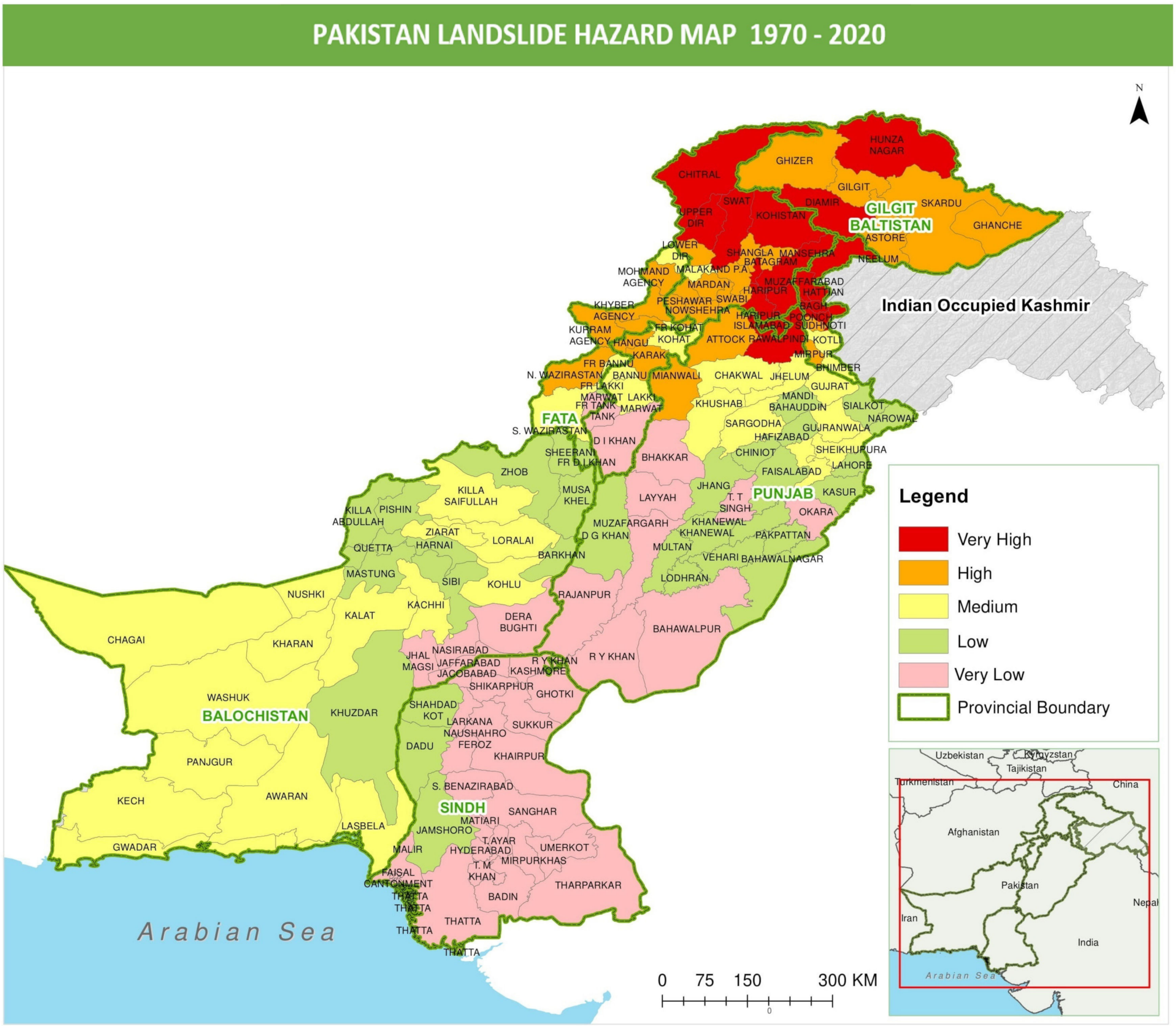

Figure 10. Pakistan Landslide Hazard Map 1970–2020 showing the intensity of landslides at district level.

Natural occurrences such as earthquakes and rains contribute to the landslide issue. In Pakistan, improper infrastructure projects, housing, deforestation, overgrazing, and insufficient agricultural techniques are the leading causes of slope destabilization, resulting in landslides [93]. These landslides not only endanger lives, property, and the environment but also result in significant economic losses owing to the disruption of communication and infrastructure networks.

4.6. Heatwave

Heatwaves are a common natural climatic hazard that has noticeable consequences for both people and biophysical systems. Worldwide, the frequency of reported hot days has been three times greater than recorded cold days during the last decade. A heat wave is a prolonged stretch of hot weather that is unusually hot for the time of year. A heatwave is also a long stretch of hot weather often accompanied by high humidity [94]. The World Meteorological Organization (WMO) defines a heat wave as "when the daily maximum temperature for more than five consecutive days surpasses the average maximum temperature by 5 degrees Celsius over the usual temperature of a region". Heatwaves are frequent in Pakistan's plains during the months leading up to the monsoon season (May and June) [95].

Heat wave occurrences may be divided into two categories based on their physical characteristics: dry and wet heat waves. Dry heat waves are characterized by dry weather, clear sky, and high solar radiation inputs. Windy conditions may also be present, which may exacerbate heat stress. Dry heat waves are most common in continental or Mediterranean climates or where the air is heated adiabatically [96,97]. On the other hand, moist heat waves are marked by extremely hot, uncomfortable, humid circumstances throughout the day and night, frequently with nighttime cloud cover, which inhibits the escape of heat collected during the day and therefore offers no respite at night [98]. Heat waves such as these are common in temperate and marine climates in the mid-latitudes, and they may be indigenous in certain areas. Heat waves are more likely to occur in places with a highly changeable summer climate or a clear hot season as a consequence of these features. They may, therefore, arise from various large-scale meteorological circumstances and climate-related mechanical processes.

In June 2015, Pakistan was hit by a severe heat wave, resulting in many deaths, particularly in Karachi [99]. From the 17th to the 24th of June, most of the country was engulfed in a heat wave. High temperatures were reported in the southern regions of the nation on 20 June. Temperatures varied from 49 degrees Celsius in Larkana and Sibi to 45 degrees Celsius in Karachi [100,101]. Multan in southern Punjab reported a temperature of 40 degrees Celsius, while Sibi and Turbat in Balochistan Province saw temperatures of 49 degrees Celsius. The regions of Pakistan where a heat wave with maximum temperatures of more than 45 °C swept over included much of southern Punjab, northern and western Sindh, as well as Karachi [102]. Due to the heatwave, heatstroke-related deaths were recorded in Karachi, Hyderabad, Noshero Feroz, Dadu, Badin, Thatta, and Tharparkar.

As mentioned above, Pakistan is having trouble with the average temperature rising as a result of climate change. In Pakistan, heatwaves are increasingly more frequent than ever. Figure 11 demonstrates the prevalence of heatwaves in various Sindh districts as well as the majority of south Punjab districts. Heatwaves also occur in Karachi, the largest metropolis in Pakistan. Baluchistan's District Chaghi, Kech, was severely impacted by previous heatwaves. The impact of urban heat waves has increased in many Pakistani cities due to fast and unsustainable growth. In Pakistan, deforestation is a significant contributor to heatwaves. A significant contributor to Pakistan's rising trend of heatwaves is also the trend of global climate change.

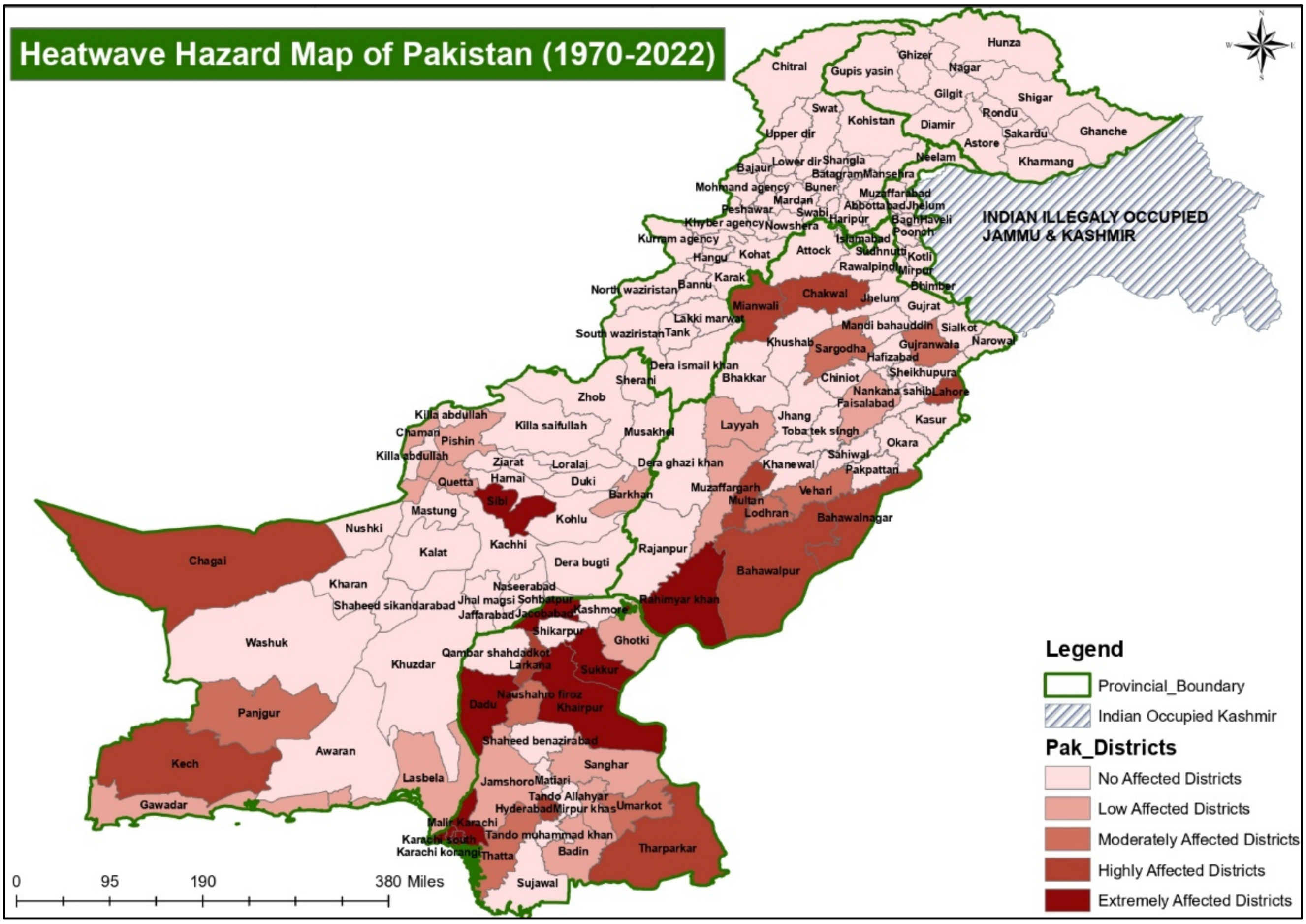

Figure 11. Pakistan Landslide Hazard Map 1970–2020 showing the intensity of heatwaves at district level.

4.7. Glacial Lake Outburst Floods (GLOFs)

Glacial lake outburst flood (GLOF) is another frequent natural disaster. Pakistan's Karakoram Himalayas are experiencing a phenomenon of GLOF [103]. In the upper catchments of Pakistan's main rivers, there are 2600 glacial lakes, all of which are proglacial. These glacial lakes may jeopardize all development projects in the immediate downstream region of the lakes, including different hydroelectric power projects, bridges, highways, and low-lying population concentrations. In 2008, five GLOF incidents were recorded from the Hunza Valley's Gojal hamlet, inflicting significant damage to the infrastructure of these regions. Although the local community has made effective small-scale measures to drain a few lakes in the Ghulkin Glacier, Pakistan currently lacks a comprehensive mitigation scheme to minimize the danger presented by the GLOF hazard [48]. The GLOF event may not always directly impact human settlements, but it may create secondary dangers in certain instances, such as in the case of Pingal Lake in Gupis Tehsil.

Many glacial lakes are created along the lateral moraines along the glacier's edges. The lateral moraines form a linear high that usually runs parallel to the glacial drift direction. This forms a glacial lake by creating a linear depression between the lateral moraine and the projecting boulders. Global warming is the source of heat in the Himalayas, Karakoram, and Hindukush, amplifying glacier melting, lake creation, and outburst [104]. A debacle, jokulhlaup, alluvion, or glacial lake outburst flood are all names used to describe the abrupt release of high water flow from glaciers. Because there are numerous glacial lakes in their catchment regions, the areas of Kalam, Bahrain, and Madyan in Swat Valley are susceptible. They may be affected by a GLOF event in the future. Kalam is located at the confluence of five main tributaries of streams that flow straight into over 15 glacial lakes, including Kandol Lake [105].

Similarly, Bahrain is vulnerable to more than ten glacial lakes, which may wreak havoc on the city of Bahrain, which is located on the Bahrain River's debris fan. Shiringal is the other populated area of the Swat Valley, with nine glacial lakes, including a couple of lakes in the catchment area of the nearby Barikot Village. In Chitral, a few GLOF events have been reported from Yarkhun Lasht or Yarkhun Valley, including Boni, which may be linked to the glacial lakes of the Broghil area [106]. The intensity of GLOF at the district levels in Pakistan is shown in Figure 12. Any GLOF event may be triggered by several causes, including seismic activity, volcanic activity, landslides, rockfall, etc.

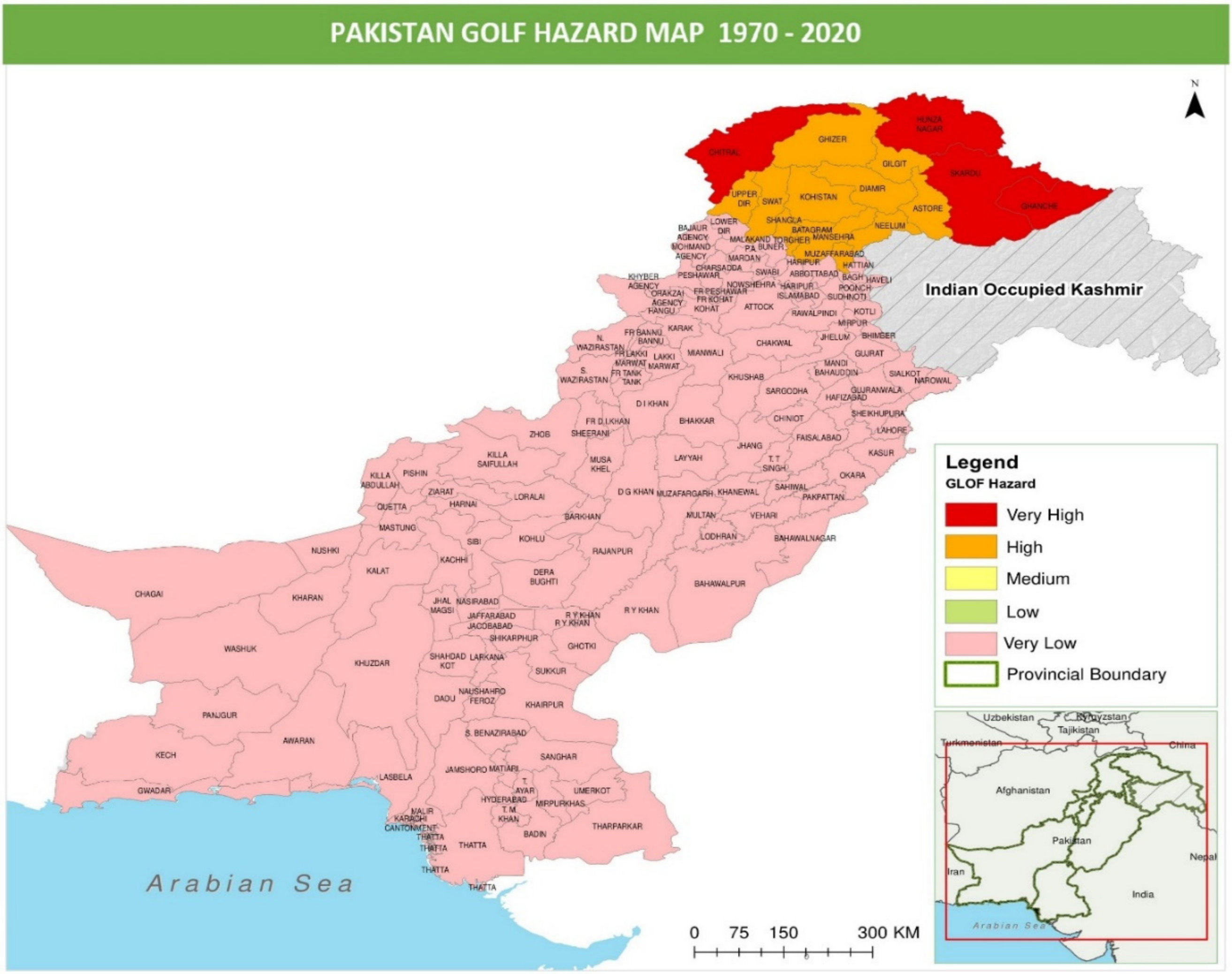

Figure 12. Pakistan GLOF Hazard Map 1970–2020 showing the intensity of GLOF at district level.

5. Risk Analysis and Management

Within the past several decades, the development of a risk prevention strategy has been advocated for effective and successful risk reduction. A strategy such as this should be built on a thorough risk assessment and evaluation [107] of possible risk reduction strategies. With the increasing frequency and severity of catastrophe occurrences, emergency response capability and more robust management measures are required, particularly for recurring hazards [108–110] such as floods, earthquakes, and landslides. Figure 13 depicts the trend of disasters in Pakistan from 1970 to 2020. According to this figure, it can be observed that the trend of occurrences of natural hazards is continuously increasing with each succeeding year. Furthermore, activities should be highlighted for disaster risk reduction by developing coherent plans and separating tasks and roles between multi-tiered disaster risk analysis, management structures, and relevant authorities at various levels. The National Disaster Management Act 2010 governs Pakistan's national disaster management system [111]. In a country such as Pakistan, where risk management plans are created at the national, state, and local levels as well as by various sectors of government, companies, the military, and civil society in general, multiple levels of decision making are required. Pakistan's hazard risk assessment was conducted in 2011, serving as a national baseline document for risk-sensitive planning at the national, provincial, and municipal levels. However, additional effort is required in Pakistan to create a comprehensive knowledge of hazard and catastrophe risks [112]. The disaster risk management cycle is shown in Figure 14, including catastrophe mitigation and preparation and disaster response and recovery. Mitigation and preparation involve the pre-hazard measurements or capacity building to face a hazard and to avoid its severe consequences. On the other hand, after the occurrence of a natural hazard event, the phases of response and recovery involve reconstruction and rehabilitation works. In addition, a lack of critical risk data, such as baseline data and risk profiles for various geographic regions, is seen as a missing link in the creation of risk-informed holistic disaster risk management (DRM) policies [10].

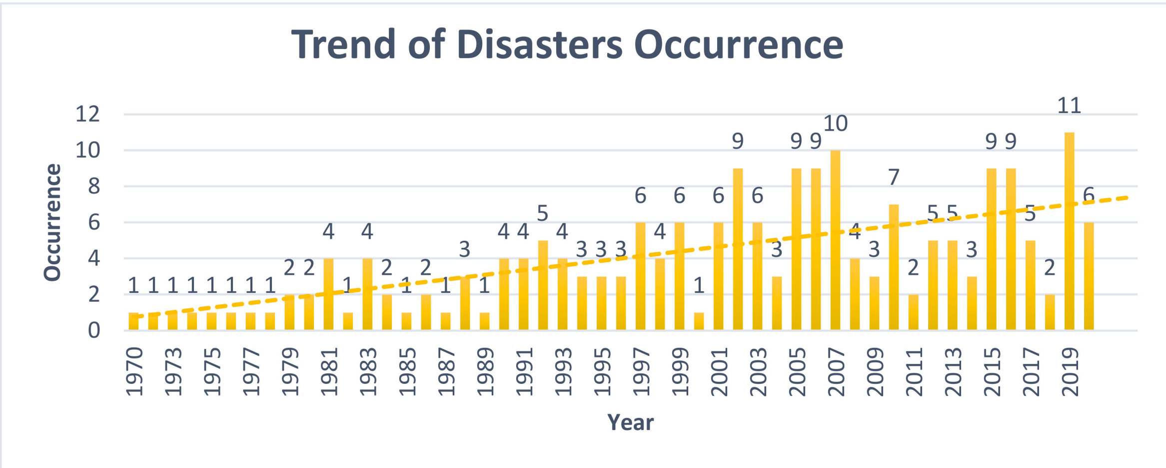

Figure 13. Trend of Disasters Occurrence in Pakistan from 1970–2020; Source: EM-DAT 2020, NDMA. Note: Disasters include those triggered by meteorological, climatological, hydrological, and geophysical forces.

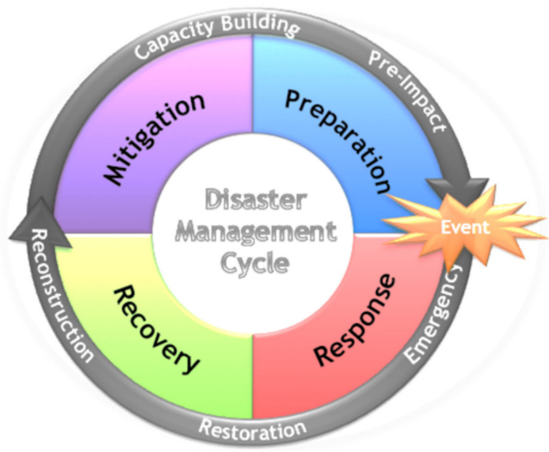

Figure 14. The Disaster Risk Management Cycle.

5.1. Risk Analysis

Several risk studies have been conducted in Pakistan on various geographic scales for various areas and hazards, including assessments of hazard, exposure, and vulnerability [113–116]. The below-mentioned three fundamental questions must be answered for any risk assessment and analysis: (i) What might happen? (ii) How will it probably occur? (iii) What are the ramifications if it does occur? Hazard is generally defined in the natural sciences as the chance of potentially harmful occurrences and their intensities exceeding a certain threshold. The quantity or value of components at risk as well as their attributes define exposure. Vulnerability analysis examines how and to what degree the components in question may be harmed.

To address question (i) from the perspective of a disaster risk analysis, all potential natural disasters in the research region must be identified and considered [117–120]. The particular context of the research region and the study's goal determine which risks are important. In the hazard risk analysis and maps guidelines, Pakistan's national disaster management authority (NDMA) suggests a list of criteria [121,122] for determining hazards at the national level. Comparative risk assessments focus on the likelihood of potentially harmful natural occurrences occurring for all listed risks, and their connections are required to answer question (ii). To address issue (iii), all risk assessments in the multi-risk methodology [123–126] should employ the same coherence exposures dataset of components at risk, allowing for a consistent evaluation of risks from various hazards. Risk assessments and impact estimates for all events must be conducted on this criterion. In reality, just a few studies include numerous risks and even reflect the goal of including all pertinent dangers in the research region [127]. This is particularly true in scientific research, and various factors, including the division of disciplines, have resulted in different terminologies, definitions, methods, and so on. The following characteristics must be consistent throughout all-natural disaster risk assessments to compare them:

1. Analyses must be carried out in the same research area, at the same geographical scales, and with the same degree of detail; i.e., the base and level of aggregation must be the same; for example, losses may be collected by the city municipality each year;
2. The same effects must be assessed, such as direct financial loss to residential buildings, business interruption losses, fatalities, and the impacted people;
3. Damage must be represented in the same way, for example, absolute damage in money value, proportional damage in percentages, damage per population, and so forth;
4. Risk assessments must be conducted using the same exposures dataset. To evaluate the data results of risk assessments, the anticipated risk indicators, such as risk curves, anticipated yearly damage, etc., must be the same;

After Pakistan's independence in 1947, because of the apparent lack of ability, expertise, and resources, a significant quantity of laws and regulations were taken into account in the new country as a legacy of colonialism without being adapted to the new circumstances. The natural disaster planning process was no exception in this regard. Furthermore, strategies were primarily focused on coping with a single kind of hazard, namely flooding, attributed to the reality that it was recurring, impacting the largest population and the country's populated regions and farmlands. Risk acceptance was still the norm at the time, with little or no regard for improving the impacted people's lives. From 1947 to 2014, Pakistan lost USD 39 billion as a result of 25 severe flooding disasters. Figure 15 illustrates the flooding hazard risk assessment of Pakistan at the union council and district level and damages to infrastructures by provinces. Millions of Pakistanis are exposed to environmental changes [128] because they live near flood plains, the coast, or in the northern areas, which are susceptible to landslides and seismicity. However, the majority of the population has a common factor: groundwater is one of Pakistan's most important resources [129].

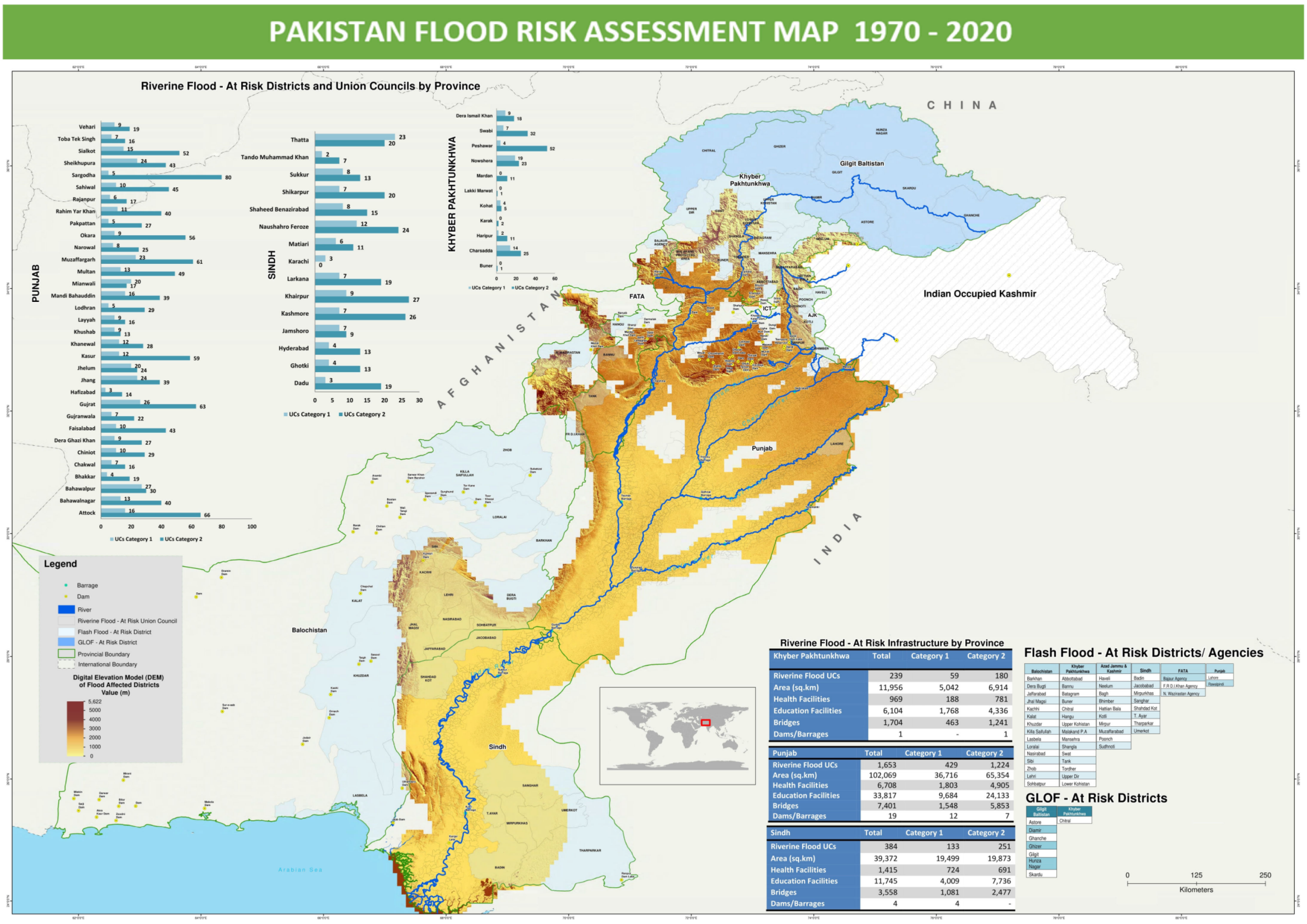

Figure 15. Flood Hazard Risk Assessment of Pakistan at union council and district level and damages to infrastructures by provinces.

Droughts may become more common due to rising temperatures and reduced rainfall as a result of climate change and changing rainfall patterns. Pakistan has been labeled as one of the most water-stressed countries [130–132], with per capita water availability dropping nearly six-fold between 1947 and 2013. Climate change and diminishing water supplies are significant concerns in rural areas, where farming is a livelihood for many people. The Pakistan federal government has continuously emphasized flood protection and management [133–136], but the country has created a poor and ineffective command and control structure for managing flood crises. Prior to 2005, there were approximately 27 distinct federal and provincial bodies ostensibly engaged in hazard response and humanitarian relief management, with no clear delineation of their duties and responsibilities at various stages of disaster management. There was an overall lack of coherence in strategy for comprehending and predicting hazards and risks, attempting to address underlying causes and vulnerabilities, and handling comprehensive approaches to emergencies [137–140], building infrastructure facilities, and helping to promote a culture of safety and inventiveness in the apparent lack of a pivotal responsible body. Figure 16 illustrates the pattern of the risk analysis map at the district level of Pakistan owing to multi-natural hazards. Moreover, a summary of Pakistan's risk analysis plans and policies from 1947 to 2020 is shown in Figure 17.

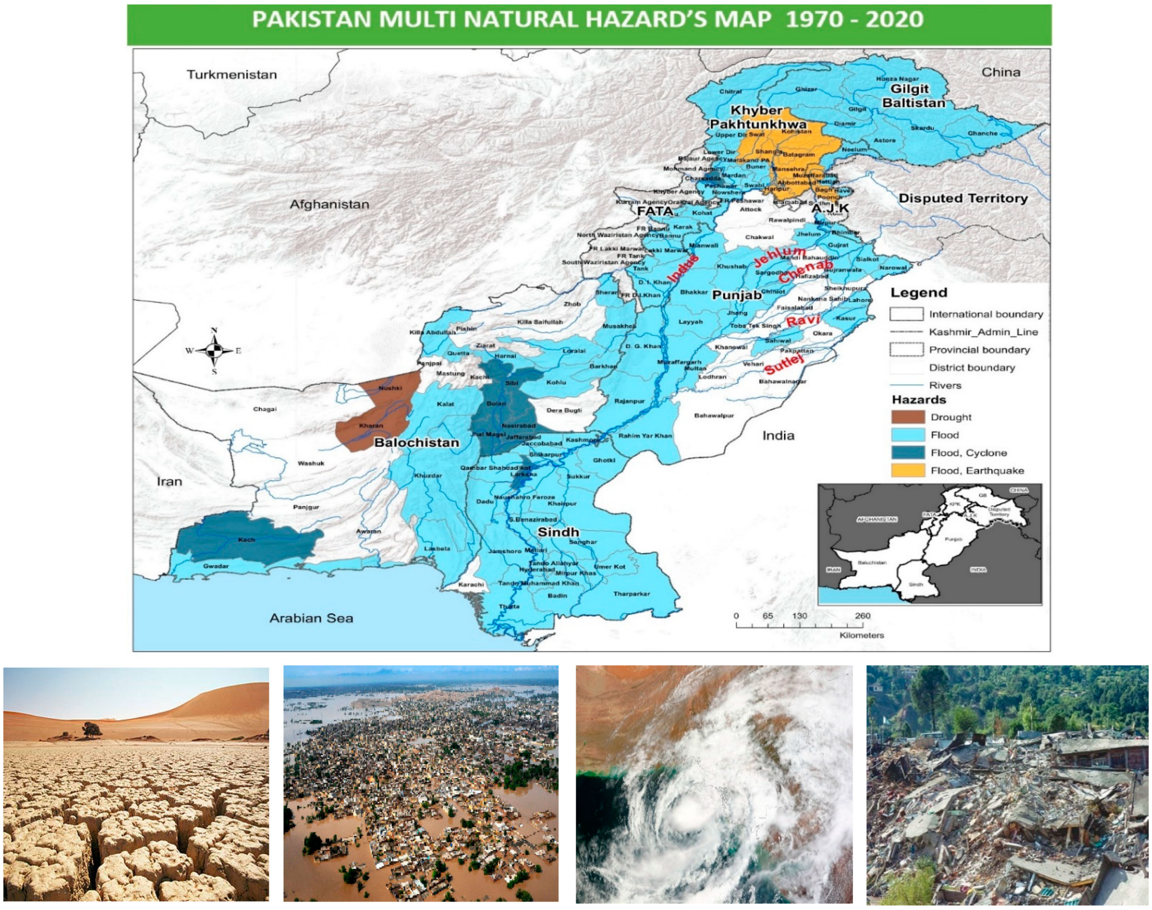

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Figure 16. The pattern of total Risk from Multi Natural Hazards in Pakistan at the district level and images of natural hazards and extreme events in the study area: (**a**) drought of 1998–2002, considered the worst in 50 years in Baluchistan, Pakistan; (**b**) damages of 2010 flooding in Pakistan; (**c**) 2010 cyclone in Pakistan; and (**d**) damages of the 8 October 2005 earthquake, AJK, Pakistan.

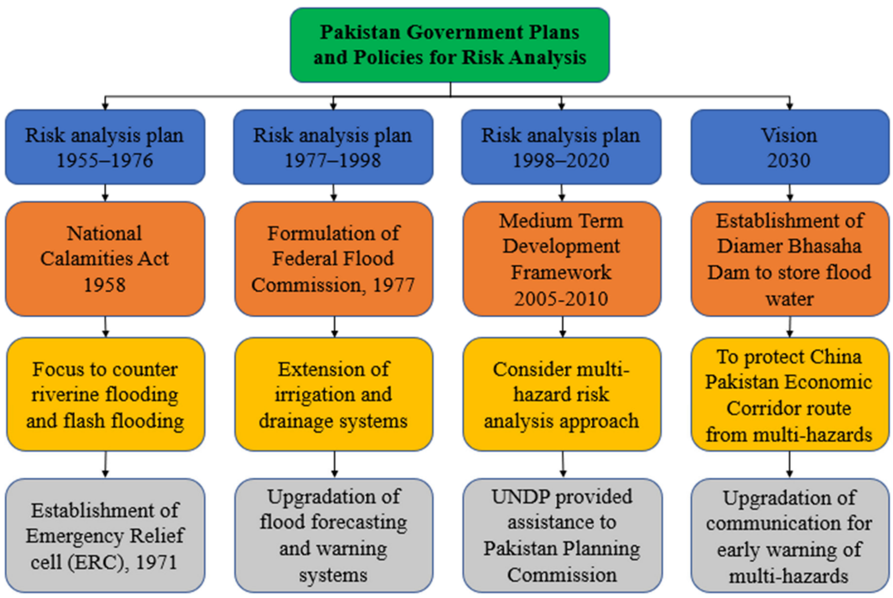

Figure 17. Risk Analysis Overview chart of the Pakistan System.

5.2. Risk Management

All essential natural disasters should be mitigated via integrated risk management [141–143]. It takes preventive, preparatory, and planning actions into account. By using proper land-use plans or structural strategies, dykes, retaining basins, and dams are preventive attempts to avert hazards such as floods [144–146]. Precaution aims to reduce harm via a combination of individual and public actions occasionally enacted through laws or regulations. Preparation aims to control and manage the disaster. Forecasting and early warning [147–149] are crucial components of a successful reaction. Aside from technical elements, risk reduction requires good communication to increase risk awareness [150,151] since implementing suitable and effective remedies often necessitates self-reliance on the part of the possibly impacted community. The composition of various management measures that make up an effective risk management plan is determined by the relevant risks as well as other physical and socio-economic factors, which are summarized in Table 3.

Table 3. Indication of relevant risk management measures for floods, earthquakes, landslides, droughts, storms, and extreme temperatures in Pakistan.

Actors	Measures	Floods	Earthquake	Landslides	Droughts	Heat Waves
Spatial Planning	Keeping hazard-prone areas free of further development	+	+	+	+	+
	Allocation of structural measures, e.g., retaining structures	**	+	*	+	+
	Precautionary land use, e.g., supporting natural water retention, designing fresh air corridors in cities	*	+	*	+	*
Sectoral Planning	Structural measures, e.g., retaining structures	**	+	*	+	+
	Increasing risk awareness	**	(*)	*	*	**
Building Regulation	Hazard-adapted building construction, building precaution	*	*	(*)	+	+
Private Households/Companies	Private precautions, including building precaution	**	*	**	+	+
	Preparative measures, e.g., emergencyplans and exercises	**	(*)	*	+	*
	Risk precaution, e.g., signing an elementary insurance contract	**	*	*	+	+
Emergency Response	Early warning systems	**	+	(*)	**	**

**, most appropriate; *, appropriate; (*), partly appropriate; +, not appropriate/not applicable.

Because of the geographical viewpoint, spatial planning may play a significant part in risk management [152,153]. It necessitates a multi-hazard strategy that analyzes all relevant hazards affecting a specific region and the vulnerabilities of that area. Because spatial planning [154] determines how specific places will be utilized, it has an impact on vulnerability in areas where natural disasters are present. As a result, formulating recommendations for harmonizing a proper planning approach and a set of methods seems more promising than formulating generic measures that should cover all risks. Spatial planning, for example, seeks to minimize flood vulnerability [155], but it is also an essential tool for reducing heat waves in cities, such as via the reconstruction of city quarters to optimize micro and local-scale temperatures. Furthermore, spatial design may help to reduce flood danger by increasing natural flood-retention structures. Figure 18 depicts the different government departments responsible for disaster management in Pakistan. The subdivisions working under these four departments can play a vital role to ensure pre hazards precautionary measures, i.e., preparedness to avoid such emergency situations and mitigation plans and techniques.

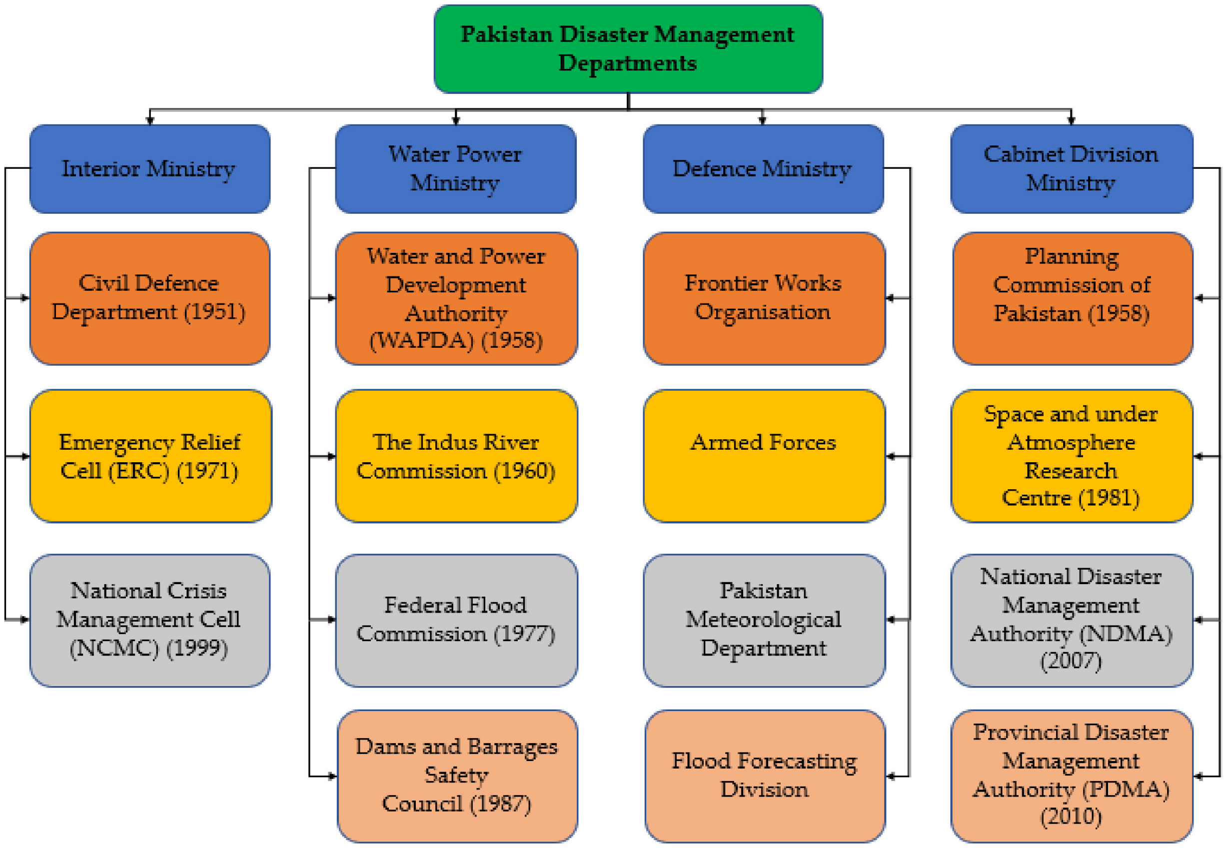

Figure 18. Multi Hazards Risk Management Departments of Pakistan.

6. Discussion

Natural hazards including earthquakes, heat waves, landslides, and floods are common in Pakistan. Pakistan was rated eighth among the nations most impacted by extreme weather occurrences between 2000 and 2019 by the Climate Risk Index 2021 [156]. Recent years have seen a number of challenges for Pakistan. Five million people were afflicted by drought-like conditions that started in late 2018 and lasted into 2019, with 2.1 million of them in need of humanitarian aid [157,158]. Depending on the nature, both floods and earthquakes create terrible harm in Pakistan. Additionally, heatwaves, cyclones, and landslides have their negative impacts, but comparatively, they affect fewer areas of the country as compared to floods, earthquakes, and droughts. Every year, Pakistan experiences various extreme weather events and natural disasters due to changing climatic conditions. Understanding spatial variations of natural hazards is an essential step in creating and putting effective climate adaptation strategies and sustainable development into practice. In the previous literature works, less focus has been given to understanding the spatial variations of these natural hazards. Moreover, this research also highlights the need for integrated risk estimates following large-scale catastrophes and understanding the relationships between various hazards. The long-term recovery after large disasters may be impacted by these interactions, which are not yet well-defined in Pakistan. The aforementioned issues must be addressed by critical work at various scales, from local to regional, in the direction of thorough national multi-hazard risk assessments. Different hazards existing in the same areas can interact and trigger each other to some extent. However, risk assessments are often conducted individually for each of the relevant hazards in an area, making it difficult or even impossible to compare distinct natural disaster risks and therefore prioritize risk reduction measures. As most research on hazard risk assessments and risk management focuses on a single hazard, with escalating co-occurrence impacts rarely included in a comprehensive multi-hazard and risk strategy, this study reveals that the current risk analysis and management strategies in Pakistan may not be able to accommodate global trends. Therefore, to detect, analyze, measure, and evaluate various natural hazards and their effects as well as their interconnections, risk management would require integrated multi-hazards risk assessments. Risk management has yet to receive enough attention from policymakers, designers, and planners. Implementing efficient multi-hazard management and mitigation strategies may take longer than anticipated due to the country's spatial risk profile. In Pakistan, the majority of rescue and relief efforts are directed on flood-related disasters. Every time there is a crisis, the government spends a great sum of money on rescue, relief, and recovery efforts. There is a lack of expertise and information on hazard identification, risk assessment and management, and connections between livelihoods and disaster preparedness within Pakistan disaster management authorities. Methods and instruments for sustainable and cost-effective interventions often have an impact on disaster management policy responses. Pakistan is not making use of the institutional capability that already exists and instead ends up forming new institutions in the wake of every crisis, which lowers institutional learning. This also emphasizes the importance for prioritizing vital industries such as agriculture, health, and education throughout the restoration period. In addition to this, institutional duties must be clarified in order to function effectively, which may be done via enhancing their capacity. The lack of disaster-focused centers and institutions means that the nation lacks the professional and technological know-how to cope with both natural and man-made disasters.

Natural hazards occur on diverse geographical and temporal dimensions and have distinct features that must be considered while conducting risk assessments and developing management methods. Systematic, standardized, and spatial variation based on multi-hazard risk analyses are essential to assess the whole spectrum of probable hazard risks.

An overall limitation in this review paper in the context of Pakistan is the lack of high-quality data for spatial planning. Efforts should be made constantly to improve the collection of data used in international and national databases such as EMDAT, NASA-GLC NDMA reports, etc., as issues relating to incompleteness, fragmentation, bias, and differences in reporting conventions remain a challenge. Pakistan needs quick risk reduction efforts carried out in the urban setting due to the rapidly increasing urban regions and cities.

7. Conclusions

The conclusions regarding assessing the spatial analysis of multiple natural hazards are as follows:

The multiple hazards map results show that Sindh's coastal areas are more vulnerable than the Baluchistan coastal areas because of Sindh's tidal flat topography and higher population concentration. In the northern region of Pakistan, urban centers are considered vulnerable due to earthquakes and heavy-rainfall-induced landslides. Pakistan needs to adopt both hard and soft preventative actions to lessen the effects of landslides, such as increasing vegetation cover to reduce landslide hazards.

Establishment of Data Infrastructure: There is a dire need to establish a national-level spatial data infrastructure for better risk assessment and planning. Moreover, this type of data should be publicly available.

Pointing out the Hotspot: The areas where some specific types of natural hazards occur frequently should pointed out as hotspots for relevant natural hazards. This will be helpful for planners and policy makers as well as for local inhabitants in taking precautionary measures.

Multi-Hazard Modelling: For all kinds of hazards, multi-hazard modelling is essential. The mapping of historical data should be accompanied by geo-spatial frequency analysis of the hazard factors that are crucial for each kind of hazard, such as water levels for floods. To increase the precision of the hazard assessment, stochastic event sets should ideally be produced. Using simplified methods, flood zone maps may be produced for the particular instance of flooding in the Indus River Basin using river flow extremes retrieved from an analysis of extreme values from prior discharge observations.

Multi-Hazard Early Warning System: Extreme climate events, including flooding, droughts, and heat waves, are occurring more frequently and with greater intensity, causing massive damage to infrastructure and natural resources. An effective multi-hazard early warning system must be developed and implemented.

These results can support policymakers for the preparation, mitigation, and disaster prevention strategies, as areas with a high multi-hazard susceptibility might be easily seen on a map.

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