Disasters in the Complex Himalayan Terrains

Shruti Kanga, Gowhar Meraj, Majid Farooq, Suraj Kumar Singh, and Mahendra Singh Nathawat

Abstract Understanding the science behind the causal factors of natural hazards in the Himalayan region is emerging. Hazards, disasters, associated risk and mitigation, and management strategies are very broad themes in their realms. However, there are multifarious, imperceptive, and intricate aspects related to these themes that are impossible to cover in any single volume. This book aims to bring forth various case studies that enhance our understanding of the policy and planning processes to mitigate the losses done by natural hazards in the Himalayas by enhancing knowledge about the science behind it. In this chapter, we describe various issues and paradigm shifts within the field of hazards in the Himalayas and conclude with an outline of the chapters that form this book's basis.

Keywords Natural hazards · Landslides · Earthquakes · GLOFs · Floods · Himalayas

1 Introduction

Due to neo-tectonic morphology and dynamics, the natural hazards in the Himalayas are part and parcel of the communities living there. The Himalayas were always

S. Kanga · G. Meraj (✉)
Centre for Climate Change & Water Research (C3WR), Suresh Gyan Vihar University, Jaipur, Rajasthan 302017, India

G. Meraj · M. Farooq
Department of Ecology, Environment and Remote Sensing, Government of Jammu and Kashmir, Kashmir 190018, India

S. K. Singh
Centre for Sustainable Development, Suresh Gyan Vihar University, Jaipur, Rajasthan 302017, India

M. S. Nathawat
Department of Geography, Indira Gandhi National Open University, New Delhi, India

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sensitive to disasters as a region, but the unplanned and reckless development aggravated the situation and increased the risk of such disasters. As an impact on countries' socioeconomic development, such calamities adversely affect the already stressed economy (Banskota 2000; Meraj et al. 2018a, 2018b). Hence, the "development" that was intended to uplift the economy helps make it more stressed if done unplanned and by destroying vital natural supports. Intensive precipitation including cloudbursts, and earthquakes, augmented with anthropogenic mining activities and destabilization of slopes, are the main forces behind the causes of many major natural hazards in the Himalayas, such as floods, landslides, and earthquakes (Altaf et al. 2014; Joy et al. 2019; Carey et al. 2021). Moreover, climate change and unplanned development activities are some of the reasons behind the destruction caused by glacial lake outburst floods (GLOFs) in the Himalayas (Mishra et al. 2019). Every year in India and other Himalayan countries, extraordinary and intensive, longer-duration precipitation causes devastating floods (Ballesteros-Cánovas 2019). Although India has standard flood management protocols, the massive destruction it brings every year and the administrations' failure to restrict the loss of life and property implies a lack of planned strategy and policy failure (Islam et al. 2016).

Moreover, flash floods have become part and parcel of urban Himalayan commuters' daily lives in India, causing severe damage to their life and property (Dewan 2015; Kanga et al. 2017). Landslides, the movement of earth material moving down under gravity's influence, is often associated with earthquakes, intense rainfalls, and floods. Moreover, factors such as vegetation devoid mountain areas are particularly vulnerable to landslides, causing the river flow block (Nathawat et al. 2010; De Blasio 2011). If and when the river blocks explode, the settlements downstream could be devastated. Landslides in the hilly states of India are common. Himachal Pradesh, Uttarakhand, Shimla, and Kargil are some of the Indian Himalayan regions that witnessed floods due to the rivers' blockade by landslides in recent years.

The science behind the Himalayas' seismicity lies in the fact that since the Eocene period when India collided with Eurasia (some 45 million years ago), it is continuously migrating to the north that has resulted in the creation of the Himalayan mountain range, penetrating around 2000 km into Asia which continues till date (Aitchison et al. 2007). In the process, Himalayas are undergoing beneath the Eurasian plates, making them the most tectonically active mountains in the world. As a result, more than ninety percent of India's earthquakes are due to the seismicity of the Himalayas. Earthquakes in Uttaranchal (1991), Gujarat (2001), and Kashmir (2005) are some of the most catastrophic earthquakes in recent history. The damage in an earthquake event is mainly due to the unplanned development in seismic areas that cause widespread deaths and property loss (Gulati 2006). Moreover, glacial lake outburst floods (GLOFs) that occur when the moraine-dammed lakes at the high-altitude glacier sites break as a result of intense rainfall or earthquake, or any other factor has been one of the significant causes of damage in the Himalayan regions (Allen et al. 2016; Rafiq et al. 2019). The most havoc-wreaking was the GLOF event in the Chorabari Tal in the Kedarnath in June 2013, and the most recent event was in Uttarakhand in February 2021. Such events are one of the manifestations of anthropogenic climate change. The youngest mountain regions of the Himalayas are considered the most vulnerable parts of the world as far as forest fires are concerned (Thakur et al. 2020). Thousands of hectares of forests are destroyed by forest fires every year in India. This hazard is so alarming that India has set up a state-of-the-art forest fire alert system based on real-time satellite data and extensive ground-based monitoring and reporting incidents.

2 Concept and the Structure of This Book

South Asia harbors the complex Himalayan terrains with over one-fifth of the world's population and is recognized as the world's most hazard-prone region. The exponential increase in population with the consequent pressure on its natural resources and continued high rates of poverty and food insecurity makes this region the most vulnerable region to hazards in the world as far as the impacts of climate change are concerned. Over the last century, generally, the climatic trends in South Asia have been observed to be characterized by increasing air temperatures and an increasing trend in the intensity and frequency of extreme events. IPCC (2014) has reported that the Himalayan highlands shall face significant warming over the next century. Moreover, the disadvantaged people of this region's countries shall be more vulnerable due to the intense and frequent extreme weather events, such as heatwaves and severe precipitation episodes, as a result of the anticipated impacts of climate change. The increasing frequency of the natural hazards due to climate change impacts in the Himalayas calls for efficient management and policymaking in these regions, which the local governments can only implement through an established science-based robust action plan.

Disaster Management in the Complex Himalayan Terrains: Natural Hazard Management, Methodologies and Policy Implications is a comprehensive edited book focusing on the science and management aspect of natural hazards using innovative spatial information sciences, satellite remote sensing, and mathematical modeling. The book is aimed to replenish the gap in the available literature by bringing the concepts, theories, and practical experiences of the specialists and professionals in this field together in one volume. There is a shortage of such a book; hence, the editors have tried hard to bring the best literature in this field in the form of the book to help students, researchers, and policymakers develop a complete understanding of the management and policy implications of natural hazards in the Himalayan region.

This volume contains effective methods, science, and management that form the title of the book. The book is divided into five parts. The first part (Part I) includes this chapter and Chap. 2 and focuses on the introduction to the disasters and hazards in the Himalayan terrains. Chapter 2 elaborately discussed the damage witnessed due to massive hazards to natural and man-made environments in South Asia by reviewing the latest literature in the field. The chapter focused on floods, GLOFs, and landslides and argued that understanding the processes and driving forces for different types of hazards is a prerequisite for properly forecasting and mitigating hazards in the Himalayas.

Part II discusses the causes and consequences of landslides in the Himalayas and contains Chaps. 3–5. According to Chap. 3, the Himalayas are characterized by the highest cases of landslides due to fragile rocks and major tectonic boundaries, resulting in the highest intensity and frequency of earthquakes. The authors focused on various modern techniques for systematic studies highlighting the landslide's extent and effect to suggest proper remedial measures. Chapter 4 focuses on the landslide causes and genesis and mitigation measures of the NH-44A Srinagar Jammu Highway in India. The authors argue that unless proper scientific procedures are formulated, the condition of the Kashmir valley's lifeline road is not going to get better soon. Chapter 5 discussed the geoenvironmental impacts of the road widening project of the NH-44A highway that has a complex ecosystem and rugged topography. The authors argue that climatic and hydrometeorological factors are playing as a catalyst in construction complications. Implementation of stepwise preventive measures can only reduce the risk of geoenvironmental hazards, particularly landslides in the area. The author proposes a cladding wall, retaining wall, micro-piling at the tower foundation with a waler beam, anchor, and shotcrete to minimize the consequences of any possible landslides. It is suggested that an independent Hill Development Authority may be constituted, mandated for preparing long-term plans for hill development in this part of Himalaya after taking care of local geological challenges. The study argues that landslide study during the project feasibility stage would save the project completion time and project cost escalation.

Part III discusses the causes and consequences of floods in the Himalayas and comprises Chaps. 6–8. Chapter 6 discussed the September 2014 floods in Jammu and Kashmir's union territory and their causes, impacts, and mitigation strategies. Extreme rainfall throughout the Kashmir valley during the first week of September 2014 has been assumed to have triggered these floods augmented by the rapid snowmelt. The authors suggested long-term mitigation measures by developing an efficient early warning system and enhancing the watershed management practices using the state-of-the-art remote sensing and GIS techniques. Chapter 7 discussed different types of floods in the Himalayas and remote sensing data to estimate river and glacial lake bathymetry. The authors specifically discussed various methods to model and map glacier lake outburst floods (GLOFs), which are considered devastating natural hazards in the Himalayan region. Chapter 8 discusses a huge shortage of knowledge regarding the characterization and vulnerability of energy resources such as small-scale hydropower to extreme events, land-use changes, and their social contestations in the watersheds. The study carried out in the Gagas watershed (Western Himalaya) focused on watermills' sustainability as small-scale hydropower using field, satellite remote sensing, and geographic information system (GIS). Around 12% of watermills were observed to be functional, and 88% were non-functional. The study argues that the frequent occurrences of extreme events such as floods, with 31% of the total area within very high to high flood susceptibility, aggravate the expenditures on maintenance of small hydel projects, thus impacting the local economy.

Part IV discusses the assessment and forecasting of earthquakes in the Himalayas and comprises Chaps. 9 and 10. Chapter 9 monitored earthquake-related deformation using satellite technology, known as Interferometry Synthetic Aperture Radar (InSAR), to derive deformation rates to a moderate earthquake that occurred in the western part of Nepal near Dipayal Silgadhi on November 19, 2019. The authors used 42 interferograms covering the epicentral area with latitude ranging from 29.1°N to 29.8°N and longitude ranging from 80.5°E to 81.8°E. Such studies are critical due to the role they can provide in the mitigation and management of earthquake-related losses in the complex Himalayas. Further, Chap. 10 has discussed the implementation of a neural network-based earthquake forecasting model that involves deep learning algorithms to detect and locate earthquakes in an effective way. The authors considered eight seismicity indicators to form the input of the proposed neural network and observed that the proposed network provides 90% accuracy and an F1 score of 0.89 for the earthquake data during 1980–2020. Such results undoubtedly are extremely to develop new standards of earthquake monitoring and mitigation measures in the Himalayan subcontinent.

Part V discusses the hazard mitigation strategies in the Himalayas and comprises Chaps. 11 and 12. Chapter 11 discussed India's forest fire alert system with a special reference to the UT of Jammu and Kashmir's fire vulnerability assessment. Using actual forest fire incidences from Jammu and Kashmir forest department for 2002–2018, and MODIS Satellite Fire Data (2012–2018), forest division, ranges, and compartment boundaries forest fire vulnerability assessment of the UT of Jammu and Kashmir has been carried out. A correlation index of MODIS (3141) and actual fire incidences (2438) from 2012 to 2018 was derived, which showed a correlation coefficient of 0.97 using the seven-year dataset of actual fire points. Since the points derived from MODIS satellite data cover a larger extent, the number of points varies with actual forest fire points. The results showed many regions of the UT fall in the high fire vulnerability category. They can only be managed if the forest fire alert system of the UT is followed very strictly. Chapter 12 elaborately discussed the impact of climate change on the patterns of precipitation across the world. As a result, there is an increase in the disasters like flash floods, glacier lake outburst floods (GLOFs), snow avalanches, landslides, landslide lake outburst floods (LLOFs), etc. The authors showed that extreme precipitation events that increased over India in the last 113 years have resulted in the region's surge of disasters. The authors have shown how established scientific literature has shown that warming due to climate change has dire consequences over the Himalayas. At the end, the authors discussed some of the policy and decision-making strategies taken by the Himalayan region of Kashmir.

3 The Way Forward for Disaster Risk Reduction in the Himalayan Region

A diverse range of different plant species can be found in the Himalayas covering almost four million square kilometers (1.6 million square miles) from Afghanistan to Myanmar. One of the most biodiversity-rich places is also the dangerous. Since the terrain is so steep and subject to earthquake and landslide activity and heavy rainfall and snowfall, the Himalayas are especially susceptible to floods, landslides, avalanches, and earthquakes. It has been discussed throughout this book how, to date, the number and severity of natural hazards within the Himalayas are on the rise, due in part to climate change. A general threat to life and livelihoods is posed by environmental degradation. Though a community's vulnerability to natural hazards also includes exposure to disasters and their impact, they can also result in property and personal injury. While there are some aspects of risk and exposure that stem from the physical and environmental aspects, socioeconomic factors such as poverty, human settlement, habitat, lack of preparedness, adaptive capacity, and susceptibility all impact how vulnerable the population is.

While many families from the region struggle to rebuild their homes and livelihoods, poverty leaves them with few resources. A widening gap between the rich and the poor exists in the region. These facts point to an increased risk of natural disasters (see Chaps. 2 and 5). Hazard, exposure, and vulnerability are the three key factors that drive disaster risk. Changes in the environment, such as global warming, are causing natural hazards to grow in both intensity and occurrence. The number of people and the value of property exposed to a hazard and the community's overall vulnerability all increase its exposure to that hazard. The IPCC's latest assessment report further expands on the interactions among these critical elements for handling climate change risk. Chapters 11 and 12 adopt a policy framework to reduce risk and increase resilience due to this understanding of disaster risk, hazard, exposure, and vulnerability. There are some critical areas that policy and decision makers must set up to cope with natural hazards. These include multi-hazard environment assessment, assessing the impacts of climate change and variability, managing accessibility and connectivity in the most vulnerable regions, and formulating regional governing bodies that could take the appropriate steps at the times of emergencies.

Enhancing community resilience to hazards by lowering vulnerability and pursuing resilience building measures necessitates a thorough understanding of catastrophe risks, which can aid policymakers in prioritizing actions that will raise their population's resilience to catastrophic disasters. A framework is needed to assess risks from hazard events and recommend measures to help communities in the Himalayas become more resilient. It includes some of the most basic disaster risk reduction elements such as planning and execution, command-and-control mechanisms, monetary incentives, persuasion through knowledge, and early warning systems. Hence, depending on the type of hazard event under consideration for resilience building, a comprehensive program taking into cognizance the science behind the evolution of such a hazard will pave way for the effective and long-term mitigation strategy.

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